Occupational Health Research in Workplaces Transitioning from Modernity to Post-Modernity

by

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AUTHOR'S DECLARATION

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

STATEMENT OF CONTRIBUTIONS

I hereby declare that I am the sole author of chapters 1 and 5 of this thesis.

I declare that I am the lead author of Chapter 2. The manuscript that makes up Chapter 2 was published in the peer-reviewed journal *New Solutions*. The manuscript was a result of a research project I led as principal investigator with support from my co-investigators. My colleagues at Ontario Public Service Union (OPSEU) were invaluable in helping to engage union participation and collecting the data. I was primarily responsible for the data analysis, writing the manuscript and addressing the reviewers' concerns.

I declare that I am the lead author of Chapter 3. This manuscript as accepted for publication in the peer-reviewed journal *WORK: A Journal of Prevention, Assessment & Rehabilitation*. I was the project coordinator on a study of musculoskeletal problems among plumbers and the manuscript was based on this work. I was the lead author on this manuscript, which is the second manuscript resulting from this research initiative. The paper included in this thesis went beyond the quantitative findings of the first manuscript to examine the organization of the workplace and evaluate the possibility of workplace change.

I declare that I am the lead author of Chapter 4. The manuscript that makes up Chapter 4 has been submitted to *New Solutions*. While I was the project manager for the construction related projects at the Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD), I co-authored 12 papers on innovation in the construction sector, published in peer reviewed journals. As lead author for this manuscript, I conducted the secondary analysis of the previous collected qualitative data to evaluate the innovation process. I must acknowledge that my co-authors input was invaluable.

ABSTRACT

Occupational health is a complex concept and the offspring of a marriage between law and science. The marriage is influenced by multiple extended families or networks, which act together and in opposition to create policy and modify work practices (Levenstein &Wooding 1999). The extended families now live in societies that are transitioning from modernity to postmodernity. For the purposes of this paper modernity describes the era when computers and data collection became readily available. Post-modernity describes the era when access to information and its accompanying power provided by that information became universally available because of access to the internet.

Research into occupational health has several goals including the identification of risk, the introduction of potential practices to reduce risk, and setting standards for which compensation is awarded. It is my hypothesis that the societal structure influences not only the subject of this research but also the methods of research, the conclusions of researchers and the potential impact of the research. This applied research programme brings together three studies, that focus on musculoskeletal disabilities (MSDs), that have all been conducted during the transitional period from modernity to post-modernity. Each study examines the creation, dissemination and implementation of knowledge - key products of research.

In this period of transition, the ability to conduct research is also in transition. Data collection is changing because there are fewer large workforces tied together with large insurance and corporate data bases. There is an increase in contingent work with workers changing work relationships on a regular basis. The economic impact of adverse health outcomes

is blurred because insurance coverage is no longer mandatory. In addition, the ability to transfer knowledge is more complex because compulsory training is less common.

The first study examines the development of knowledge about MSDs in a workplace that is in the initial stages of transition to post-modernity. The workplace is now primarily staffed by a part-time and transitory workforce, which was not fully engaged in health and safety activities. In this workplace, the union identified greater than expected MSDs but could only identify limited prevention activities. So, the full- time workers took the lead to build a body of knowledge that could be used to reduce injuries in the future. Participatory research methods gave voice to the workers' experiential knowledge. That knowledge improved the tools promoted by academic researchers which ultimately resulted in a body of knowledge that has the potential to improve work practices. Unfortunately, at the beginning of the process we did not pay enough attention to one of the participating families, the employer, which did not participate or promote changes in work practices. As a result, we cannot report on any specific health and safety improvements. However, we are left with a body of knowledge and a group of workers with the skills to collect data and the ability to continue to promote safer working conditions.

The second study looks at the potential adverse health effects resulting from the introduction of new work processes in a non-traditional work setting. In this case the source of potential long-term injuries was identified by the workers. The workers together with an interdisciplinary research team documented adverse health findings. Because the workforce was contingent, the economic benefits which could be attributed to ergonomically beneficial tools were not obvious. As a consequence, the acquisition of better tools was not pursued by the employer/contractors. However, the research team was able to document developing adverse

health outcomes that could set the stage for compensation in the future and introduce prevention ideas to the workforce.

The final study examines the knowledge creation process in workplaces that are nearing the described characteristics of post-modernity. The stories of workplace parties identified the characteristics of successful innovators and welcoming non-traditional workplaces. A secondary analysis of qualitative interviews shed light on the common characteristics of innovators. That analysis also confirmed the importance of networks to disseminate knowledge with the aid of social capital owned by innovators. We were also able to document the benefit of fluid work demands which allotted time to make mistakes and pursue change.

These studies establish that it is necessary to not only to be guided by established research methods but to also be cognizant of the context in which the research is conducted. With modified research methods, the teams were able to collaborate with transitioning workforces to create knowledge about health outcomes, disseminate that knowledge, and set the stage for the application of that knowledge. These studies illustrate that research which can contribute to safer workplaces must accommodate the societal boundaries in which it is conducted.

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I want to thank my family and friends for this too long PhD journey. But for their support and encouragement I would have given up long ago. They were all supportive and did not give up on me notwithstanding the personal and professional barriers which popped up during the process. I must also thank my construction project colleagues, who were all young enough to be my children and who included me in the decision-making processes and research initiatives. I would also be remiss to not acknowledge my colleagues in the union community who I have met over the years. Without the union representatives who opened the doors for data collection and encouraged participation from their colleagues none of this work would have been possible.

This work would not have been possible without the encouragement and support of my supervisor Dr. Philip Bigelow. I also extend thanks to committee member Dr. M. Hilbrecht, Dr. E. Neiterman, Dr. S. Fischer. Dr. W. Lewchuk and Dr. A Yazdani. I must also thank Dr. R. Wells who offered much support during the early years of this journey. Finally, I would like to thank Betina Butler who provided ongoing administrative help not only for the projects but also for this thesis. All of these people I am honoured to now call friends.

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The views expressed in this thesis are those of the author and do not necessarily reflect those of the Province of Ontario.

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CHAPTER 1

SETTING THE STAGE

1. SETTING THE STAGE

1.1 Introduction and Personal Background

During the last 50 years I have worked in the fields of occupational health and workers' compensation. Originally, I was a worker advocate representing workers before the government run Workplace Safety and Insurance Board (WSIB). Subsequently I investigated complaints against the WSIB for the Ontario Ombudsman and was then appointed on two separate occasions as a vice-chair of the Workplace Safety and Insurance Appeals Tribunal (WSIAT) to hear both worker and employer complaints against the WSIB. For ten years I chaired the province's Occupational Disease Panel (ODP), a statutory body that was responsible for funding research about occupational diseases and recommending policies to the WSIB. Most recently I was a researcher working with a team investigating occupational injuries in the construction sector. These experiences led me to contemplate the relationship between research, compensation policy and injury prevention.

While at the ODP, we made 21 recommendations for compensation for a variety of illnesses. Even though each of the recommendations received unanimous support from scientific, labour and management Panel members, only three of the recommendations were adopted. The majority of reports formally presented to the WSIB did not apparently receive any formal review. In my opinion, the decision not to consider the Panel's findings was based on the potential costs associated with possible claims rather than a weakness in the scientific evidence. This pattern of limited policy development is also supported by data from a paper entitled "Using scientific evidence and principles to help determine the work-relatedness of cancer" produced for

the Ontario government (Demers, 2020). Those authors reported 4,044 claims for cancer were made to the Ontario WSIB between 2009 and 2018 and 41% of those claims were allowed. However, in a rapid search using Google Scholar during the same time period more than ten times more (52,900) peer reviewed research papers on occupational cancer were published. From my perspective this research should have resulted in more accepted claims, given the cancer findings identified in the research. This professional experience has led me to wonder if the work of researchers is having proportional impact on policy makers and if not, how we can take greater advantage of the work of researchers.

As a result of my journey, I have come to recognize that occupational health is a complex concept and the offspring of a marriage between law and science. The marriage is influenced by multiple extended families or networks, which act together and in opposition to create policy and modify work practices to limit the development of disease (Levenstein & Wooding, 1999). To study the courtship and its offspring it is necessary to undertake what Ferreira et al. (2020) describes as:

> transdisciplinary approaches, methods, social actors, and complementary and blurred practices to an effective and meaningful design and implementation of new products, services, and systems. Its social, cultural and educational relevance or holistic understanding will be underlined as strategies to achieve the sustainability of social systems, to share social value and promote resilience and wellbeing in a highly complex and changing world. (p.37)

The recognition of an occupational etiology benefits workers, who can be compensated for a disability or who can enjoy improved working conditions. For employers, the recognition of occupational risks and hazards can be beneficial because it provides an opportunity to

improve workplaces, industrial relations and, in turn, productivity. For society, a strong occupational health system can limit health care costs and the impact of long-term disabilities.

The occupational health research process that investigates health outcomes, evaluates prevention tools, and transfers knowledge is complex. I argue, as have other authors, that societal structure influences not only the subject of the research but also the methods of research, the conclusions of researchers and the impact of the research (Rip, 2022; Usher, 2005).

To explore the social process of occupational health research, I have situated my work in the current period of societal transition – the period from modernity to post-modernity. The description of this transition is aptly described by Michele Barrett (1999) in the following way:

> Modernity becomes a description of a social order whose characteristics are an industrial division of labour, a secular democratic nation state, rationalism, and the market. But it is not simply a socio-economic order; it has a distinctive philosophical orientation. The category of post-modernity represents the disintegration of this order in a world where the global and local have displaced the nation, migration and diasporization have produced hybridization, consumption has replaced production, time and space are compressed, media and identity rule in the social theory as well as in the world. (p.13)

The three projects that form the bulk of this thesis provide insight into the research process as a social process itself (Khan, 2020). As a result of the transition of the world of work, the research design was modified to recognize changes in the organization of work, the power dynamics within the workplace, the method of data collection, economic factors, and the role of the state. In part, each of these studies address the identified design elements resulting from the transition of the workplace. None of these studies provide definitive rules but each sheds light on some of the questions that need to be addressed for future occupational health research design.

My goal in completing this dissertation was to use the acquired knowledge and experience to facilitate change. I wanted to encourage all workplace parties to collaborate with

each other and create knowledge about occupational health issues. I also wanted to ensure all workplace parties have comparable opportunities to develop of new paths for the dissemination and implementation of that knowledge.

1.2 Modern Society and the Workplace

In his work on organizational structure and functioning Chia (1995) describes modernity as "being" - a state that can be described with boundaries and standard forms of organization.[1] In modern societies it is possible to identify an operational hierarchical order. In that world bosses and workers, researchers and the researched and experts and lay participants are readily identified. This understanding of modern society is based on the economic binary analysis advanced by Marx (1986) and further explained by Braverman (1974). The perspective assumes that there are two primary classes, the dominators and the oppressed. The dominators have the power to control the oppressed because of their control over the means of production. Workers, who are systemically precluded from having access to the entire production process have limited power to influence the work process. This is described by Braverman:

> Every step in the labor process is divorced so far as possible from special knowledge and training and reduced to simple labour. (Braverman 1974:82)

That division of labour prevents workers from following the course of production from conception to execution and accordingly precludes them from acquiring sufficient knowledge to execute substantial change in the work process.

[1] I have separated modernity from post-modernity to enhance clarity. The boundaries are not rigid and modernity and post-modernity coexist in the current transitionary era.

This binary power analysis also explains how occupational health knowledge was created and continues to be used. Smith's work on Black Lung Disease clearly exemplifies how what is known is defined by those who have power. She reported, when physicians early in the US mining history were responsible to the miners' benevolent associations, it was possible for the experts to describe the work environment as a significant etiological factor in the development of respiratory illness. Conversely, when physicians were financially responsible to mine owners, lung conditions were deemed attributable to lifestyle conditions [smoking] (Smith, 1981). Because of the lack of or secret nature of knowledge, workers were stymied by the power of the owners from having access to complete knowledge and institute change (Walters and Haines, 1988).

Elite scientists controlled the development of scientific knowledge, and the hegemony (capital) continues to influence the activities within the academy (Gramsci, 1970). Workers, scientists who have not gained entrance into the academy and scientists who resist the status quo are often excluded from regulating working conditions. The power of the elite can limit not only what we know but also what questions we ask. In his work on Scientific Revolutions, Kuhn (1971) identified the tension between those who control the knowledge (the teachers) and new scientists. The controllers of knowledge are usually those who have created the current scientific paradigms or those who have been trained by the paradigm makers. A move to a different research approach or to a different research subject could be perceived as diminishing the importance or negating the value of the work of established researchers and accordingly undesirable.

Along with the binary analysis of power, Marx and Engels also introduced the concept of dialectical materialism, a concept which is critical to some approaches to research. They took the position that all aspects of society are determined between people and their relationship to the material environment (White, 1997). This theoretical approach supports the modern approach to research, looking for quantitative data to understand reality.

I recognize that some of the literature identifies modernity as beginning as early as the 12th century (Habermas, J., & Ben-Habib, S. 1981) or as late as the 18th century (Wood 1997), However for the purposes of this research, I have taken a narrower perspective and have defined modern workplaces as those which became evident after WWII. Soldiers were coming home from the battlefront and needed jobs. There was an unmet need for consumer goods. Probably just as significantly there was a desire for peace and societal stability. During this period workers were organizing, and labour unions were starting to exercise collective power. Mass production was seen as the way forward with big factories and big unions influencing how many workers made a living. Finally, the introduction in the 1970s of computers for business is probably one of the most significant components of this working definition of modernity (Trelease, 2016). After Microsoft introduced its version of the personal computer in 1982 (Black,1989) employers began to collect occupational health data on computers (Owen,1995; Campbell-Kelly, 2001). This new form of knowledge changed the balance of power because it offered the ability to create quantitative knowledge that was persuasive to controlling organizations like corporations and the state.

Modern work relationships, which continue to exist, are characterized by workers who have one employer and work on the employer's premises and under the employer's direction. These workers are deemed to have a standard employment relationship [SER] (Lewchuk, 2022).

The extreme of modern work practice is scientific management first developed by Frederick Taylor (Taylor, 1911). He took the position that work activities should be isolated so workers could not independently control the work process. In that environment, which continues until today, workers have limited access to information to ensure that control is maintained by management. This work regime is particularly evident in the Just-In-Time [JIT] environment (Spencer & Carlan, 2008; Womack et al., 2007; Landsbergis et al.,1999), which supports outsourcing and component manufacturing. JIT discourages any activity which does not add immediate value to the end product and limits workers participation in the entire work process.

The modern workplace was and is controlled by owners of production. There is some intervention by the state to address grievances about working conditions and develop regulations and standards concerning the hours of work and working conditions (Tucker, 2003; Palmer, 1992). The state also began to offer improved social benefits like unemployment insurance and health care. In Ontario, workers' compensation benefits have been available since 1914 following Sir Justice Meredith's Report. In the 1960s there was a significant push to enhance the benefits and provide more protection for workers (Tucker, 2003; Ison, 1983).

In this era, the economic impact on employers of occupational injuries was identifiable and impactful (Tompa et al., 2007). Compensation for work-related injuries was and is controlled by government programmes, such as the WSIB in the province of Ontario. Most employers were and are required to pay premiums to the government run system. Individuals with a standard employment relationship are eligible for payment of healthcare and loss of income benefits for illness deemed by the system to be work-related. The system originally was aimed at compensating the results of specific accidents like trip and falls and well documented diseases

like silicosis (Weiler, 1980). In the later part of the 1980s WSIB policy expanded to compensate workers for musculoskeletal disabilities (MSDs). Today MSDs compose about 30% of the recognized claims. Within this system most owners of the means of production are protected from individual lawsuits by the payment of premiums. Workers also benefit from a simple application of a no-fault insurance scheme and avoid the delays associated with litigation. This insurance scheme encourages employers to reduce costs by modifying work practices which can be identified as risks because of a higher-than-expected number of claims. Very often these increased risks are identified by occupational health researchers using workers' compensation data - the foundation of quantitative research. Under this regime employers are encouraged to introduce ergonomically designed tools, redesign workstations and eliminate chemical risks to reduce claims and save money (Weiler, 1980).

During this period, the state also took an active role in health and safety research in response to political pressure. In this jurisdiction, there were multiple epidemiological studies into carcinogens in the workplace following widespread pressure coming from the mining and other sectors (Waterson and Dingwall, 2016; Aronson et al.,1994; Kusiak et al., 1991, Weiler, 1983; Muller et al., 1983). Interestingly during the 1970s, the workers (unions) had to send a delegate to an international conference to get access to the initial research results. Subsequently there were negotiated releases of data to unions. Through additional labour negotiations occupational research projects began to be funded either by the government or through collective agreements. In 1983, the provincial government established the Industrial Disease Standards Panel (which became the Occupational Disease Panel) to fund and coordinate research into occupational diseases. The Panel was responsible for providing advice to the compensation

system and produced over thirty reports until it was disbanded under a conservative government in 1991. The Panel was subsequently replaced by the Occupational Cancer Research Centre, which conducts research into the etiology of cancer but has no statutory authority.

The Ontario government also established an agency to coordinate and validate health and safety training and to facilitate the development of joint health and safety committees. In 2001 the current Occupational Health and Safety Act was proclaimed. Within the rigid organizational structure of a modern work environment there was the growth of labour experts including health and safety specialists (Palmer, 1992). The specialists were greatly influenced, like the rest of society by the boom in technological advances and the importance given to quantitative data. This is exemplified by the numbers of occupational hygienists in Canada which grew from less than 20 before 1970 to more than 700 by 1990 (Verma, 1995). As it became technologically easier for example to measure minute containments in the air, it also became easier to demand more precise scientific standards to regulate the workplace. Accordingly, there was an increase in government regulations like Workplace Hazardous Materials Information System (WHMIS) proclaimed in 1988. That provided information and also provided standards which were rigid, and some would say encourages a dictatorial emphasis on the measurable standards, which gave more power to experts. These experts had access to knowledge and accordingly power, which could determine acceptable working conditions. This legacy of reliance on quantitative (positivist) assessments continues to this day.

The modern process of knowledge discovery was and is focussed on a rational/positivist approach; an approach which identified measurable events and processes (Usher, 2005). Positivists for example look to measurable data like the wage gap to describe the relationship and

differences between men and women to understand the social. This approach presumes that the researcher is the knower and the researched are the knowable (Guba & Lincoln, 2004). The positivist approach is well documented in systematic reviews, which are often described as the gold standard for identifying causality. Very often the researchers using this approach will begin with several hundred studies, identified by literature searches, but when the final analysis is conducted less than 20 studies will be included in the analysis. The exclusion may have resulted from a lack of statistical power, inclusion/exclusion criteria or only tangential relevance. As a result of this approach to research, hundreds of studies never make it to the desk of policy makers because either the results were not statistically significant or the incidence of disease was not double the incidence in the general population (Van Eerd et al., 2010; Bassil et al., 2007). This quantitative approach is clearly seen in occupational health research where repeating testing and evaluating exposure levels are the focus of much government sponsored research efforts (Malchaire et al., 2002). [2]

Although in a modern environment workers had limited access to scientific knowledge, workers did have indigenous knowledge and could exert some power. Workers have and had the ability to exercise resistance, labeled by Taylor as systematic soldiering (Taylor, 1911; Braverman, 1974). This worker influence did not result in significant control over the means of production, but it resulted in modifications in individual workplaces. For example, by bargaining for joint research, the United Auto Workers created a fund to conduct research into the health

[2] The long process of quantitative research and policy development is clearly shown in the WSIB policy on asbestosis. In 1964 Dr. Selikoff published his work on the effects of asbestosis exposure and the WSIB decision to deem asbestosis a confirmed occupational disease was published in 1992.

effects of metalworking fluids [MWFs] (Eisen et al., 1992). Without that collective action the research may never have been conducted. Ultimately that research was used to modify workplaces and limit exposure to MWFs in many parts of the auto sector by collective agreements. Alternative forms of coolants are used and the means of production have been altered (CAW, 2006).

In our work in the construction sector, we identified multiple technological innovations which could have increased productivity and/or reduced health risks. The quantitative data confirming the reduction in risk was not, however, sufficient to encourage the adoption of tools. One of the best examples of this issue is the rebar tying tool. The tool allows workers to stand up and tie rebar into place before a concrete floor is poured. The workers rejected the tool because it diminished their status as skilled workers and increased productivity demands (Vi, 2006). As you will see in this work on plumbers, if we had looked beyond the technological advantage of the tool or to workers alone, we may have been more successful in reducing risks.

In summary, the modern workplace was and is often controlled by the owners of the means of production and driven by mass production and technology. That societal structure set the stage for large epidemiological studies and occupational health research to be dominated by quantitative methods, which are often formulaic and dependent on available quantitative data. The choice of research topics is often selected if there is quantitative data available from a large workforce with a large data base. Other occupational research was and is conducted by looking at measurable physiological impacts of workplace exposures. The ability to evaluate measurable events was and is an important starting point for much modern research.

The dissemination of research during modernity was often driven by the researchers' need to publish in academic journals and this remains an important factor. The dissemination of information did become more widespread in the 1980s when occupational health training was made mandatory by the state. At that time researchers began to share results with joint health and safety committees. Concurrently, the new cadre of occupational health experts took advantage of the growing body of health and safety publications to share their work.

Anecdotally, I sat on 600 cases at the final level of appeal for workers' compensation benefits. During my first appointment I rarely received any research to assist in the decision-making. More recently I received a standard summary of medical evidence, but it was often outdated and incomplete. This administrative appeal process is designed to be exploratory as well as oppositional. That means that many employers and workers represent themselves or employ lay representatives. Consequently, the system (Tribunal) has the opportunity to provide the most complete evidence for decision-makers. Unfortunately, the best evidence often does not make its way to the hearing.

Finally, as the body of research grew so did government regulations about exposure limits and the quantitative research was used to create new standards. The application of research results was, and continues to be, linked to economic benefits resulting from the prevention of injuries. If the prevention costs exceed lost-time benefits, the research will have limited buy-in.

1.3 Post-modernity and the workplace

Chia describes post-modernity as "becoming which emphasizes a transient, ephemeral and emergent reality" rather than the "being" of modernity. Boundaries are deconstructed, which means new more fluid and diverse sources of control and power are becoming identified (Urry,

2000). In summary the post-modern world is one of fluid boundaries, porous entities, and frequent changes.

The transition from the rigidity of modernity to the fluidity of post-modernity is accompanied by New Social Movement (NSM) theories. They assert that the limited class analysis common during modernity fails to recognize the complexity of identity and action that exists in a multidimensional society (Conway, 2004; Urry, 2000; Touraine, 1988). That does not mean that NSM theorists completely dismiss the role of economic class as a component of social change, but the significance of economic class in their analysis varies. NSMs are often characterized by identity politics, being organized around women's rights, gay rights, and human rights (Carroll, 1997). An alternative (not oppositional) argument is raised by Touraine (1988), who takes the position that the class analysis advanced by Marx is insufficient to understand a post-industrial environment. According to Touraine, in a post-industrial society it is important to understand both the **ends** of production as well as the **means** of production. Symbolic goods like knowledge are the ends of production and control over the means of production is often complex and not limited to one group. Accordingly, a simple economic power-based analysis is not sufficient to understand change.

Perhaps furthest away from the traditional class analysis is Conway (2004). In her description of the development and work of Metro Network for Social Justice (MNSJ) an anti-globalization movement in Toronto in the 1990s. Members of the coalition came from traditional left political groups but also included members who had begun to rethink their identity. The members also recognized that they had to work in horizontal units, which traversed national (state) boundaries and transcended economic class boundaries. While looking to movements as

horizontal networks, Conway also recognized that oppression was a force that brought the coalition together and instigated action aimed at change. This mélange also had interesting access to a variety of sources for academic research relying on physicians' spouses who had access to political power and a skill set for lobbying, which was equal to many paid corporate spokespeople. This kind of group represents Melucci's "nomads of the present who create collective identities within complex societies in a post-modern world" (Melucci 1996). This mélange of forces is particularly relevant to occupational health.

This period has also been described as reflexive modernity. Beck, a theorist, and developer of this concept has written extensively on what he describes as a risk society. Risk societies are characterized in part by several concepts that are critical to understanding work and occupational health including globalization, individualism, and technological and scientific influences (Beck et al. 2003). Contingent work is the embodiment of individualism when the state is removing itself from protecting workers and workers are becoming more and more responsible for ensuring their own well-being. Of equal and maybe more significance is the impact of technological change which has allowed productivity to increase astronomically. Not only has that increase resulted in a change in the industrial workplace and limited job opportunities but it has also introduced unexpected consequences. When machines were being designed to increase productivity, it is unlikely the health impact of repetitive strain injuries was on the minds of inventors. Beck would certainly describe these injuries as risks not hazards. Hazards are the result of nature (a hurricane), but MSDs are the consequence of a human (technological) intervention (Jarvis, 2005). In the work world the unexpected consequences of

technological change are critical and in society as a whole we are creating many unanticipated risks, which will require attention**.**

The societal changes previously discussed led me to the conclusion supported by others that the research into occupational health in a post-modern environment is best pursued through a broad lens (Ferreira et al., 2020; Crawford et al., 2020; Min et al., 2019). The work of Latour, Callon and Law concerning Actor Network Theory (ANT) is a theoretical foundation upon which it is possible to understand that environment [3]. Building on the work of Goffman and Foucault, Latour identified multi-focal actors and actants with different origins and different abilities to influence social transformation. The Actor Networks (ANs), he described are the consequence of ever-changing networks, composed of people (actors) and non- human entities (actants) (Jarvis, 2005; Latour, 2005; Latour 1992). Latour indicates during the change process, different players - individuals, groups, organizations, technologies - will not remain constant but will come into prominence and then recede. In some circumstances they may disappear altogether. This is of particular relevance in a post-modern world when workers can act as managers, work processes are subject to change because of the introduction of technology and power structures are not constant especially in a gig environment.

[3] This is not a unique approach has been successfully used by Zoller in her work examining the reasons for assembly workers' consent to health hazards (Zoller 2003). She describes the significance of identity as a source of consent and that identity in a post-fordist world includes not only class but gender, race, and organizational position.

Callon expands on the ANT concept in his work identifying solutions to declining access to scallops in France (Callon,1984). The theoretical discussion on the sociology of translation begins this research and he wrote:

> Four 'moments' of translation are discerned in the attempts by these researchers to impose themselves and their definition of the situation on others: (a) problematization: the researchers sought to become indispensable to other actors in the drama by defining the nature and the problems of the latter and then suggesting that these would be resolved if the actors negotiated the 'obligatory passage point' of the researchers' programme of investigation; (b) interessement: a series of processes by which the researchers sought to lock the other actors into the roles that had been proposed for them in that programme; (c) enrolment: a set of strategies in which the researchers sought to define and interrelate the various roles they had allocated to others; (d) mobilisation: a set of methods used by the researchers to ensure that supposed spokesmen for various relevant collectivities were properly able to represent those collectivities and not betrayed by the latter. In conclusion it is noted that translation is a process, never a completed accomplishment, and it may (as in the empirical case considered) fail. \(p.196)

I was not strictly guided by these methodological goals in the development of the studies included in this thesis. But by using this analysis we can begin to develop a research path for transitioning workplaces, with the knowledge gained during my research process.

There are multiple other examples of the use of ANT to understand and facilitate change; however, this approach is not accepted by all social theorists. Some think that ANT is not sufficiently critical to be considered a theory and is no more than a descriptive world view (Rudy, 2005). I disagree and argue that theory allows you extend thinking more fully to understand the functioning of a social entity (the workplace) or a social process (research) and engage with the multiple actors and actants to influence change. In our work in the construction sector, we identified multiple technological innovations which could have increased productivity and/or reduced health risks. The quantitative data confirming the reduction in risk was not, however, sufficient to encourage the adoption of tools as exemplified by the rebar tying tool. As

you will see in this work on plumbers, if we had looked beyond the technological advantage of the tools and looked to both workplace parties we may have been more successful in reducing risks.

This leads to a picture of multi-focal broad-based forces, which are influential in research into occupational health. As Levenstein and Wooding (1999) articulate in their work to understand a movement, it is necessary to identify all the players and their competing and supporting relations. In occupational health, the competing forces include productivity, professional standing, and the overall economy. These competing forces are exemplified by the workers' demands for safe workplaces which can be muzzled by the unions because of concern for the economic viability of companies (Storey & Tucker, 2006; Levenstein and Wooding, 1999). In those circumstances labour and management may join forces to introduce technological advances to ensure some job security, while also acquiescing to more dangerous and more precarious work.

There are fewer structured workplaces in the post-modern world. Some experts estimate that 30 % of the labour force is contingent (Vosko, 2000). Others have found it difficult to estimate the number of workers who are not in SERs because those workers are often disconnected from the usual sources of data collection (Lewchuk, 2022). Contingent workers often determine their own workspace, have control over work activities, and work in isolation. In part this all leads to what Lewchuk describes as “working without commitment.” It means that there is no commitment on the part of owners to the workers they do not know and no commitment on the part of workers to employers who offer only temporary work (Lewchuk et al., 2011). Of equal importance in understanding occupational health issues in the post-modern

environment, workers can define themselves as independent operators, who can decide whether to avail themselves of government programmes like workers' compensation.

These characteristics of post-modernity may exclude workers from large data bases used to create knowledge (Boden et al. 2015; Lund & Naidoo, 2016). Accordingly, the positivist approach is being "challenged" or some would say enhanced by more qualitative analysis of workplace conditions. My simple estimate from Ontario Ministry of Labour research grants during the last three years, suggests two-thirds of the funded studies are using quantitative methods. The remaining third of the studies used qualitative methods to investigate organizational issues rather than chemical or ergonomic exposure samplings (MOL, 2017).

These work organization issues require workers to often educate themselves about workplace risks and solutions. In modern workplaces there are often defined health and safety programmes which are required by legislation. These opportunities may be available in the post-modern world but they are not as comprehensive. Conversely, technology has allowed workers and citizens to have access to information that was previously held exclusively by those who controlled the means of production (Hall et al., 2006). Class barriers have been clouded by social media giving workers access to information, which had been previously off limits. Socially legitimized experts (e.g., credentialed union health and safety (H&S) experts) come to the arena from more heterogeneous backgrounds and are more prepared to question the previous paradigms. Post-modernity has expanded the agenda and facilitated change because it has slowly opened the previously hidden access to scientific data. In the 1999 when the internet became more readily available it changed the balance of power with respect to occupational health. The availability of the internet meant that knowledge was more widely disseminated, and the power

of knowledge was also more widely available. Rhebergen et al. (2010), highlighted the change in availability of knowledge when they described a specific internet tool.

> This network tool is a promising new strategy for offering company workers high quality information to answer OSH questions. Q&A network tools can be an addition to existing information facilities in the field of OSH, but also to other healthcare fields struggling with how to answer questions from people in practice with high quality information. In the near future, we will focus on the use of the tool and its effects on information and knowledge dissemination (Rhebergen, et al., 2010).

In the post-modern world identity politics awakened whole groups of people, who were previously unaware of their rights and needs and has made a significant impact on occupational health and safety. During the second wave of feminism, the role of women in the workplace gained more and more attention. Getting women's health on the agenda has rarely been easy. However, as more women entered the labour force, more women became researchers like Karen Messing, Pat Armstrong, Donna Mergler, and Katherine Lippel. These scientists began to resist the old paradigms identified by Kuhn. In 1995 Messing edited a book entitled, *Issues in Women's Occupational Health: Invisible, la sante des travailleuses.* one of the first steps in getting women's health on the radar (Messing et al., 1995). But for NSMs and identity politics I submit that this agenda shift would not have occurred.

In this transitioning post-modern society, there continues to be a reliance on quantitative evidence supported by the confirmation of experts. There is, however, a change. The door has opened to the transfer of health and safety responsibility to workplace parties which means participatory research and participatory health and safety activities especially with respect to ergonomic change (Dixon et al., 2009; Cole et al., 2003). This has also set the stage for

experiential knowledge to be more openly articulated and championed. Furthermore, the demand for scientific certainty is changing and the determination of a statistically significant finding is becoming less necessary (McShane et al., 2019). Consequently, there are implications for the application of knowledge from different sources (experiential and technical) in the workplace.

All of this leads to a picture of multi-focal broad-based forces, which are influential in pursuing research into occupational health. The competing forces are exemplified by the workers' demands for safe workplaces, which can be muzzled by the unions because of concern for the economic viability of companies (Storey, 2000; Levenstein & Wooding, 1999). In those circumstances, labour and management may join forces to introduce technological advances to ensure job security for some workers, like Just-In Time manufacturing. At the same time, the workplace parties may acquiesce to more dangerous and precarious work resulting from increased demands of production (Spencer & Carlan, 2008; Landsbergis et al., 1999). It is within this turbulent environment that this research is challenged to identify not only the multiple networks but also their influences on each other.

Unlike the modern positivist view of knowledge, which is confirmed quantitively, the post-modern view of knowledge is socially constructed (DeWitt et al. 2016; Berger and Luckman 2002; Swidler and Arditi 1994). Simplistically that means beauty is in the eye of the beholder. A more complete understanding is offered by Berger and Luckman:

> We need not enter here into a discussion of the semantic intricacies of either the everyday or the philosophical usage of these terms. It will be enough, for our purposes, to define 'reality' as a quality pertaining to phenomena that we recognize as having a being independent of our own volition (we cannot 'wish them away'), and to define 'knowledge' as the certainty that phenomena are real and that they possess specific characteristics. It is in this (admittedly simplistic) sense that the terms have relevance both to the man in the street [sic] and to the philosopher. The man in the street [sic] inhabits a world that is 'real'

> to him, albeit in different degrees, and he 'knows', with different degrees of confidence, that this world possesses such and such characteristics. (Berger and Luckman 2002: 13)

When planning workplace interventions, the source and type of knowledge can be broad. For example, experiential (lay) knowledge can be of value in a structured or bureaucratic employment environment if it has been validated by traditional scientific methods (Kuhn, 1991). In a post-modern environment because the workplace is less regulated, the acceptable sources of knowledge are also less defined. This allows workers to take advantage of knowledge they have gleaned from their colleagues and their own research. That does not mean there is no place for quantitative or positivist knowledge which can be used to limit physical hazards.

Another factor that must be considered is society's embrace of a neoliberal political regime in which the role of the state is also evolving, and some would say devolving. The state is limiting its role as monitor/policing agent of the workplace and delegating responsibility to workplace parties to internally regulate the workplace (Gray, 2009; Tucker, 2003). Finally, these precarious/contingent workers are less likely to have the support of a collective resource (union) to protect themselves (Benach et al. 2016, Lewchuk et al., 2011). Therefore, the available channels to transfer knowledge are often less structured and maybe more difficult to access.

The significant economic incentives to improve the workplace during modernity are also different in the period of transition. Often contingent workers do not apply for government benefits because they have not contributed to government programmes like WSIB or Canada Pension [CPP] (Tompa et al., 2007; Lewchuk, 2022). Consequently, there may be a lacuna in the data collected by government programmes and fewer economic incentives to reduce accidents. Another adverse economic incentive in the post-modern world is the structure of the WSIB

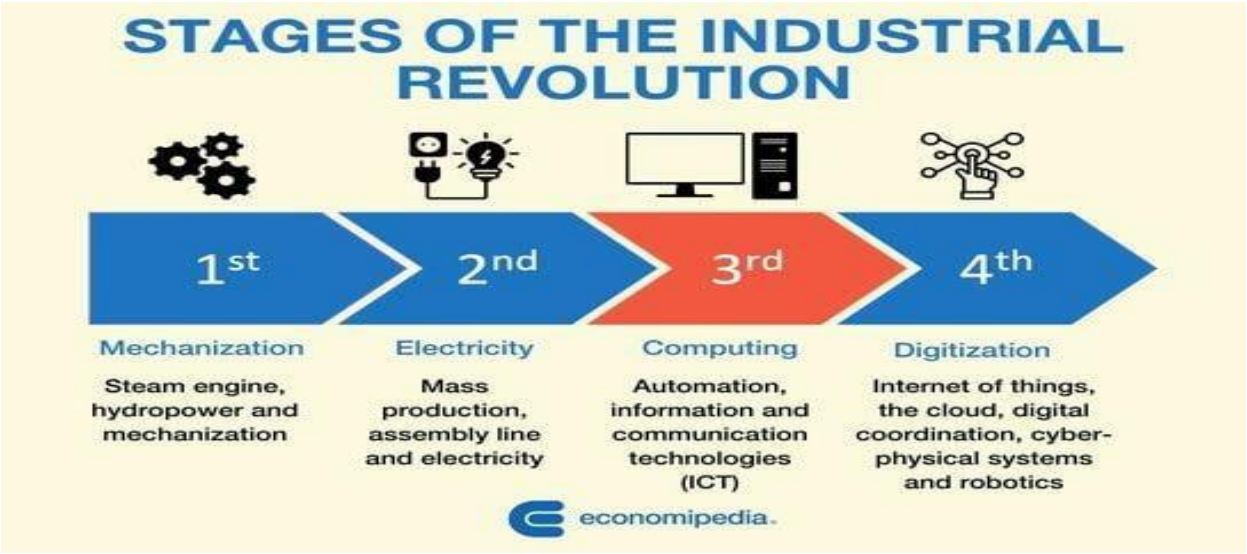
policies. In this world we see many workers hired on short-term contracts through employment agencies. These agencies assume responsibility for the government required benefits like WSIB. As a result, an unsafe factory may be protected from elevated costs because the employment agency assumes costs of the injuries. Conversely if contingent workers are left to their own defences, they may be willing to buy better equipment if it is going to allow them to keep working and avoid early retirement.

In summary, post-modernity results in broader types and sources of knowledge through the world-wide-web. It also sets the stage for smaller independent workplaces to thrive and change work practices without the limits of large bureaucracies. Finally post-modernity is conducive to workers moving from workplace to workplace which encourages the transfer of knowledge more readily.

1.4 The Transitioning Workplace from Modern to Post-modern

The three studies included in this thesis share characteristics of both modern and post-modern workplaces. Some authors have suggested that this period of time can be described as Fourth Industrial Revolution. That is an era characterized by knowledge not goods as the product of labour, globalized forces replacing individual factory owners and contingent workforces (Min et al. 2019; Liao et al., 2018; Davis N.,2016; Prisecaru P., 2016). These three workplaces do not represent the completion of the Fourth Industrial Revolution but workplaces in transition. I would argue that these studies are situated in Industrial Revolution 2.9 and moving to Revolution 3.8.

Contemporary social historians describe the passage from one revolution to another by the subject of the authors' interest. It may be the means of powering production like the introduction of steam or nuclear power as exemplified by the graph below. Alternatively, the progression can be delineated by the control over the means of production that are now controlled by multinational corporations in contrast to earlier family-owned business.



For the purposes of this paper, the modern age is characterized by changes in technology and the introduction of computers in the 1960s and the widespread availability of personal computers in the late 1970s. During this period, it was more possible to gather and analyze information including the rates of disability. In this discussion post-modernity encompasses not only the ability to create knowledge more easily, but it also acknowledges widespread /universal access to knowledge because of the introduction of the WWW in the 1990s (Treteuse, 2016). When that access to information was enhanced, its accompanying power provided workers with the independent ability to control how, when and where they work.

These transitionary workplaces have provided the opportunity for less structured knowledge creation. The value of workers' indigenous knowledge increased and set the stage for workers to create new tools (maintenance hole cover lifter, a tool studied in a previous project). These more complex workplaces offer the opportunity for social networks, as a means of knowledge transfer, to operate within them (Carlan et al., 2012). Finally, the impact of new knowledge was greater because the knowledge was and is more readily available.

1.5 Methodology

During the transition to post-modernity, sociology has become a mainstream discipline, which examines the construction of knowledge and the process of social interaction. Blumer (1969) described a process in which human interaction occurred first through the use of symbols and secondly through the interpretation of the symbols by the sender and receiver (Berg, 2004). The concepts of interpretation and agency of the receivers and senders were critical to the development of qualitative research methods (Goffman, 1969). They set the stage for a process of inquiry that allowed for interpretation of the social process and a need for the development of tools necessary to conduct the inquiry. This notion of interpretation and interaction required sociologists to move on from studying structure to a greater analysis of processes that were fluid and ever changing.

This is particularly true in an environment like the workplace in which power is complex and the functioning of the social is conducted by multiple actors (Latour, 2005). To understand the workplace, the road to the answer is not straight forward and it maybe necessary to modify methods and gather information from multiple sources along the way. If the researchers are focussed on preconceived ideas set out in established theories the recognition of new ideas

coming from different sources may not be evident. Qualitative research allows for unstructured interviews, which permit participants to take the discussion to unexpected places. Indigenous participants (workers) have an opportunity to set the research agenda and participate in an interactive process to complete the knowledge continuum from creation to implementation.

The three research studies fall within the umbrella of mixed methods with a special emphasis on qualitative research. The first study of retail workers falls clearly within the frame of Participatory Action Research (PAR) and quantitative data collection. The second study is also a mixed method study. It relies on quantitative data and analysis and participatory methods to set the stage for the dissemination of the created knowledge. The final study looks at the impact of facilitators and context on innovation in the construction sector by a secondary analysis of multiple unstructured interviews.

Participatory Action Research (PAR) may have the most ability to impact workplace change and is therefore worthy of special consideration in this thesis. The history and value of PAR is decades old and its value in knowledge creation now well accepted. It was during the social movements during the 1960s and 1970s that PAR "officially" was born (Hall, 1981; Hall, 1992; Park, 1993)

Peter Park described the development of PAR not simply as a process of knowledge creation but also as a force for social transformation, self- reliance, and self- determination. Park came to these views by relying on Habermas' Critical Theory (Cotterell & Morris, 2011). While he used different language, Park's thinking was similar to Habermas, and he described three versions of knowledge. Instrumental knowledge, the first version is used for controlling the

physical and social environment in the sense of passively adapting to and manipulating the environment. Secondly, he described interactive knowledge, predicated on connectedness and inclusion and one of the foundations of second wave feminism. Finally, Park described Critical Knowledge, a knowledge that was reflexive and active. This was the kind of knowledge fundamental to PAR (Park et al., 1993; Smith, 1987).

Using qualitative methods and PAR when designing these studies, we gave voice to the workers, who played a major role in data collection, analysis and dissemination of knowledge. Not only did the worker participants document usually quiet forms of experiential knowledge but they also encouraged broader paths for dissemination. In summary the studies of transitioning workplaces employed mixed methods to create, disseminate and implement knowledge.

1.5 (i) Study specific methods

The following section sets out the methodology employed in the three studies. The first two studies are mixed methods using tools developed for both quantitative and qualitative research. The third study is a secondary analysis of multiple studies, which are part of a three-part construction innovation programme. The specific tools, surveys and some correspondences are contained in the appendices. The material in this section and in the appendices serves as a companion to the methods described in each of the published manuscripts (i.e., Chapter 2, Chapter 3, and Chapter 4).

1.5 (ii) The retail study (The Path from Survey Development to Knowledge Activism)

This study was focussed on a unit of a large public service union, that served retail workers in the government-run liquor sales operation. The study began when I attended multiple meetings held over the 18 months with the union's provincial health and safety committee. We

(the academic researchers) were invited to participate in those meetings, and it was jointly decided to conduct a survey of the membership. The union senior officers agreed to help fund the study and compensate representatives for their time in participating. The research team decided not to include the employer in the planning process because it had not been cooperative in previous initiatives. However, a letter was sent to the employer to notify them of the study and invite them to participate if they desired.

A survey was designed based on the CRE-MSD's validated physical load survey and tested with some participants (Yazdani et al.2016). Together with the Provincial Health and Safety Officer (PHSO) and other members of the research team changes were made to the survey. I introduced the survey to the local H&S representatives at three meetings - Oshawa, Toronto, and Windsor. Collectively 150 union health and safety representatives attended those meetings.

Based on the input from the H&S representatives survey questions were modified to fit the context of the retail operation. We collaborated with Dr. Helen Chen, an expert in health informatics at the University of Waterloo, in developing a system for managing survey data collection using REDCap software. Throughout this process we were assisted by an undergraduate student who used this work as her undergraduate thesis. Because we did not want to rely on employer resources, the survey was sent to staff from lists maintained by local union activists. We received 428 responses (71 casual workers, 37 managers, 13 warehouse workers, 307 regular retail staff). Approximately 75% of respondents worked 8-hour shifts.

During this process I met with the union's bipartite provincial health and safety committee on two occasions. In addition to the primary goal of introducing the project to the appropriate

officers, we hoped to engage the employer. In spite of evidence of significant potential savings supported by evidence from a similar employer, this employer expressed no interest.

A final report, which is contained in the Appendix I was submitted to the union's Provincial Health and Safety Committee, which included graphs for all significant physical loads' findings. Because I was appointed as a Vice-Chair to WSIAT and in keeping with government ethics guidelines I was prohibited from continuing to conduct any activities with labour or management alone. The Union Provincial Health and Safety Officer (PHSO) did, however, present the findings to the Annual RSI Day session. Shortly after the PH&SO retired. The union representatives and I did work together recently and produced a paper jointly authored and published outlining the process and results of the survey development (Carlan et al. 2022).

1.5 (iii) The plumber study (Evolving Pipe Joining Methods and their Association to Musculoskeletal Symptoms for Residential Plumbers)

A Health and Safety Representative from the plumbers' union approached a member of the research team because he was concerned that new piping methods were increasing the risk of MSDs. Acting as project manager I arranged several meetings that included tradesmen and the research staff. It was decided to document the physical exposure of plumbers using a variety of pipe joining methods. With the assistance of the union and graduate students we visited 25 worksites. Because we had not yet informed the employer association of the study plans, we only attended worksites when we could be accompanied by union co-investigators.

A research team member obtained different crimping tools, which represented manual and hydraulic mechanisms. He was able to share the tools with working plumbers to be tested for a week. The workers provided feed back about the different tools.

At the same time a survey was designed to be disturbed to union members. Questions included demographic factors, work history, musculoskeletal discomfort in the previous 12 months and last 7 days which were adapted from the Nordic Questionnaire on Musculoskeletal Disabilities.

Multiple methods of survey distribution were employed. The survey was sent to 600 residential plumbers. The alternative forms of mailing were specifically chosen to encourage those recipients unlikely to respond to either a postcard or a University of Waterloo letter. At the same time the original H&S representative and other union representatives were making the rounds to different worksites and encouraging the membership to participate. The questionnaire in a fillable form was also loaded onto the CRE-MSD and Union websites. We received 186 survey responses.

At the same time, an original field and lab-based biomechanical assessment of plumbing tasks was conducted. The investigation documented fatigue effects of residential plumbers during their workday and workweek. For the exploratory laboratory study, the team recruited 10 university-aged participants. That work resulted in a paper that provided the physical findings for exposed individuals (Yung et al. 2014).

The original research team met with 20 plumbing contractors during a regular meeting organized by IHSA staff. Alternative crimping tools were introduced. The employers were provided with information about the costs and ergonomic value of the hydraulic tools. Only 1one employer expressed interest in exploring the benefit of the tools.

A focus group was also held with union representatives to discuss the research findings. They shared concerns about the Generation I and II tools. Specifically, the tools were expensive

and required frequent modifications. They also indicated that Generation I tool was heavy and not suitable to small spaces. The Generation II tool was modified yo be lighter and more compact.

Before completing the final version of the paper, I interviewed a number of plumbers, who had the ability to independently choose building materials and tools. They were questioned about their choice of tools and the factors that influenced their decisions. They all indicated that when possible they used more expensive piping which accommodated hydraulic tools because the tools were less physically demanding. Only when it was not practical did they rely on use manual crimping tools.

This research paper included quantitative data about the incidence of MSDs, the concerns about building materials, and tools that are commonly used. It goes beyond the quantitative data to explore how the organization of work and socioeconomic factors influence plumbers' health and safety.

1.5 (iv) Construction innovation study (Health and Safety Innovators in Construction)

For more than 10 years, I worked as a project manager for a research team which investigated the innovative process in the construction sector. Much but not all that work was tool or process specific (e.g. ladder racks and crimping tools). As a result, I interviewed approximately 59 union and management health and safety representatives about the innovation process during the construction programme. All interviews were recorded and transcribed. During that process we conducted repeated reviews of the literature on workplace innovations. To learn from the plethora of data we decided to do a secondary analysis of the transcripts. Guided by the literature we created a selective sample of 11 innovations that represented

important characteristics including the size of the companies and a variety of trades. In this analysis we only included innovations that were part of an active implementation process. The implementation did not have to be successful but had to be part of an active implementation process. Because this research relied on secondary analysis there were no new interview schedules produced.

We identified themes which recurred in the interviews about the 11 tools. The themes were also previously identified in the peer reviewed literature on innovations.

1.6 The organization of this thesis.

This applied research programme brings together three papers which examine the occupational health research process, including the creation, diffusion, and implementation of knowledge. Each of the papers is situated in different phases on the path from modernity to post-modernity and focus on musculoskeletal disabilities (MSDs), which account for approximately 30% of all lost time claims in most jurisdictions (WSIB, 2022). Like any study of transition, the results are messy and not conclusive. Added to the mess of transition are problems associated with the study of MSDs, which have a long latency and occupational and non-occupational aetiologies. My goal is to identify different research methods and analysis, which might be of assistance to future researchers, who will without a doubt be confronted with issues arising out of the transition. I think that you will observe that if more time was spent at the beginning of the process to identify important actants in the workplace, there may have been more opportunities for implementation.

The first study examines the development of knowledge about MSDs in a workplace that is the initial phase of the transition to post-modernity. The large retail organization has moved from a modern structured full-time workforce to a workforce primarily staffed by part-time and transitory workers. In this workplace, the union identified greater than expected MSDs; however, it could only identify limited prevention activities. Because most of the workforce was transitory the full-time workers took the lead to start to build a body of knowledge that could be used to reduce injuries in the future. Participatory research methods gave voice to the workers' experiential knowledge. That knowledge improved the tools promoted by academic researchers, which ultimately resulted in a body of knowledge that has the potential to be used to improve work practices. We were left with a body of knowledge and a group of workers with the skills to collect data and the ability to continue to promote safer working conditions.

The second study looks at the potential adverse health affects resulting from the introduction of new work processes in a non-traditional work setting. This study is situated midway along the path to post-modernity because although plumbing is considered a traditional (modern) trade, the organization of the work process shares many characteristics with post-modernity. In this case the source of potential long-term injuries was identified by the workers. The workers together with a mixed methods research team documented adverse health findings. Unfortunately, because the workforce was contingent, the economic benefits which could be attributed to ergonomically beneficial tools were not obvious. Therefore, the employers declined to participate in the research process. Conversely evidence from independent contingent plumbers who purchased tools independently had moved along the way to minimize of injuries. Notwithstanding the absence of employer participation, the research team was able to document

developing adverse health outcomes, which could set the stage for compensation in the future. What we did learn is that complete success may not be possible during a period of transition, but some success can still be important.

The final study digs into the characteristics of successful innovators in non-traditional workplaces. This study is most closely associated with post-modern work environments. The secondary analysis of qualitative interviews shed light on the positive characteristics of innovators. The research confirmed the importance of social capital owned by innovators when initiating change. We were also able to document the benefit of fluid work arrangements common among transitioning workplaces, which assisted the mobilization ad dissemination of knowledge. By relying on the evidence provided by all of the workplace parties, issues were problematized, and we documented how new ideas were developed to minimize risk. All of the innovations took place in workplaces that allowed for non-added value activity, a characteristic of post-modern workplaces. In these examples we learned that allotted time to make mistakes was beneficial in the path to safer workplaces.

Each of the three studies examined different research paths which went beyond the methods used in traditional/modern research. They identify different sources of knowledge, different methods of dissemination and different ways of implementing the new knowledge. Ultimately, my goal is to encourage and use the new knowledge created in transitioning workplaces with new dissemination approaches, including the use of social networks and grey literature and interaction with tool manufacturers. If this knowledge is used broadly or conceptually, it can develop initiatives across the system to minimize risk, to address systemic issues, to develop preventative programs, and to gain support from government inspectors.

Chapter 2

The Path from Survey Development to Knowledge Activism: A Case Study of the Use of a Physical Loads Survey in a Retail Workplace

Carlan, N., Szymanski, T., Van Zetten, J., Hilbrecht, M., & Bigelow, P. (2022). The Path from Survey Development to Knowledge Activism: A Case Study of the Use of a Physical Loads Survey in a Retail Workplace.
NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, *32*(1), 65-76.

2.1 Abstract

Workers at a multi-site retailer were concerned that they were experiencing higher than anticipated work-related musculoskeletal disabilities (MSDs). They approached union leadership and academic researchers. A Participatory Action Research (PAR) project was developed, which culminated in a targeted online Physical Loads Survey (PLS). The goal was to initiate discussions to design a preventative collaborative ergonomic program. Survey results confirmed that during a shift, workers had significant exposure to standing, carrying loads of more than 25 lbs., pushing and pulling loads greater than 225 lbs., and repetitive arm and hand movements. The successful survey was the first step in the development of a proactive health and safety program. The union proceeded without management participation and was able to move beyond knowledge creation to knowledge activism and change.

Keywords
union participation, MSDs, knowledge creation

2.2 Introduction

Since its creation in 2004, the Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD), based at the University of Waterloo, has developed collaborative research relationships with employers, union groups, and other advocacy organizations. Together with workplace parties, CRE-MSD conducts research to limit exposures to physical loads and potentially prevent musculoskeletal disabilities (MSDs).

One project was the development of a Physical Loads Survey (PLS), which was initially modeled on Dr. Barbara Silverstein's work in Washington State. Silverstein created a tool to assess the prevalence and magnitude of exposures to physical loads using the entire workplace as the unit of observation. The PLS identified and documented the most common physical loads, which could lead to work-related (MSDs). including force, awkward posture, repetition, vibration, and temperature. (Silverstein et al., 2009). By engaging knowledgeable workplace parties to complete the survey, the findings were representative of exposures of employees across the state. While the survey was being developed, a statewide ergonomic rule was introduced, which included an extensive phase-in period with demonstration projects and the development of training material. During and after the phase-in of the PLS, the researchers found that exposure to physical loads and related injuries was reduced. When the ergonomic rule was subsequently repealed those improvements did not continue (Foley et al., 2009). The research demonstrated not only the potential impact of a statewide approach to MSD prevention, but also the utility of a population-based survey of workplace physical loads.

Following that model, CRE-MSD's research team, which included a Health and Safety Officer (HSO) from one of the largest unions in Ontario, created a validated tool for benchmarking physical loads and refined the tool to be easily used by workplace parties in Ontario. The modified survey allowed workers or managers to document the exposure to physical loads in an individual workplacee. Findings from the original Ontario study indicated good to moderate agreement between the findings of the workers or managers, who were Joint Health and Safety Committee (JHSC) representatives, and the team ergonomist. That research team concluded that valid results could be achieved by having work-site Health and Safety Representatives (HSRs) complete the PLS, with or without professional consultations (Yazdani et al., 2015). The advantages of this approach are twofold. First, HSRs can use the survey to supplement worker-driven MSD-related prevention recommendations to the employer. Second, the survey increases HSRs′ role in the decision-making process, which in turn increases the probability that workers will accept new ergonomic interventions (Yazdani et al.,2016; Van Eerd et al., 2010; Cole et al., 2009; Mathews & Gallus, 2005).

2.3 Background

The Ontario Public Service Employees Union (OPSEU) represents approximately 180,000 members in a variety of occupations including health care, education, emergency services, social services, faculty and support staff in colleges, and workers in the government-operated liquor retailer. The Liquor Board Employees Division (LBED) is a substantial component of OPSEU with approximately 8,000 members. There is significant exposure to physical loads in more than 500 retail locations and multiple warehouses which are represented

by the union. For example, according to union records, in one warehouse, the staff moves (in and out) 2.4 million bottles of liquor (wine and spirits) monthly. Most of the LBED membership are retail workers, who have a variety of duties including stocking shelves, operating cash, and assisting customers. Warehouse employees are responsible for shipping and receiving bulk orders. This LBED workforce accounts for approximately 4% of the union's membership but accounts for approximately 25% of the union's workers' compensation appeals, the majority of which are for MSDs.

The health and safety infrastructure in this workplace is complex because it includes both statutory and contractually negotiated requirements. In this jurisdiction, the Ontario Occupational Health and Safety Act (OHSA) requires any workplace with 20 or more employees to have a JHSC which keeps records and meets quarterly. Legislated membership on the JHSC includes management and union-selected committee members. The employer must provide certification training to (at least) 1 employer and 1 worker member of a JHSC. Workplaces with fewer than 20 but more than 5 individuals regularly employed must have a worker health and safety representative selected by the union (if the workers are unionized), but the representative is not entitled to receive certification training. OPSEU also selects HSR in workplaces with 5 or fewer employees, even though there is no legislated mandate for these representatives, and they have no right to receive certification training. Few locations, among the approximately 500 work sites, in this organization are large enough to have JHSCs. Most of those JHSCs are made up of only 1 worker member and 1 employer member because most sites have fewer than 50 people employed. Most sites have 1 worker HSR only with no requirement for a designated employer representative. The HSR conducts the legally mandated

site-specific activities but is not entitled to meetings, minutes, or certification training. Other sites have HSRs with no legal mandate, so they submit official recommendations and assert rights for other OHSA activities subject to the goodwill and agreement of the employer. Therefore, the health and safety structures (and training requirements) within the organization vary greatly and operate independently and site by site in accordance with health and safety legislation and the collective labor agreement. The union has also negotiated a Provincial Health and Safety Committee (PHSC) which addresses issues that occur in multiple work sites and attempts to streamline communications among the independent HSRs operating in work sites of the same organization. The PHSC also acts as a central forum to consider provincial issues and disputes forwarded by the sites, but it is not considered by the employer to be a JHSC with rights or activities mandated by OHSA (so its recommendations are not considered official).

HSRs from across the province attended a presentation on the PLS tool by CRE-MSD at the 2015 Repetitive Strain Injury Awareness Day in Toronto and envisioned the application of the tool in their workplaces. They approached OPSEU's HSO to contact CRE-MSD and to help pilot the PLS. The HSRs wanted to document workplace hazards and create technical knowledge that would be the basis for ergonomic improvements. The local representatives, together with provincial union staff, prepared a successful application to secure union funding of approximately $40,000 to facilitate meetings and payment for lost time while local representatives were participating in the project.

Previously, the employer had initiated ergonomic prevention programs for this workforce. However, neither HSOs nor local HSRs were consulted prior to the commencement of the programs and had little formal or informal input into measures and procedures to

prevent MSDs. Rather, the employer provided updates to the PHSC about pilot projects and initiatives once underway and then collected worker feedback. For example, the union membership was initially encouraged when the employer retained an ergonomist for advice, but that enthusiasm decreased when they learned that the ergonomist′s priority was to assist in speedy return-to-work programmes, and he could only work on prevention in a limited way. In another example, management introduced a new scanner for cashiers which was not tested. During an interview, a worker reported: ″You only had to use the scanner for one day and you would know it was no good.″ It turned out that the scanner had significant quality problems and was quickly abandoned. Perhaps, it was because of the lack of consultation that these initiatives were not met with enthusiasm.

Against this background, the union membership could have decided to continue to attempt to negotiate management′s participation to begin a new proactive provincial MSD initiative. However, because of the history of non-collaboration, the union decided to independently proceed with the survey and did not ask the employer to participate. The union representatives did inform the employer in writing about the survey and offered to share the results upon completion. The union advised the employer that the survey would be emailed to workers at home. The union representatives wanted to make it clear that no company time or equipment would be used to complete the survey. The representatives were concerned that if the members violated any employer's rules about at-work activities there might be discipline or retaliation (such as a reduction in hours).

The broad goal of this case study was to create and employ knowledge to improve workplace health and safety. Many researchers including Hall (2006) and Abama (2017) have identified different forms of knowledge and we have focussed on 3 forms which include:

Technical or instrumental knowledge which is based on the knowledge developed by workers doing the job or on the specific findings of researchers. This type of knowledge can be used to solve a specific problem like reducing weights to minimize lifting requirements.

Strategic or tactical knowledge goes beyond technical knowledge and addresses process issues. It is aimed at organizational issues which impact the change in processes.

Political or conceptual knowledge is the knowledge that creates the possibility of looking at issues from a broader vantage point. It can be used to introduce a collaborative approach to health and safety and prevention activities like prevention through design or to encourage a greater role for the government in health and safety.

The specific goal of this research was to develop and use technical indigenous (workers′) knowledge about the workplace to develop a program to reduce ergonomic hazards. We hoped to establish that a collaborative research team could document ergonomic hazards, which could be the basis for modification of work practices and collateral hazard reduction. The auxiliary goal was to allow HSRs to expand the role of workers beyond technical representation that limited their activities to the tasks defined in the OHSA. We wanted to provide technical knowledge creators (frontline staff HSRs) with the resources to strategically use their newly acquired knowledge to address issues that recur throughout the entire system. Finally, we wanted to set the stage to use the new knowledge politically to develop initiatives across the system to mobilize workers, to persuade and

convince managers to address systemic issues, to develop preventative programmes, and to gain support from government inspectors (Hall et al., 2006; Abma et al.,2017).

2.4 Methods

The union′s interest in the survey was piqued because members were motivated after participating in CRE-MSD′s presentation on its PLS. Members opined that their ergonomic hazards were not adequately addressed and saw an opportunity to do something about it. Unfortunately, statistical data concerning MSDs is not readily available in this workplace for several reasons. Although the employer is required to share information about work-related injuries with the union, this reporting is not necessarily uniform. Each of the 500 work sites reports independently and some workplaces do not always share this information with the provincial union. There are also disagreements between the union and the employer about the significance of a relationship to work. If the employer initially determines the disability is not work-related, there is no obligation to share the information about the disability with the union.

Notwithstanding the limited statistical data, the union has received multiple reports from its membership from across the province about significant numbers of MSD complaints. There are reports to the union that there are some workplaces where its entire workforce is restricted because of MSDs. Furthermore, the number of LBED MSD appeals to the Workplace Safety and Insurance Board (WSIB) proportionally dwarf similar appeals in other sectors of the union. In addition to this information, there are reports from individual workers, one of whom reported: *"When you work here it was only a matter of time before you get injured"*. To address the MSD concerns, a mixed research team was created, made up of provincial union HSOs, provincial and local Health

and Safety (H&S) representatives, researchers from the university, and colleagues with technical skills to revise and distribute the PLS.

The methodological foundation of this research is Participatory Action Research (PAR). PAR is a methodology that includes the community as well as academic researchers to participate in setting the agenda, designing research, collecting and analyzing the data, and disseminating the results to encourage change. The goal is to create knowledge and provide direct and immediate benefit to the community (Moir,2015; Cornwall and Jewkes,1995). A companion process to PAR, Participatory Ergonomics (PE), was also employed in the development of the original and revised PLS. The PE approach recognizes workers are often the stakeholders most familiar with the work processes and the most suited to identify a comprehensive list of workplace hazards. Not only is PE valuable for the indigenous knowledge it brings to a project, but it also provides workers with the power and influence to create change Dixon et al., 2009; Yazdani et al., 2017; Kramer & Cole, 2003). This research plan consisted of 3 components: independent research about the workers′ compensation system and the ergonomic hazards in this workplace, union and worker reports, and survey results. The University of Waterloo Office of Research Ethics reviewed the research and granted ethics clearance (ORE #21355).

The project began with several meetings with a designated research team. The project team worked on the PLS and dissemination plans. With financial support from the union, the research team held 3 meetings across the province with 56 HSRs from individual work sites to introduce the project. Notably, some of the HSRs had not previously met as groups, so it was an opportunity for them to express concerns and network. At each meeting, the CRE-MSD

researcher introduced the purpose of the survey, provided instructions on how to complete the survey, did a demonstration of the survey, and answered questions. During those meetings, the HSRs provided insight into working conditions, which were useful in the analysis.

Relying on the previously validated surveys, the PLS was designed to identify 26 types of loads, e.g., carry loads, trunk flexed, lift > 23 kg, lift people, hand above the shoulder, repetitive arm, power grasp, computer use, standing, driving off-road, kneel/squat, and high vibration. The original PLS was structured to estimate the exposure to hazards for the entire workplace. With significant input from the project committee, the PLS was modified to allow workers to record their exposure and did not require them to estimate the exposure for the entire workplace. The original survey also assumed a standard work schedule, and the frequency/duration of exposure was measured in frequency/shift. After the preliminary 100 responses, we learned that hours of work were not standard for the majority of LBED members. This caused confusion because some shifts were only 2 hours long and that complicated the completion of the survey. We changed the measurement of exposure to hazard to include times/shift and/or an estimate of frequency—often, occasionally, and never. After the survey was modified, it was emailed to all identified LBED members. We did not track the number of original emails that were sent. The final PLS is provided as an Online Supplemental Material available on the *New Solutions* website (SAGE Publication).

After the survey, we developed a selective sample of 10 participants representing different groups (e.g., management, casual, warehouse, and full-time employees) and conducted interviews. The interviews were conducted by phone, with each interview taking approximately 23 min. They were recorded and the interviewers took detailed notes. The interviews included

questions about the survey itself, such as ease of completion, the most common causes of injury, the processes in the workplace that were potentially hazardous and could result in workplace injuries, illnesses, or fatalities, and barriers to improving health and safety.

We received 428 completed surveys. We used REDCap electronic data capture tools hosted at the University of Waterloo to collect and manage the data (Harris et al., 2003; Harris et al., 2019). This server is protected by the university′s firewall, and data is protected through a strict security and access control policy. Only authorized researchers with Research Ethics Approval were able to view the data. Authorized REDCap researchers monitored the input and provided an analysis of the data.

After the results of all the data had been analyzed, the university researcher prepared a brief written report addressing the issues of importance and it was presented to the PHSC. At that meeting, the university researcher also presented a report from a similar workplace, which had introduced a proactive ergonomic process.[17] No joint labor and management actions have taken place since that PHSC meeting. The project team continues to pursue the issue. The item "University of Waterloo Ergonomic Study" appears in provincial committee minutes for 9 quarterly meetings from February 9, 2017, to February 20, 2020.

2.5 Findings

Comments from union members at the meetings and the results of the qualitative interviews provided significant information in addition to quantitative survey results. The qualitative data revealed that in this organization, several factors warrant consideration when designing a proactive MSD program: the complicated health and safety infrastructure, the

workers′ compensation system, the physical locations of and organization of the work sites, and the full or part-time status of the employees.

2.5 (i) The Survey Results

The PLS was distributed to all LBED locals to contact their members and through mass union emails. We received responses from 428 employees. There was a mix of employees from different job classifications: 71 casual, 37 managers, 13 warehouse, and 307 retail workers. We did not attempt to contact fixed-term employees.

Part-time staff, which comprise approximately 70% of the workforce, represents only 16% of the responses. One explanation offered by the HSRs was that part-timers were concerned about their relationship with management and reluctant to respond. According to part-time staff who sat on the project team, part-time staff rely on and value the goodwill of management to be assigned shifts each week. The study participants explained that part-time workers feared that if management knew that they were engaged in a union activity, it might make them stand out (or identify them as activists), which could result in retaliation, but not discipline, which could potentially reduce the number of shifts that they would be offered in future.

Figure 1 shows the exposures to physical loads according to the size of the workplace. Workers in small workplaces were required to carry heavy loads 90% of the time compared to workers in medium and large workplaces who carried heavy loads only 50% of the time. The same kind of difference is noted when workers in small workplaces reported standing

approximately 90% of the time compared to workers in medium and large workplaces who reported standing slightly less than 50% of the time.

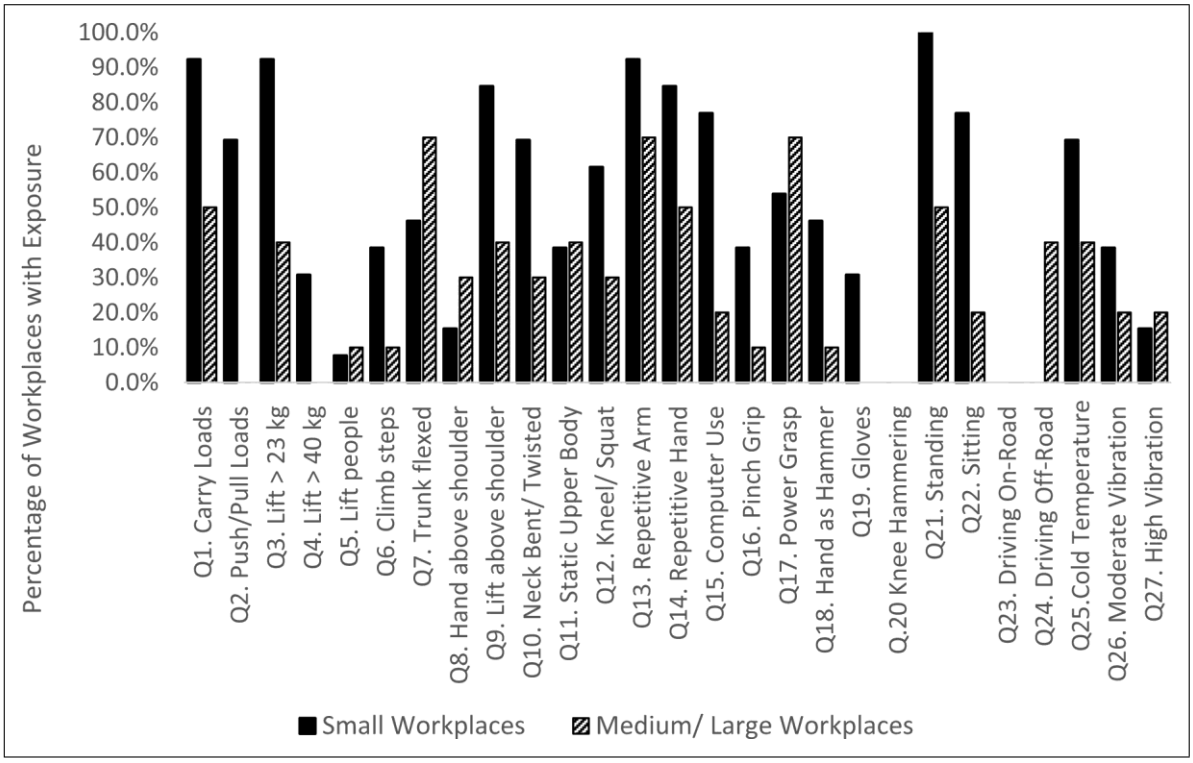


Figure 1. Comparison of physical load exposure between small and medium/large workplaces.

The five most prominent physical loads were standing with limited walking, carrying loads greater than 25 lbs, pushing or pulling loads greater than 225 lbs, performing whole arm movements more than 2 times/minute, and movement of hand and forearm more than 10 times/minute. Figures 2 to 6 show the workers' estimates of their exposures. If the participants were not able to calculate the specific frequency, the PLS allowed participants to provide a descriptive estimate (never and occasionally). In summary, these workers

categorized their exposure to physical loads in order of magnitude: awkward position, force, and repetitive movement.

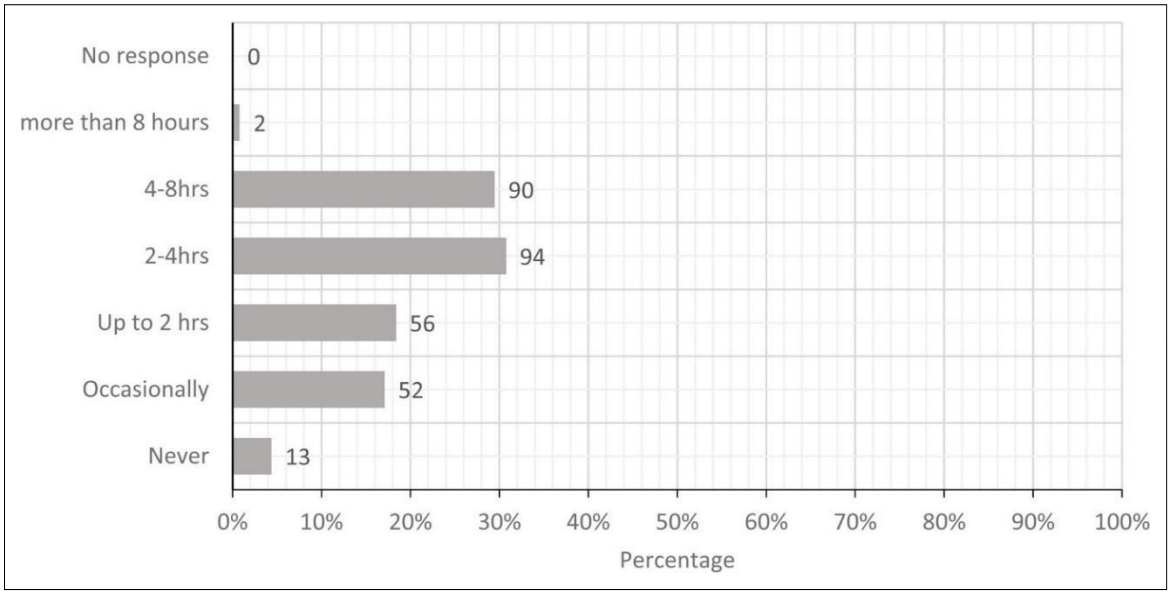


Figure 2. Today, how often did you stand with infrequent walking?

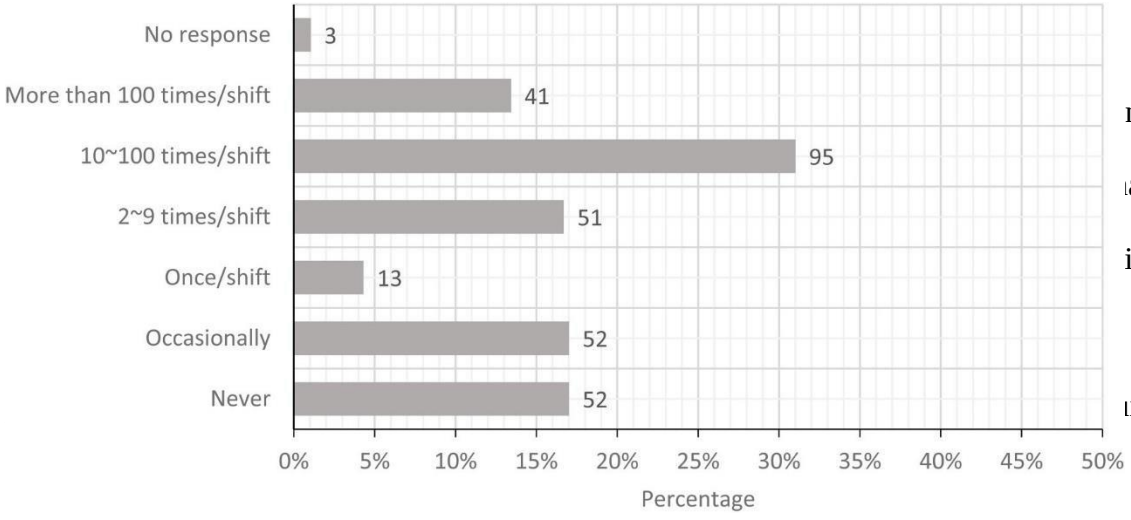


Figure 3. Today, how often did you carry loads more than a few steps (loads greater than 10 kg or 25 lbs.)?

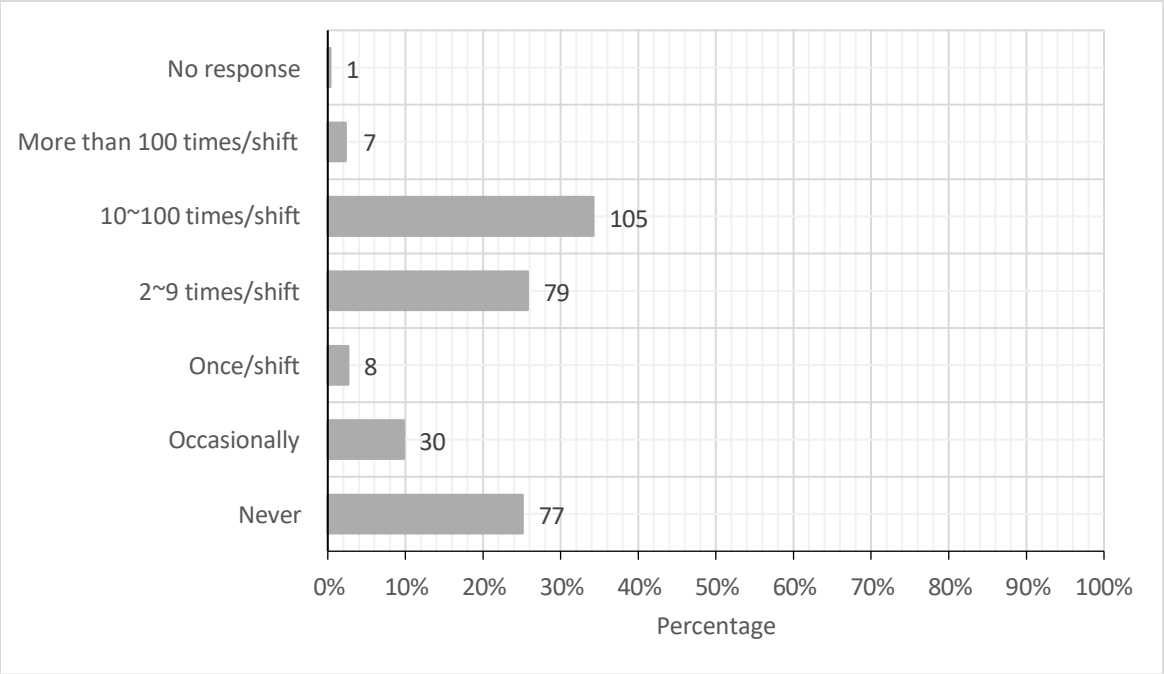


Figure 4. Today, how often did you push or pull loads more than a few steps: wheeling more than 100 kg (225 lbs) or dragging more than 35 kg (75 lbs)?

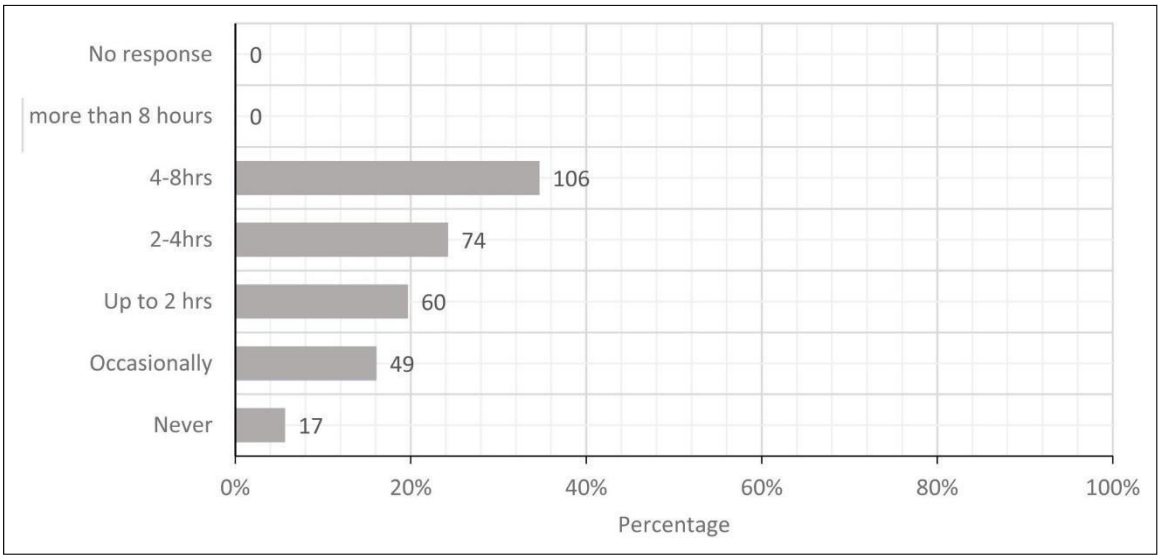


Figure 5. Today, how often did you perform repetitive movement of the whole arm more than twice per minute?

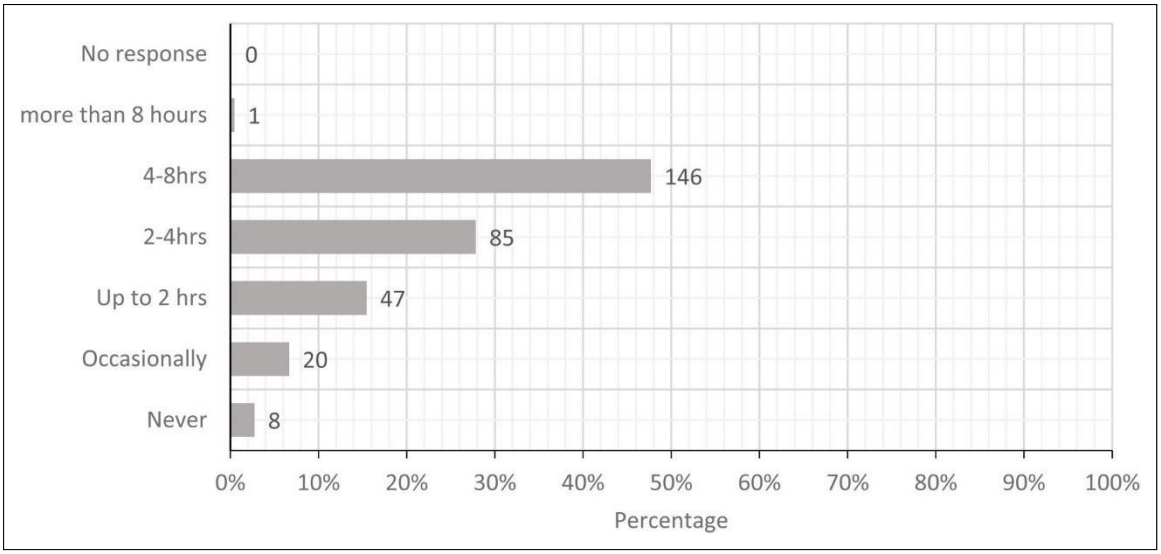


Figure 6. Today, how often did you move your hand, wrist, or forearm more than 10 times per minute not typing?

Not only did workers in small locations manually move more material around the store, but often had to unpack deliveries by hand (also known as de-stuffing the load).

2.5 (ii) The Health and Safety Infrastructure

Because of the complicated health and safety infrastructure in this organization, the project team thought that the PHSC was the appropriate venue to initiate a discussion with the employer. It is important to remember that the PHSC has no authority either legislatively or corporately to initiate change independently, but it could ask for a programme to be included on the corporate agenda. It was open to the project team members to report on the survey to their individual workplaces.

The university researcher presented a report to the PHSC which highlighted the survey results and identified the most common physical load exposures. This was the first opportunity for the project team to provide information to the management representative. In addition to the

survey results, the researcher introduced a report from a similar workplace, which had developed a proactive ergonomic organizational program. That study established that a participatory ergonomic initiative had not only reduced claims but increased productivity and improved labor relations (Lanoie et al., 1995). At the same time, the university researcher also presented a proposal designed for another similar workplace to assist with cash stations (Van Winckle et al., 2020). Because the employer member did not have corporate authority to take any action, consideration and decisions about the reports and possible programmes were deferred until there were further decisions by the corporation.

2.5 (iii) The Worker's Compensation System

In this jurisdiction, most injured workers are covered under a government-run system (WSIB) and there are 2 sub-branches in that scheme. Workers and employers covered under the first branch (Schedule 1) are protected from legal court cases by an insurance plan which is funded by employer premiums. This branch provides the employers with some protection from the full costs of injuries because of the principle of collective liability (all covered employers share the costs of all claims). The second branch, known as Schedule 2 (of which this organization is a part), covers large employers and most government workers. Schedule 2 employers are bound by the WSIB legislation and claims are managed by the WSIB, but the employer pays the full costs of all claims so there is no collective cost-sharing. The third smaller group is reserved for unscheduled employers and allows them to carry private insurance and does not limit legal claims. Because the employer is a Schedule 2 employer, any cost savings from a specific MSD prevention program could have an immediate positive impact on operating costs (WSIB, 2020).

2.5 (iv) Workplace Locations and Organization

Another factor affecting the frequency of workplace injuries is the complex operation of this workplace, which is made up of stores and warehouses of various sizes province wide. Some of the retail outlets are in very old buildings, with layouts that make it impossible to mechanize shipping and receiving. In these workplaces, the staff manually load and unload all stock. Other stores are large and have physical space and mechanics for loading and unloading, called "pallet drop" stores. Some of the retail outlets employ only 2 staff, while others employ up to 100 staff. These operational characteristics limit the mechanization of tasks and preclude opportunities for job rotation, especially in small stores.

The workers also identified an unexpected issue. In the very large facilities, wrapped pallets of product arrive directly from suppliers. According to our participants, the suppliers employ short-term contract workers to wrap and prepare the products for delivery. These contract employees are not adequately trained and the wrapping process itself became an additional hazard. For example, if the wrapping is not applied correctly, it requires significant force to remove.

The participants also indicated that the cashier duties were the least desirable for several reasons. First, cashiers are restricted to 1 workstation with limited ability to move around. Cashiers are assigned to these duties for 3 hours and are not usually provided with any seating. Second, cashiers are required to scan continuously resulting in excessive repetitive lower arm movement and lifting.

2.5 (v) The Organization of the Work Force

Another factor is the organization and composition of the workforce. There were four discrete worker groups, three of which included in the survey distribution.

1. Management in small stores who have the same responsibilities as bargaining unit members (e.g., cash, stocking shelves, and loading and unloading shipments),
2. Full-time staff who are stationed at one location and have defined regular full-time hours, benefits, and pensions,
3. Casual regular part-time staff who can work at different locations, even on the same day. They can accrue sufficient hours to earn benefits and pension credits. Their hours vary and are assigned on a weekly basis by managers' estimates of demand. Many of these workers have been deemed part-time for several years waiting for a full-time position to become available. These workers are union members and participate in H&S projects including this project,
4. Contract fixed-term staff. The fixed-term employees are hired for short contracts during busy seasons (e.g., summer and Christmas seasons).

The casual staff are part-time regular staff who augment the needs of the employer on an ongoing basis. The terms of the current collective agreement have limited the casual staff to 70% of the workforce. Before 2017, casual staff may have composed up to 80% of the staff. A significant proportion of part-time employees have no benefit ties to the employer.

In its attempt to address the high number of MSDs, the employer initiated 2 programs, which are affected by staffing characteristics and are somewhat controversial. Because the current programmes are in place, we have limited our considerations to what currently exists and have not addressed these controversies. One programme deals with return-to-work following an injury.

The second programme deals with job rotation aimed at preventing injuries by sharing exposure to physical hazards. Although these programmes could work in concert, they operate separately.

The return-to-work program encourages workers to return to work as quickly as possible with restricted duties. The controversy lies in the fact that workers are offered accommodated work immediately after injury, often before their individual restrictions, or even their medically sanctioned return-to-work dates, are known. According to worker reports, these injury accommodations mean that many staff cannot be rotated to certain tasks like unpacking loads or doing cash. In some workplaces, there are greater numbers of restricted employees than unrestricted employees and that increases the unrestricted workers′ exposure to physical loads.

The job rotation program is meant to be proactive. It aims to reduce exposure to physical loads for all workers. A daily schedule is posted in each workplace that is intended to help ensure that individuals spend a maximum of three consecutive hours on one task. However, according to union records, it was not unusual to have a higher number of restricted staff than unrestricted staff. Therefore, according to worker reports, the rotation schedule may not have been effective in limiting exposure to loads because rotation was not possible. In reality injury accommodations in the work-place (that are not shown or illustrated in the rotation schedule) override the rotation possibilities, making the schedule more of a plan than reality.

In addition to scheduling challenges, there are issues related to the status (permanent vs temporary, part-time vs full-time) of the workforce. In recent years, the staff has transitioned from majority permanent full-time to majority part- time. The union reports that the increase in part-time staff may be, in part, an initiative to reduce labor costs because of the reduction in the

benefit costs. Having so many part-time workers on limited shifts is another reason that job rotation programs are difficult to organize and maintain. Irregular staffing practices reduce the likelihood of equitably sharing strenuous physical activities, which in turn also have the potential to adversely affect morale. Furthermore, although some part-time staff members have a long history with the employer, many are transient with no entitlement to benefits and accordingly have limited ties to the workplace. That lack of connection to the workplace, and in turn, the lack of commitment on the part of the employer to its transient staff has the potential to reduce the application and effectiveness of health and safety programmes. Part-timers′ lack of attachment is not unusual and is well-documented in the literature reporting on Canadian and global workplaces. That research also confirms that health and safety programs can be less impactful because of transient workforces (Underhill& Quinlan, 2011; Quinlan et al., 2001: Lewchuk et al., 2008).

2.6 DISCUSSION

Multidimensional knowledge concerning health and safety issues in this organization has been enhanced because of this research. The workforce has gained a marked increase in the technical knowledge about their exposure to physical loads. The collective activity by the union health and safety community enhanced their strategic knowledge. The value of this knowledge is explained by the HSO who stated:

> *When we first go in…. well what do they (the academic researchers) need me for? But then that disappears, and you realize that you have something to bring. I felt like people (academics) respected the skills I had which weren′t the same skills as they had.*

The various forms of knowledge identified by the HSO and discussed in the introduction include—technical, strategic, and political knowledge. They lay along a continuum from the specific (technical) to procedural (strategic) and finally institutional (political). This case study documents the journey from the creation to the application of different forms of knowledge.

The project resulted in the development of technical knowledge, which produced a reliable survey that could be widely distributed. The labor team members provided practical knowledge about the organization to the academic team members. The academics gained insight into the duration of exposures, especially in a primarily part-time workforce. Accordingly, the survey instrument was modified to accommodate the non-traditional working schedules and allowed it to be used with ease by the participants. The academics provided knowledge about the foundations of a survey that could produce results, which would be persuasive to management and H&S policy experts. Together labor and academic researchers collaborated in a process that allowed for the viable distribution of the PLS. The academic members guided the processing and analysis of the data. The union members provided input that improved the tool′s usability. As a result of this knowledge creation process, the newly created PLS is a validated tool that can be used systematically to identify hazards in this and other workplaces.

In addition to the development of the PLS, this project also identified hazards that needed attention, including at least 5 key physical loads to which a significant portion of the working population was exposed. The survey itself provided a framework for the monthly inspections conducted by the local H&S representatives. Site JHSC members can use the monthly survey results

to contribute agenda items for discussion at JHSC meetings and make recommendations that legally require a formal response from the employer. The newly created technical knowledge and documentation of the workers′ exposure to physical loads has set the stage for a formal proactive collaborative ergonomic programme, or at least the development of written recommendations to the employer.

From a strategic perspective, the creation of the PLS went beyond addressing the high number of MSD injuries to issues that affected LBED employees′ relationship with each other and the provincial union organization. Union members were afforded the opportunity to work together on issues that affected individual work sites and the entire organization. The union′s support gave the PLS credibility for the workforce and involved members in a collective activity. The union financial resources also brought HSRs from across the province and union staff together to learn from each other about common hazards and solutions. Site-based HSRs and JHSCs (who operate independently) had a chance to communicate, compare notes, and work together on unifying health and safety initiatives. This is of particular value because the legislation does not include a mandate for HSRs and JHSCs at independent sites within a multi-site organization to interact or communicate about occupational health and safety. This broad-based collaboration was of particular benefit to the union because the employer does not acknowledge the PHSC as a legislated entity. While the PHSC provides a unified voice for LBED, it is a negotiated structure without the power that health and safety legislation has over individual work sites. Therefore, the PHSC has difficulty in gaining organization-wide

improvements for hazards such as MSDs, where the employer believes their measures and procedures are already adequate.

The survey results also identified worker status (part-time or full-time) as a strategic consideration. Research has documented the negative impact of a contingent workforce on health and safety initiatives due to the limited time and opportunities that part-time and temporary workers must engage in health and safety training and programs (Underhill et al., 2011; Lewchuk et al., 2008; Quinlan et al., 2001; Benache al., 2016). Those research findings resonate in this case. The PLS responses showed a much lower response rate of part-time employees. It may be that part-timers are not interested, were missed in the distribution process, may think that their opinions do not count, or they may be excluded from participatory programs. Alternatively, part-time staff who received the email may be concerned that engaging in health and safety programs could negatively affect their relationship with management. That relationship is seen as a gateway to obtain preferred scheduled hours or other aspects of task assignments. Regardless of the reason, the limited input from part-time employees (who compose most of the work- force), throughout this process may also have a critical impact on health and safety initiatives. This work organization issue goes beyond the technical issues about exposures to specific physical loads and addresses systemic issues which impact the effectiveness of return-to-work and job rotation programs. Change that might result from the acquisition of this strategic knowledge is an issue that requires additional attention from both the employer and the union if MSD rates are going to be reduced.

Although the research has helped to create knowledge, there are barriers to change resulting from this new knowledge. A major stumbling block identified by Yazdani et al. and

others is the negative impact of the absence of management′s commitment to integrate health and safety into its business plans. Those researchers found that many individual ergonomic initiatives are implemented only on a short-term basis. Whereas business management frameworks that include ergonomic practices are continuously revisited, improved, and sustained (Yazdani et al., 2015; Dixon et al., 2009; Yazdani et al., 2017). The other stumbling block is the need for sustained pressure from the union to promote an organization-wide MSD program. While we recognize that this union has multiple responsibilities, including the need to negotiate benefits and full-time wages, and the need to address other health and safety issues which include violence in this workplace, there is also a need to promote organizational MSD programs.

In this case, there may have been organizational change if the union and its LBED members had chosen to exert political knowledge to ensure that health and safety were not a sidebar issue but a critical component of any management system. However, based on experience, LBED did not believe they would have obtained the employer′s support at the outset of the project. Therefore, LBED members made a strategic choice and undertook the project on their own with the hope they could bring results and evidence to the employer to encourage change. Unfortunately, employer participation was not forthcoming and organizational change has not yet come to fruition. Nonetheless, the worker representatives brought the issue forward themselves and did move ahead without the employer. There were changes associated with knowledge creation—albeit not the desired development of an organization-wide MSD prevention program.

We also began to understand how the development of technical knowledge can enhance existing knowledge and create new activism. Twenty years ago, in 1997, Von Krogh et al. challenged researchers (knowledge creators) to develop knowledge activists. Those authors saw knowledge activists as catalysts of knowledge creation, as connectors of knowledge creation efforts and merchants of foresight. This analysis is consistent with the more recent thoughts of others who have considered the application of knowledge. In their earlier work, Hall et al. recognized that knowledge activists were characterized by the wide-ranging base of their knowledge and the focus on the underlying causes of disabilities (Hall et al., 2006). Recently, Hall et al. (2016) advanced the discussion of political health and safety knowledge activism and were able to correlate the impact of this specific type of knowledge activism with its ability to create change. Specifically, they found that political knowledge resulted in change that went beyond the introduction of instrumental knowledge.

We found that the road from the development of technical knowledge creation to political knowledge activism is not linear, but it exists. In the first instance, union representatives realized that they have more power when they help create documented technical knowledge and have access to that knowledge. When that knowledge is strategically used it has the potential to advance the development of proactive PE, a political goal. The fact that technical knowledge has not yet resulted in structural change, which would include collaborative proactive ergonomic programs, confirms Hall′s conclusions that political (institutional) knowledge activism is critical. The union participants, in this case, now have a broader network of health and safety specialists and have gained technical and strategic knowledge during this process. The union in this workplace has used significant

political knowledge to negotiate good working conditions and fair wages. There is now an opportunity to move health and safety issues to a political platform and bargain for systemic collaborative health and safety initiatives. This case has set the stage for further knowledge creation and further evidence-based workplace change.

2.6 (i) Limitations

There were some limitations in the data we collected. The survey should have included some demographic questions, such as gender, which could have provided a more detailed analysis. Also, the employment status of the workers (full or part-time) should be collected in the future because of its impact on the successful implementation of health and safety programs. Inclusion of gender and workers′ status in the survey questionnaire can be easily done in the future use of the survey. Additionally, we do not have a good estimate of the response rate. Originally, the decision to conduct the study was made by a small working group that did not represent all 500 work sites. Consequently, the decision to circulate the survey was not mandatory but left to the individual union representatives in each workplace and we did not calculate the total number of possible respondents. In the future, we would recommend that the number of possible respondents be recorded. That information along with the status of the workers should provide more insight into the nature of the hazards and possible solutions.

2.6 (ii) Conclusion

Notwithstanding the limitations, it is important to recognize that the union and its membership were activists. They decided to proceed with a research initiative with or without management support to develop a technical knowledge base for future activities. It would have

been easy to ask for management support and if that request was rejected to abandon the project. Instead, there was an independent decision to conduct research to improve individual work-places and perhaps initiate more broad-based change. We have learned that the union′s attention to health and safety issues and support for worker-suggested initiatives inspired members to become knowledge activists. At the instigation of a few knowledge activists, a greater number of workers became knowledge creators and may in turn become knowledge activists.

Chapter 3

Evolving Pipe Joining Methods and their Association to Musculoskeletal Symptoms for Residential Plumbers

Carlan, N., Vi, P., Yung, M., Du, B., Bigelow, P. L., & Wells, R. P. (2023).
Evolving pipe joining methods and their association to musculoskeletal symptoms for residential plumbers.

3.1 ABSTRACT

BACKGROUND: Recently the plumbing trade has transitioned from traditional copper piping to flexible plastic piping (PEX) for residential water distribution systems. However, there has been very limited research into the ergonomic implications of the modernized processes.

OBJECTIVES: This research documents the physical workload and risks of musculoskeletal disorders (MSD) with the use of new tools and processes for joining piping. The research also identifies the factors which can facilitate or limit the use of new ergonomically beneficial tools.

METHODS: This mixed methods research included workplace observations, interviews, an experiment, a survey of plumbers in residential construction and focus groups with both plumbers and plumbing contractors.

RESULTS: Advantages and disadvantages of the various techniques for joining pipes showed that manual crimping has advantages (i.e., productivity and lower cost) that make it desirable for plumbing contractors. Power devices, which were not widely used, have great potential to reduce MSD risks especially if the size and weight of the tools decreases with newer technologies. A continuing barrier is the cost of power equipment.

CONCLUSIONS: The move to provide ergonomically beneficial tools was not as rapid as the willingness to change piping materials. Productivity and costs of tools are barriers to ergonomic interventions.

Keywords: new tools, plumbing, construction, ergonomics

3.2 INTRODUCTION

Investigators at the Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD) and the Infrastructure Health and Safety Association (IHSA) were in the process of conducting a major research project investigating innovations aimed at reducing musculoskeletal disorders (MSD) in the construction sector. During that process, the researchers were contacted by a health and safety representative of the United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of United States and Canada (UA) Local 46. He requested an investigation of worker reports of MSD suspected to be related to changes in pipe joining systems. That contact led to this study.

Changes in the construction materials, have the potential to reduce or add to health risks. For example, in the 1960s when hard plastic pipes (e.g., ABS (acrylonitrile-butadiene-styrene) and PVC (polyvinyl chloride) for DWV (drain/waste/vent) pipe systems were introduced, plumbers experienced significant solvent exposure which had the potential to adversely affect their health. Subsequent surveys identified and confirmed chemical exposure risks associated with the installation of plastic plumbing systems (Methner et al., 2000).

With respect to this study, polyethylene piping systems have gained in popularity in Canada and the US and are becoming alternatives to more traditional polyvinyl chloride (PVC) and chlorinated polyvinyl chloride (CPVC) plastic piping. In Ontario, plastic piping has become the material of choice in new residential and commercial construction. Cross-linked polyethylene pipe, or PEX, is the fastest growing polyethylene system and rapidly replacing copper in residential and commercial hot and cold-water distribution (HCWD) systems (Franklin Associates, 2011). In 1996 it was estimated that copper accounted for 80% of the US plumbing

system market, however, PEX use has been increasing by 40% per year (Romano, 2006). According to the Home Innovation Research Labs (HIRL) 2016 Builders Practices Survey, over 60% of piping in residential plumbing in the US is PEX (MacNevin, 2020).

Past investigations of MSD hazards in plumbing have focused on more general aspects of the tasks including manual material handling, kneeling, awkward postures during installation, and overhead work (Rose, 2007). However, limited research addressed MSD risks related to tasks involved in joining plastic pipes. Rose surveyed Swedish construction workers and observed significant musculoskeletal strain while using powered jointing machines and recommended an analysis of the risk associated with manually operated and power crimpers There is lack of comprehensive reviews of the impact of the changes on workers' health since the introduction of new joining methods.

This study allowed us to document the joining methods used in contemporary construction plumbing and determine if any of the methods were associated with risk factors that may lead to an increased prevalence of MSD. Additionally, the researchers have been able to examine the role health and safety plays in the decision-making process when new materials and work practices are introduced into the construction sector. Tangentially, this study is a good example of how research can be informed and triggered by the experience of workplace parties.

3.3 BACKGROUND

Plumbers perform a variety of tasks that put them at risk for non-traumatic MSD of the neck, back and upper extremities (Schneider and Susi, 1994; Schneider,2001). Tasks such as roughing-in waterlines require prolonged work in awkward positions and at times forceful, repetitive movements. Overhead work, which is associated with pain and disorders of the arms

and shoulders (Bernard et al., 1997) is common when running and joining pipe. US data reported, that 15.9% of all construction workers reported severe hand discomfort. That problem is worse for plumbers, who report severe hand discomfort at the rate of 23.8% (Schneider,2001). Our analyses of 2011 Ontario accepted worker compensation claims for plumbers revealed that 42% of the total lost-time injuries were related to MSD, while MSD accepted claims for all construction workers was only 35% (WSIB, 2012).

Traditionally plumbers in the residential sector used copper piping in various sizes from ½″ to 1″ with ½″ and ¾″ for water supply systems. To install the piping, the plumbers must cut the pipes to the appropriate length, which according to the plumbers, requires significant force (see Figure 1).

Figure # 1 Copper cutting

The rigid piping is soldered and often requires above shoulder work. The newer plastic PEX piping is available in two forms, the most common being non-stretchable (PEX B) which is joined by crimping a metal coupling on the joint. For each crimp there must be a cut but the flexibility of PEX requires fewer over shoulder cuts. PEX piping comes in the same diameters as copper piping and comes from the manufacturer in rolls which are 100 to 300 feet long. The crimp/joint can be made using a manual crimper (Figure 2) or a power crimper (Figures3&4).

Figure #2 Manual crimper

All of the crimpers have removable heads which can be adapted for each different pipe size.

Generation I power crimpers were designed with a battery pack at the base of the tool.

Figure # 3 Generation I tool

Figure 4: Generation II Tool

Generation II tools are designed as inline tools. PEX A, stretchable piping, is an alternative to the non-stretchable PEX B. PEX A is joined by inserting a length of pipe into another pipe that has been stretched by a power tool (Figure 5).

Figure #5 Flexible Piping Stretching Tool

The stretched pipes return to their original size to form a secured joint. All the joining for this stretching process is made with power tools weighing approximately 2.2 kg. The pipe assembly and cutting processes are similar for both stretchable and non-stretchable PEX systems.

UA Local 46, which initiated this research, is unique in North America because it has a section of approximately 600 members who work exclusively on low-rise residential construction projects. In this environment, the plumbing contractors enter into an overall cost agreement with the developer to service multiple homes. These plumbers often operate on a production basis (two roughed-in houses per day) and use PEX B almost exclusively. According to the union H&S representative these production practices reduce the task variation and increases daily crimping activities. Stretchable piping PEX A, which allows for the use of expansion fittings (as opposed to crimped fittings) costs approximately a prohibitive 15% more than PEX B piping. UA Local 46 members expressed concerns that manual joining/crimping of PEX B requires more force than the other systems and that completing the required number of crimps each day was leading to pain in some workers.

In addition to the analysis of the physical loads associated with joining methods, it is also necessary to consider the work organization. The employment relationship in this environment deviates slightly from the norm. In this union environment some contracts are limited to union contractors -contractors which employ union members. When a union contractor requires a plumber, the contractor contacts the Local and a member plumber is dispatched. The dispatched plumber becomes an employee of that contractor, which assumes most employer responsibilities, including health and safety protection. The contractor determines what materials are to be used and accordingly supplies the tools required to complete the assigned tasks. If alternative tools

like power crimpers, as an alternative to the common manual crimpers, were to be used, it would be a contractor's decision. If there is a health and safety issue or grievance, the Local will intercede on behalf of its member to resolve the problem. The differences from the normal employee-employer relationships are that the hiring pool is controlled by the Local and the Union controls the benefit and retirement packages funded by the employer. Workers' compensation insurance coverage is the sole responsibility of the employer. It is necessary to understand this relationship to also understand the process of choosing tools.

3.4 METHODS

The interaction between UA Local 46 and the academic researchers led to a mixed method, which included qualitative interviews, a survey, observation of work activities, focus groups with the workplace parties, and a laboratory-based experiment. UA Local 46 was a facilitator in recruiting participants and providing information about the work practices. All participants provided informed consent for all potential risks. The research activities were reviewed and approved by the Office of Research Ethics, University of Waterloo #08-007.

3.4 (i) Observations and Interviews

While the questionnaire was circulating, a representative of IHSA visited 25 low-rise residential construction worksites with two types of crimping tools: Generation I pistol tools as well as the lighter Generation II power inline crimping tool. The plumbers were given an opportunity to keep the tools and use them for a week.

Other researchers visited additional worksites and conducted unstructured interviews with five plumbers. The interviews were open-ended but focused on their pipe joining and cutting tasks and any potential health impacts. Photographs were taken of participating plumbers

while they worked to provide a visual documentation of work tasks and tools used. At all times during the research, the union health and safety representative acted as a technical advisor to the research team, answering questions about the organization of work, union contracts, and work practices.

3.4(ii) Survey

The questionnaire was designed in consultation with ergonomists in the construction sector along with UA Local 46. To ensure the questionnaire addressed the variety of pipes and joining systems, field visits to residential construction sites were carried out. The questionnaire contained sections that addressed demographic factors, information about the job (work schedule, experience, tenure with company, safety training, overall physical demands, work speed, job satisfaction), job tasks (percent of time working overhead, at waist and floor level, percentage of time using manual, stretchable, and power crimping tools for PEX and non-PEX pipes, percent of time installing copper pipes). Questions on musculoskeletal discomfort in the past 12 months and last 7 days were adapted from the Nordic Questionnaire on Musculoskeletal Complaints and related to the shoulders, wrists/hands, upper and lower back (Kuorinka et al., 1987).

Usability questions included items on perceived comfort, productivity, ease of use, and grasping effort to operate the tool. Additionally, there were questions about the potential to limit the adoption of the tools which included initial cost, compatibility with jobsite conditions, difficulties with maintenance and safety-related issues. Respondents were encouraged to provide detailed explanations and describe other factors they felt affected their adoption of each tool or joining method (Vi, 2006).

The leadership of UA Local 46 helped the research team target 600 low-rise residential plumbers. In the first round of recruitment, the Local mailed out the survey with stamped self-addressed envelopes, as well as a letter signed and endorsing the study by the Union Business Manager (the equivalent of a Local Union President) in a University of Waterloo envelope. A follow-up post-card was sent to union membership signed by union officials, and finally another reminder was mailed in a union envelope to the original list. The alternative forms of mailing were specifically chosen to encourage those recipients unlikely to respond to either a postcard or a University of Waterloo letter (Dillman et al., 2009). At the same time the original H&S representative and other union representatives were making the rounds to different worksites and encouraging the membership to participate. The questionnaire in a fillable form was also loaded onto the CRE-MSD and Union websites.

3.4 (iii) Focus Groups

After completing the preliminary data analyses of the surveys, interviews, and observational components of the study, there was a meeting with UA Local 46 members. Preliminary findings were presented, and we received detailed feedback and additional information about the activities of the plumbers and their health concerns.

In addition to our interaction with the Local, the researchers attended a regularly scheduled business meeting with approximately 20 of the plumbing contractors who were responsible for most of the new construction work in the Greater Toronto Area (GTA). This presentation was time-limited by the participants. The IHSA representative made a presentation demonstrating the various crimping tools. For many of the contractors, this was the first opportunity to be introduced to power crimpers. At that meeting the contractors shared their

views about the available manual and power tools and asked questions about the impact on productivity and costs.

3.4 (iv) Experiment on perceived exertion during crimping

A field and lab-based biomechanical assessment of plumbing tasks was conducted. Our field-based investigation documented fatigue effects of residential plumbers during their workday and workweek; this data have been reported in Yung et al (2014). In that study, the researchers confirmed that installation and joining PEX B by manually crimping was the primary work task, contributing to increasing fatigue of the hand/arm over a workday, and persistent fatigue over the workweek.

We reported on an exploratory laboratory study, which documented perceived exertion while using different crimping tools for PEX B. We recruited 10 university-aged participants (6 males, 4 females; mean age 25.4 years, SD 4.9; mean weight 75.4 kg, SD 14.7; mean height 171.9 cm, SD 7.6 cm; mean hand breadth 8.5 cm, SD 0.5), with no current or past injuries of their upper extremities. Three experimental conditions were investigated: crimping with a manual ½ inch compact crimp tool (Waterline, Mississauga), crimping with a Generation I powered pistol grip press tool (RP 210, Rigid Tool Company, Ohio), and crimping with a Generation II powered in-line grip press tool (ROPRESS, Rothenberger, Illinois). Total masses, including battery and ½ inch pressing jaws, for manual, pistol grip, and in-line grip were 0.6 kg, 3.4 kg, and 2.2 kg, respectively.

Crimp ring ½ inch fittings were prepared prior to the experimental session. A crimp ring fitting consists of PEX piping, straight plastic fitting, and ½ inch copper crimp ring. All crimp ring fittings were stored at room temperature (23 degrees Celsius). To minimize potential order

effects, conditions were presented to participants in a randomized order. We provided at least 2 minutes of rest time to reduce potential fatigue effects and practice time to minimize learning effects. Each condition consisted of 3 trials (i.e., 3 crimps), which were later averaged. Participants were asked to crimp with their dominant hand. Crimps were completed with one hand but upon the researcher's discretion, a 2-handed crimp was performed if a 1-handed crimp was unsuccessful. At the completion of each trial, participants were asked to rate their perceived exertion of their dominant hand and arm using Borg's category-ratio (CR-10) scale. The scale's anchor points corresponded to "no exertion at all" and "absolute maximum exertion".

3.5 DATA ANALYSIS

3.5 (i) Interviews and focus groups

The interviews were not recorded but the research team kept detailed notes. The comments from the plumbers were consistent about the nature of their jobs and effort required for different joining methods.

3.5.(ii) Survey and experimental data:

Respondents fell into one of three exposure groups: 1) primarily installing copper, 2) primarily using manual crimping, 3) primarily using power crimper or power stretchable PEX tools Due to small number of plumbers using power stretchable tools, these plumbers were combined with plumbers using power crimping tools.

Comparisons of outcome measures (e.g., discomfort/pain in the last 12 months etc.) as well as task-related independent variables (e.g., percent time doing ceiling tasks etc.) between the groups were performed using Chi Square for categorical variables and ANOVA for continuous variables. The main outcome measures were MSD symptoms and /or disability in last

12 months and mean severity of musculoskeletal discomfort/pain scores using a Borg 0 to 10 point category-ratio (CR) scale (Borg,1998). Independent variables were the participants, tasks and tools, and psychosocial factors. Each potential risk factor was examined separately with each outcome variable and those significant ($p < 0.10$) were introduced into multivariable models.

Unconditional logistic regression was used to model the odds of reporting musculoskeletal problems in each of the anatomical sites. Logistic regression modeling started by preselecting independent variables based on the biological plausibility of associations and on univariate logistic regression. Variables were selected using the backward stepwise method. The likelihood ratio test and 95% confidence intervals were used. In the logistic regression diagnosis, the Hosmer- Lemeshow goodness-of-fit test and residual analysis were used (Hosmer et al., 2013). We chose to use conservative alpha of 0.05.

Data from the experimental study were used to compare perceived exertion for the three conditions (manual crimp of a ½ inch fitting; powered pistol grip crimping tool on ½ inch fitting; powered in-line grip press tool on a ½ inch fitting) using Friedman's test with subsequent Wilcoxon signed-rank tests and Bonferroni corrections that set the alpha level at 0.017. All statistical analyses were performed using Statistical Analysis Software (SAS Institute Inc., version 9.4, Cary, NC).

3.6 RESULTS

3.6 (i) Interviews and observations

The ergonomists and project manager had an opportunity to interview plumbers on a variety of worksites. The description of standard working conditions was consistent with the

reporting in the background section. In addition, the tasks and onset of MSD symptoms were consistently reported.

In this work environment, PEX B was the standard, and the plumbers were crimping manually. None of the workers interviewed were using the power crimping tools on a regular basis. Our team introduced Generation I power crimper into the workplace, and it was not well received because of its weight and the inability to be used in enclosed spaces. The Generation II was more acceptable because it was lighter and could be used in small spaces, but it was not as efficient (i.e., less productive) as the manual tool.

The plumbers reported that both types of PEX piping are flexible and easy to use in the warmer weather; however, in the winter PEX B piping becomes much more rigid and cutting and crimping required additional force. Plumbers, who used PEX B, confirmed that they performed approximately 300 to 600 crimps and cuts per day to rough-in two houses. The number of baths, sinks and other plumbing fixtures vary per house and account for a range of the number tasks. Participants described that the pace of work required a minimum of 75 repetitive actions in an hour. All the participants reported that when their work was exclusively installing PEX B systems, they would experience forearm pain, which on occasion was sufficiently severe and prolonged to keep them awake during the night. They also reported that toward the end of a workweek, muscle fatigue would lower their productivity. They did not experience the same degree of pain and fatigue when performing the other joining methods for prolonged periods of time.

During our discussions, the plumbers reported that strenuous grip force was required for manual crimping and less force was required when using a power tool for stretchable piping. The

plumbers reported copper piping work was the second most stressful because of the force necessary to cut the pipes. The interview findings were supported by data from the survey as plumbers, who reported that the manual crimping, which required the most grasping force, resulted in the highest level of wrist pain.

We also had an opportunity to question four self-employed plumbers, who had the opportunity to select their own materials and tools. All of them used PEX A with power expansion tools whenever possible. They used PEX B only when it was needed to be compatible with existing piping.

3.6 (ii) Survey findings

A total of 186 plumbers completed the survey (response rate of 31% from the low-rise residential sector); all but one respondent was male. The mean age of the respondents was 40.8 years, and mean height and weight were 177.8 cm and 85.8 kg, respectively. The majority of respondents were journeyman plumbers (76.9%), had over 10 years' experience in the trade (56.3%), and had been with the same employer for over 5 years (52.2%) (Table1).

Most of the plumbers reported using a variety of piping and joining systems. Most respondents (n=159) reported having used manual crimping tools and completed usability questions on this type of tool. Only 27 respondents reported ever using power stretchable tools and completed usability questions for those tools. Using the self-reports of time spent performing specific tasks, 14.4% of participants predominately used copper pipe, 77.2% predominately used PEX B pipe and manual crimping, and 8.4% respondents reported using plastic pipe with power crimping tools or expansion tools. When respondents were grouped by their predominant plumbing method, there were no significant demographic differences.

Respondents reported performing tasks above their shoulders (34.9% “most” or “all”), followed by floor level (21.5% “most’ or “all”), and finally prolonged work at the waist level (14.8% “most” or “all”). When using copper piping the respondents worked over the shoulder 47.8% of the time, for primarily manually crimping 34.6% of the time, and primarily power crimping or stretchable tool 28.6 % of the time.

The overall pace of work was perceived as “too fast” or “much too fast” by 43.4 % of those mainly performing manual crimping, 41.7% of those mainly installing copper, and by 35.7% of those using predominately power crimpers/expanders (Table 2). When asked “In the last month, how often have you felt exhausted after your shift?” 135 respondents (73.8%) reported “over half the time.” Reporting physical exhaustion every day or most days over half the time to most days was significant and was also associated with discomfort/pain and disability of the wrist/hand, whereas other work factors (working overhead, working at floor level, etc.) were not significant.

Most respondents (93.6%) reported MSD symptoms over the last 12 months. Low back discomfort was most frequently reported (80.5%) and upper back symptoms were least reported (46.1%). The majority of respondents (71.2%) reported that musculoskeletal discomfort prevented them from carrying out their normal activities at least once in the last 12 months. We have no evidence that any plumber laid off work because of a MSD or applied for workers’ compensation benefits.

Table 4 shows the distribution of musculoskeletal discomfort/pain and disability associated with the most frequent plumbing method. Multiple logistic regression analysis showed that predominately manual crimping was associated with discomfort/pain and disability

of the wrist/hand (OR= 5.69 95% CI 1.6 to 20.4) and shoulder (OR= 4.61 95% CI 1.22 to 17.4). Respondents who mainly installed copper pipe had higher discomfort/pain in the wrist/hands (6.46) and shoulders (5.64). Those reporting mainly using power joining tools had more discomfort/pain in their lower back (92.9% discomfort/pain prevalence; 84.6% disability).

The majority of the sample (91.2%) reported performing manual crimping at some time during the day. When the respondents were classified by the number of crimps they performed (0-50, 20-100, 100-200, or >200 crimps), mean wrist/hand discomfort/pain scores increased with increasing number of crimps (Table 4). When the entire sample was categorized into ranges of reported wrist/hand discomfort/pain (0-3, 4-7, 8-10), mean perceived grasping effort (scored from 0-10) was associated with increasing wrist/hand discomfort/pain (Table 5).

When considering the perceived advantages of using copper piping, quality was the most frequent response (71 %), and productivity was noted the least frequent (7%) (Table 6). Safety, ease, and comfort were noted as advantages by 30%, 21%, and 19% of respondents, respectively. The most frequently noted disadvantage of copper piping was cost (75%), followed by effort (35%), safety (27%) and incompatibility (12%). The mean perceived grasping effort for installing copper piping was 3.8.

For manual crimping, the most frequently perceived advantages were saving time (67%) and productivity (65%) followed by ease (45%) and safety (26%). The most frequently reported disadvantages of manual crimping were effort (48%), safety (31%), and quality (28%). The mean perceived grasping effort to operate manual crimping tools was 5.2.

The reported advantages of power crimping were ease (62%), saving time (40%), productivity (40%) and comfort (40%). Cost was noted most often as a disadvantage (78%)

followed by maintenance (31%) and incompatibility (25%). Responses for power stretchable crimping indicated ease (77%), saving time (74%), comfort (67%), and productivity (63%) were the most frequently noted advantages. Disadvantages included cost (83%) and maintenance (44%). The mean perceived grasping effort for power stretchable crimping was 2.6.

3.6 (iii) Experimental findings on perceived exertion during crimping

Participants in the laboratory experiments rated their hand and arm exertion highest when completing a manual crimp (median score of 8.9 out of 10; very strong to extremely strong exertion). Rankings of perceived hand-arm effort when using Generation I tool (median score 2.7 out of 10; weak to moderate exertion) and Generation II tool (median score 2.1 out of 10; weak exertion) were significantly lower as compared to manual crimping. This data is consistent with our survey, which revealed higher prevalence of hand or wrist discomfort/ pain among plumbers who manually crimp, compared to plumbers who used power tools.

3.6 (iv) Employers' concerns

During the meeting with contractors, they raised concerns about costs, productivity implications and the ergonomic value of the power tools. They indicated that the weight of the Generation I tools would be as problematic as the force needed to manually crimp. The majority of contractors did not see the need to invest in power crimpers because there was no obvious financial benefit. The tool was expensive (approximately $1,500), needed regular maintenance and did not improve productivity. Furthermore, there was also no evidence that the use of power tools would influence workers' compensation benefits because there was no history of crimping related claims. To date, power tools are not commonly used by plumbers employed by contractors.

3.7 DISCUSSION

Changes in work processes in the construction are regularly introduced and focused on reducing costs and increasing productivity. This conclusion is supported by our survey results which indicate 99% of respondents had previously used copper pipe but the majority (85 %) are currently using the more efficient and less costly plastic piping with manual or power pipe joining techniques.

This study documented physical symptoms including wrist, forearm, low back pain and fatigue at the end of the work week related to the introduction of plastic piping. Plumbers who predominately used copper reported that 48% of their work was mostly overhead whereas those using plastic systems reported less overhead work (35% for manual crimping; 29% for power crimping). From our observations of plumbers, as they cut and joined pipe using the three piping systems, it was apparent that the flexibility of plastic piping was the reason for less overhead work. Given overhead work is a risk factor for pain and MSD of the shoulder (Merlino et al., 2003; Rose, 1980) the change to less frequent overhead work with plastic piping should be beneficial.

MSD symptoms of the wrist and hands had the highest 12-month prevalence for those who mostly performed manual crimping (48%) and was lowest in the power crimping group (33%). This finding is supported by information from interviews and observations of plumbing tasks and our lab-based findings on the ratings of perceived exertion when crimping with manual or power tools. The correlation between discomfort scores for the wrist/hand and the number of manual crimps performed each day further supports this relationship. Findings from the lab-based study demonstrated that perceptions of hand-arm exertion were high when participants

manually crimped a ½″ fitting and were significantly lower for Generation I and II power crimping tools. These findings are concordant with data obtained during observations of work tasks at construction sites, interviews with plumbers, and from the survey.

The 12-month MSD symptom prevalence over 90% was similar regardless of the plumbing method used, ranging from 93% for those mainly power crimping to 96% for those reporting mainly using copper piping (overall mean for all respondents was 94%). The 12-month period prevalence of low back symptoms were consistent with other studies of construction workers have also documented high prevalence rates for back symptoms (Gilkey et al. 2007; Forde et al., 2005; Merlino et al. 2003). A high prevalence of reported lower back problems and high degrees of back discomfort for those in the power crimping/stretching group may be due to the low number of plumbers who were in the mainly using power devices group (n=14) or may be related to some aspect of the task. Plumbers interviewed mentioned that the Generation I power crimpers are heavy and this may be a factor in explaining the high prevalence of back symptoms.

We found that all plumbing techniques had the potential to result in MSD symptoms. The significant grasping effort required for manual crimping along with the high number of crimps performed on a daily basis could put these plumbers at risk for MSD of the forearm, wrist and hand. From our empirical findings and observations, Generation II power crimpers and stretchable power crimping tools may be designed in a way to reduce MSD risks of the forearm, hand, and wrist; however there seems to be an increased impact on the lower back. Regardless of the area of discomfort there is sufficient evidence in our research to associate the work of a plumber with the onset of MSD complaints.

Our findings are consistent with earlier research which found relationships between the use of hand tools and MSD symptoms. For example, Rosecrance et al. (2007) found that construction workers, who used hand tools more than 3 hours per day, had five times the prevalence of carpal tunnel syndrome compared to those working with hand tools for less than one hour daily (Rosecrance al., 1996). In another study, Albers et al. described the high risk of MSD when joining pipe using contemporary methods (e.g., manual crimping) compared to moderate MSD risk for joining pipes that involves welding, soldering, and brazing (Albers et al. 2006). Their ergonomic assessments of construction industry tasks were performed prior to the introduction of power crimping or power stretchable tools and their recommendations for ergonomic interventions was to use tools that were the best designed for the job.

We also considered factors like ease of use that could impact the decision to invest in new tools. These findings generally concur with information obtained during interviews and are also widely held by contractors working in the low-rise residential sector. Manual crimping was the least expensive and allowed for good productivity. Major differences which were apparent in the selection of tool, were comfort as an advantage for power stretchable (67%) and power crimping (45%) as compared to manual crimping (9%). Greater effort was most frequently reported as a disadvantage of manual crimping (47%) versus 11% and 13% for power crimping and power stretchable, respectively. Our sample reported that safety, comfort, and ease of use was an advantage and hardly ever a disadvantage for power stretchable and power crimping tools. Difficulty with maintenance was noted as a disadvantage for powered stretchable (44%) and power crimping (31%) when compared to manual crimping (16%).

Applying Rogers' criteria for the adoption of innovations, we see that manual crimping has a relative advantage because it is the least costly and the simplest intervention (Roges, 2003). Consistent with that finding is also the finding that initial and maintenance costs of power tools is a significant barrier to their introduction. In the case of these plumbers employed by contractors, there was no economic advantage of power tools. Furthermore, this initial cost was not mitigated by fewer workers' compensation claims because there are limited, if any claims, for these benefits. However, we did learn that independent plumbers were prepared to use more the more comfortable albeit more expensive material (PEX A) and the power tools associated with that method. Accordingly, the primary barrier for contractors, who had the authority to buy the more expensive tools, – costs – could not be overcome and the innovation has not been widely adopted.

Finally, we found the reports of early innovators, who introduced change into the construction sector, to be instructive. There is evidence that the best results for reducing ergonomic injuries are achieved when Occupational Health and Safety (OHS) was integrated during the planning phase of project (Hare & Roy, 2006; Tarcisio et al., 2008) This integrated approach was advanced by Lingard et al (2009) who proposed the life-cycle approach, which illustrates that the integration of OHS into all aspects of decision-making could improve and enhance the prevention of injuries. This life- cycle model has been implemented by the Australian government to create a positive OHS culture in construction projects. It recommends the integration of 8 principles, including developing a safety culture, leadership and commitment, developing cooperative relations, promoting OHS in planning and design, consulting and communicating OHS information to project stakeholders, managing OHS risks

and hazards, maintaining effective OHS measures across the project lifecycle, monitoring and evaluating OHS performance (Lingard et al., 2009). Taking a different approach Weinstein suggested that locus of control is a crucial element in the adoption of power tools and innovations that require capital investment. If individuals made their own decisions on which crimping method to use, then it would be likely that individual perceptions of safety, comfort, and ease of use would be important in making decisions on adoption (Weinstein et al., 2007).

In summary we found that the changes in work practices (plastic piping and manual crimping) were associated with increases in wrist and forearm symptoms. Because these workers have not made formal complaints or claims there has not been documented validation of the MSD issues. Even though there is a lacuna in the formal reporting, we submit that the workers' complaints should be cause for concern. The workers' reports in this study added to the biological plausibility of a relationship between excess manual effort and MSD symptoms, as well as similar findings for workers in other trades performing similar tasks are sufficient to support a relationship between symptoms and work practices. Unfortunately, the introduction of plastic piping did not include the consideration of potential to adversely affect workers' health at the early life-cycle development of the practice. These findings may set the stage for the introduction of tools which can prevent disability and the conduct of further research to confirm a scientific causal relationship.

3.8. CONCLUSIONS

Our results indicate that the new plumbing processes that involve manual crimping have the potential to increase the risk of MSD symptoms. Analyses of survey data showed increased odds ratios for reported discomfort/pain and disability of the wrist or hand for manual crimping.

Reports from workers obtained from interviews and during feedback sessions focus groups support these survey findings. Findings from the lab-based experiment also supported increased risk for MSD symptoms in the arms and hands due to prolonged manual crimping.

There are good reasons to expect that the use of rigid plastic pipe and manual crimping is common in low-rise residential construction in the GTA and may also be common in other urban areas that are undergoing rapid population growth. It is apparent that cost and production considerations are major drivers for the selection of the piping systems and joining method when a large volume of houses need to be completed by each plumbing contractor.

In light of the findings from the multiple aspects of our investigation, the problem of MSD symptoms and risks from pipe joining tasks is complex and the solutions are not simple. Although the prevalence of MSD symptoms was higher for those mainly performing manual crimping and respondents felt that manual crimping was generally less safe and less comfortable than the other methods, this information, has not yet appeared to influence adoption decisions. It may be that such information has not been available to decision-makers or not considered as important as cost and productivity.

In an Applied Ergonomics Editorial Molen et al. opined that it was time for implementation of tools and processes, which specifically reduce the risk of developing MSD (Molen et al., 2005). This research is a step along that road. Because we were engaged by the plumbers and their union, we had an opportunity to observe the work practices during the period of transition from copper to plastic piping. This gave the team an opportunity to examine the impact of the work process rather than the incidence of injuries. As a consequence, we think that

this research could influence workplace parties to pre-emptively modify practices and employ new tools which can potentially reduce future MSD.

3.9 FUTURE RESEARCH

Findings of this investigation stimulated researchers at the Centre for Research Expertise for the Prevention of Musculoskeletal Disorders to undertake a study of the levels of fatigue experienced by plumbers using various techniques. Action research should continue to be conducted on pipe joining techniques to better understand the overall prevalence of the various techniques and understand how they are changing. Research findings on MSD risks for the various methods could be included as part of an intervention study in which plumbers, tool designers, academics, architects and contractors are brought together to encourage the diffusion of systems and tools that meet productivity/cost requirements and also ensure plumbers are protected from MSD risks.

List of Tables

Table 1. Characteristics of survey respondents (n=186)

		N	%	Mean	SD
Age (n=182)		-	-	40.8	21.8
Sex (n=183)	Female	1	0.6	-	-
	Male	182	99.4	-	-
Height (n=181)	Cm	-	-	177.8	2.88
Weight (n=181)	Kg	-	-	85.8	31.3
Body Mass Index (n=180)	BMI	-	-	27.1	3.60
Tenure as plumber (n=183)	< 5 yr	22	12.0	-	-
	5 to 10 yr	58	31.7	-	-
	>10 yr	103	56.3	-	-
	< 1 yr	7	3.8	-	-
Time with current employer (n=182)					
	1 – 5 yr	80	44.0	-	-
	5 – 10 yr	44	24.2	-	-
	> 10 yr	51	28.0	-	-

Table 2. Perception of work demands by use of plumbing methods.

Mainly Copper (n=24)			Mainly Manual Crimp (n=122)		Mainly Power (n=16)	
Factor	N	%	N	%	N	%
Work Speed						
About right	14	58.3	72	55.8	9	64.3
Too fast	10	41.7	49	38.0	5	35.7
Much too fast	0	0	7	5.4	0	0
Feel exhausted after shift						
A few days	2	8.3	29	22.5	0	0
Half the time	6	25.0	20	15.5	2	14.3
Most days	14	58.3	49	38.0	6	42.9
Every day	2	8.3	23	17.8	4	28.6

Table 3. Reported pain and disability by use of plumbing method

	Mainly Copper (n=24) Crimp/Expansion (n=14)				Mainly Manual Crimping (n=129)				Mainly Power				
Factor	N	%	Mean	SD	N	%	Mean	SD	N	%	Mean	SD	**p**
Pain in last 12 months													
Any location	**23**	**95.8**	-	-	**122**	**94.6**	-	-	**13**	**92.9**	-	-	
Shoulders	**15**	**71.4**	-	-	**77**	**64.7**	-	-	**6**	**42.9**	-	-	
Wrist/hands	**15**	**71.4**	-	-	**92**	**75.4**	-	-	**6**	**42.9**	-	-	
Upper back	**8**	**44.4**	-	-	**52**	**47.7**	-	-	**4**	**33.3**	-	-	
Lower back	19	86.4	-	-	98	81.0	-	-	13	92.9	-	-	
Disability in past 12 Mo	21	87.5	-	-	91	70.5	-	-	13	92.9	-	-	
Shoulders	7	43.8	-	-	26	26.0	-	-	1	11.1	-	-	
Wrist/hands	8	50.0	-	-	28	28.9	-	-	3	33.3	-	-	
Upper back	**4**	**25.0**	-	-	**20**	**23.0**	-	-	**2**	**28.6**	-	-	
Lower back	11	57.9	-	-	52	51.0	-	-	11	84.6	-	-	
Mean pain scores													
Shoulders	14	-	5.64	2.84	92	-	3.67	2.94	10	-	2.2	2.82	0.0147*
Wrist/hands	13	-	6.46	2.15	93	-	4.77	3.03	11	-	3.27	3.52	0.0356*
Upper back	19	-	4.27	3.17	81	-	3.57	3.28	9	-	2.22	2.68	0.3579
Lower back	14	-	5.5	2.5	96	-	5.34	3.14	13	-	5.92	3.09	0.8125

'*' - Mainly copper differs from mainly power crimp/expansion.

This table gives the number of people who answered each of the questions. The percentages in Table 3 above are based on these numbers not the total number in the group.

Table 4. Wrist pain and number of manual crimps performed per day

	Wrist pain		
Manual crimps	N	Mean	SD
<50	**24**	**4.50**	**3.18**
50-100	**48**	**4.52**	**3.05**
100-200	**30**	**5.37**	**2.70**
>200	**18**	**5.61**	**3.26**

F=3.76 p=0.0124 [<50 differs from 50-100 and 100-200; 50-100 differs from >200]

Table 5. Wrist pain and grasping effort reported for most commonly used technique.

	Grasping effort reported		
Pain level	N	Mean	SD
0 to 3	**83**	**3.70**	**1.96**
4 to 7	**46**	**3.65**	**2.11**
8 to 10	**27**	**4.39**	**2.98**

F=1.14 p=0.3225

Table 6. Comparison of advantages and disadvantages of four pipe joining methods

	Copper		Manual Crimping		Power Crimping	
Factor	N	%	N	%	N	%
Advantages	**131**		**159**		**40**	
Time*	9	6.9	107	67.3	18	45.0
Productivity*	7	5.3	103	64.8	18	45.0
Quality*	93	71.0	15	9.4	13	32.5
Safety*	30	22.9	41	25.8	15	37.5
Ease*	21	16.0	72	45.3	25	62.5
Comfort*	19	14.5	15	9.4	18	45.0
Other	14	10.7	11	6.9	2	5.0
Disadvantages	**139**		**121**		**36**	
Cost*	104	74.8	23	19.0	28	77.8
Incompatibility*	16	11.5	16	13.2	9	25.0

CHAPTER 4

Health and Safety Innovations that Reduce Musculoskeletal Disorders in Construction

An Examination of The Characteristics Shared by Workplaces and Innovators

Submitted to *New Solutions*

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4.1 ABSTRACT

Musculoskeletal disorders (MSDs) are among the most common workplace injuries suffered by construction workers in all trades. Implementation of health and safety innovations to reduce MSDs is a multi-faceted process in this complex sector. This paper investigates the characteristics of workplaces and champions engaged in the innovation process. During a primary research initiative, interviews were conducted with fifty-nine health and safety specialists and the introduction of twenty innovations were documented. Ten innovations were selected for additional analysis because they offered insight into the characteristics of welcoming workplaces and champions. The results indicate companies that were stable, survived economic downturns, offered a collegial atmosphere and allowed staff to experiment provided willing hosts. The champions exhibited participation in multiple networks, ownership of social capital, and a complex work history. We found champions can thrive to prevent MSDs in companies where they are encouraged to experiment, make mistakes, and try again.

Key Words: construction; musculoskeletal disabilities; ergonomic innovation.

4.2 INTRODUCTION

In 2020, the construction sector accounted for seven percent of the Canadian GDP and employed more than 1.3 million workers in forty identified trades (Statistics Canada, 2020; Building Trades Council, 2021). Occupational health disabilities associated with construction have been widely studied (Alsharef et al., 2020; Carlan et al., 2012; Weinstein et al., 2007; Raidén and Dainty, 2006; van der Molen et al. 2005). Much of that research explores disability prevention at the macro level examining the design of projects, the organization of work and the activities of the workers. Because many construction companies are medium and/or small they may not benefit from studies of large workplaces or project designs. This research examines an important subset of the injuries described as musculoskeletal disabilities (MSDs), which account for approximately thirty percent of all workers' compensation claims in Ontario (Wells, 2009). We are examining prevention initiatives at the level of the individual company and by local change agents or champions. Ultimately this research may provide a greater understanding of the innovation process at workplace level.

The origin of this research was a multi-year program in the construction sector, focussing on MSDs. There were three phases to the research program.

Phase I. Health and safety specialists at a labor management meeting of refrigeration/air-conditioning specialists identified an innovation for their subsector — a hydraulic ladder-lift (Figure 1). The lift allowed a ladder to be moved onto the roof of a vehicle without requiring the operator to climb on to the truck and lift the ladder. The participants identified 33 managers as potential opinion leaders, and they were asked to try the ladder-lift at no cost to their companies. Thirteen managers agreed to participate, and they were followed to determine the effectiveness

of the innovation. In addition, workers/operators who used the lifts were interviewed briefly (Kramer et al. 2009).

Phase II. The same research team along with active health and safety professionals selected 20 innovations to observe that they expected would reduce MSDs. Innovations were introduced to workplace parties by sharing tools, circulating fact sheets, and conducting focus groups with company health and safety committees. After introducing the tools, thirty-five managers, five health and safety specialists, and six union health and safety representatives were interviewed. The interviews focused on the characteristics of companies that introduced innovations including corporate structure (private /public ownership), unionization, the status of workers (permanent/contingent), and barriers and facilitators influencing the adoption of the innovations.

Figure1: Hydraulic Ladder-lift

Phase III. The researchers explored different paths of knowledge transfer. Building upon previous work, the team developed a theoretical framework for the evaluation of knowledge

transfer within workplaces. They concluded the transfer of knowledge can be evaluated by the context, the type of knowledge, and the method of facilitating the research (Kramer et al. 2012).

That original research team found the adoption of certain prevention strategies and innovative tools confronted notable barriers because of the complexity of the sector. The work itself is not standardized; rather, it is flexible and varied. The safety risks are always changing in an evolving workplace. The supervisor/worker relationship is not linear and often results in a diffuse and irregular reporting relationship. A significant proportion of the workforce was contractual or contingent. Finally, the culture of the sector is bound by the traditional work practices of workers, many of whom are proud of their skill set and are often resistant to change.

In addition to the complexity of the sector, the very nature of MSDs creates research challenges. The causes of many work-related injuries are apparent--a fall or slip--but the causes of MSDs are rarely so obvious. Often, it is years after exposure to workplace risks that pain develops or a disability associated with a MSD is evident (Yazdani and Wells, 2018). Consequently, the worker's exposure may have started with Company 1, but the worker may not have sought medical treatment or made a worker's compensation claim until they were working for Company 2, 3, or 4. Because of that long latency, the benefit to the employer of reduced claim costs associated with the purchase of an ergonomically designed tool may not be realized. Furthermore, even though there are new tools limiting workers' exposure to physical loads, the nature of the work makes it difficult to eliminate repetitive activities. Finally, the disabilities themselves may mirror disabilities related to natural aging and workers may not see them as work-related. As Wells (2009) reported, these complications may limit the ability of

methodologically sound MSD research to influence change; therefore, the MSD problem is far from being solved *(*Oakman et al., 2016; Wells, 2009).

The goal of this research is to examine the characteristics of the bricks that are the foundation for the creation and transfer of knowledge. Specifically, this paper examines the characteristics of companies and the people who encourage adoption. This micro examination of knowledge creation and transfer may be of value in the construction sector which engages many independent operators, contract, and gig workers. These workers are often excluded from large health and safety programs run by trade associations and knowledge transfer initiatives.

4.3 THE LITERATURE

The literature outlined below informs this research in part. It is not the goal to provide an exhaustive review of the literature but to highlight that body of research that is critical when defining the characteristics of both innovative companies and individuals.

Current theories of occupational health and safety, knowledge transfer, and innovation indicate successful knowledge transfer should include consideration of the context in which knowledge is transferred and the method of transfer (Kramer et al., 2012). To understand the context, we relied on the study of learning organizations introduced by Morgan (1986) as a platform for change. He posited that learning organizations provide an opportunity for double-loop learning. Double-loop learning means individuals begin by investigating a problem with the goal of correcting the problem. Then those double-loop learners take the additional step of investigating the source of the problem to eliminate it. In learning organizations, the staff are allowed to investigate, explore, experiment, search for the underlying cause of the problem and take steps to correct a

structural flaw. The discussions of learning organizations have progressed to include the work of Senge who indicates in his book, *The Fifth Discipline* (1997), that a systemic approach is necessary for the functioning of a learning organization. More recently, the work of other authors (Flood and Room, 2018) has examined power dynamics and its impact on learning and systemic transformation.

Understanding the context and stability is also explored by Farjoun (2010). He explains that sometimes stability implies rigidity without an opportunity to move beyond the current structure. Farjoun continues: "Stability and change are not paradoxical; they need not be mutually exclusive or interfering but can enable each other" (p. 222). Specifically, he wrote that successful change requires "stability, regularity, and predictability so that actors can understand and trust the settings of investment, purchase, savings, and production and so that transactions are profitable" (p. 202). An empirical component of stability also includes sufficient financial resources to allow for experimentation.

Together these two bodies of work identify the supportive context for change as one which is sufficiently stable to allow for exploration in an environment which permits experimentation and failure as well as success. This stability allows for what Rogers (2003) and Weinstein et al. (2007) describe as trilability (the opportunity to try an innovation before adoption) which also encourages experimentation. Taking a slightly different approach, Xue et al. (2014) refined the concept of trilability by discussing the innovation process. According to those authors, a key element of the process leading to success is the post-introduction evaluation process. In other words, the employer must be sufficiently stable to allow time for refinement or

experimentation after the tool is introduced. The ability to allow for experimentation is identified by all the authors.

With respect to the people participating in the innovation process Rogers identified five different groups of individuals. For our purposes three groups are relevant. Innovators are the first to try something. The next group of individuals along the path to innovation are early adopters who buy or employ products after the tool or innovation has been adopted by innovators but well before it is in common use. The third group of individuals - early majority adopters – try new ideas before the average person but are not usually leaders. With respect to tis research because of the small sample size we will look at the three groups as a single entity and describe them as champions.

Another stream of thought indicates that champions often engage in social networks. Sometimes engagement is response to corporate priorities rather than a personal interest, but in each case the champions benefit from the engagement (Yazdani and Wells, 2018; Xue et al., 2014; Carlan et al., 2012). The more meetings champions attend the more they learn about different initiatives; the more they became a source of knowledge to others, and the more they can influence systemic change (Greenhalgh, 2010). This form of social interaction allows for multi-directional communication which is critical to knowledge acquisition and transfer in the complex construction sector (Carlan et al., 2012; van der Molen et al., 2005)

That ability to network enhances the acquisition of social capital, which is non-monetary wealth that can be measured in terms of positional, experiential, or academic knowledge. Social capital enhances the status of its owner as a leader and can be expended by individuals to

accomplish a goal (Adler and Kwon, 2002; Bresnen et al., 2005). With specific reference to the construction sector, social capital is described as:

…. a personalization strategy — one that depends heavily on social ties might be more effective in capturing and passing on program-based knowledge and learning across programs rather than a more mechanistic approach to knowledge transfer based on codification that is perhaps best suited to a more stable and routine environment (Bresnen et al. 2005, p. 236).

In addition to owning social capital innovators also have flexibility in common. Albert Bandura (1989), a social psychologist, examined the specific characteristics of individuals who influence action and, in this case, influence change. Much like Morgan (1986), Bandura reported that people who acknowledge errors and work through solutions are likely to influence the change process. This ability to be adaptable, learn from mistakes and, in some cases, be persuasive and persistent is critical to the role of the champion.

Furthermore, the relationship of innovative individuals to their corporate environments is important. In their systematic review, Yazdani and Wells (2018) reported that a lack of collegiality or trust, fear of job loss, or loss of authority is a barrier to innovation. Conversely, a collegial atmosphere allows individuals to try something new, fail and not get fired.

In summary, the literature around organizational change and innovation identifies multiple themes. Welcoming environments are characterized by the willingness to allow individuals to try and try again within a stable workplace, which has the resources to allow for experimentation. The innovators/champions who work in these organizations are characterized by participation in social networks, valuing social capital and exhibiting flexibility.

4.4 METHODS

This research was conducted using qualitative methods. We began with a collection of twenty innovations identified in Phase II. Ten of the innovations were excluded from the present study because the workplace parties did not invest money or time to make them work. The ten innovations that were included in this analysis were part of an active innovation process, whether the implementation was successful or not. Additionally, we selected innovations which came from companies of different sizes. This criterion was based on our previous research about ladder lifts, as well as the existing literature, which indicated that companies of different sizes have different adoption of innovation rates (Eakin et al., 2001; Kramer et al., 2009). The selection process was also influenced by the company trade to provide a cross-section of the construction sector.

In total during all three phases of the research program, fifty-nine interviews were conducted by the program coordinator. The original interviews were semi-structured and addressed the methods of introducing innovations and the characteristics of innovations. The interviews were conducted by phone, digitally recorded, and ranged from twenty to sixty-five minutes in length. Participants were asked to describe the characteristics of the innovations, the success or failure of the innovation, and the employer's decision-making process. In addition to these structured questions the participants had an opportunity to explain their own work histories and the social environment of their workplaces. Our data set for this research was the ten interviews with innovators who had championed the ten selected innovations.

Our analysis of the interviews was conducted employing a qualitative methodology. Using a deductive thematic analysis framework, we identified characteristics shared by

welcoming workplaces. The existent literature identified the characteristics of willing host companies as learning organizations, with the resources necessary to experiment without adverse consequences. Additional research described champions The literature providing insight into the characteristics of innovation champions as individual who travelled in multiple social networks and through those journeys acquired social capital.

We also applied an inductive approach and evaluated the previously collected interview data to identify additional themes (Braun & Clarke, 2006; Fereday, J., & Muir-Cochrane, E., 2006). The narratives lead use to understand the importance of flexibility and collegiality as important characteristics of both workplaces and champions.

The findings set out below are supported by the participants' narratives. Pseudonyms have replaced the names of participants. The participants represent small (less than 20 employees), medium (up to 500 employees) and large companies (over 500 employees). All companies and their employees have at least five years of experience in the field. Characteristics of the companies, participants and innovations are set out in Table 1.

When the participants were originally recruited, they agreed that their input would be included in a multi-phase research program. All the research was approved by the University Research Director. No conflicts of interest were identified.

Table 1: Characteristics of Selected Companies, Participants, and Innovation.

Total number of employees	Main activity	Health and safety innovation	Innovators' Employment Role	Factors influencing adoption of innovation
<5	Electric contractor	Ladder rack	Owner 0perator (P1)	Networking, safety
< 5	cement work	Mechanized screed	Owner operator (P2)	Safety, production
2	Floor installation	Floor nailer	Owner operator (P3)	Networking Production; safety
< 100	Electrical contractor	Ladder rack	Health and Safety Committee member (P4)	Safety
< 100	Paving	Maintenance hole cover lifter	Worker (P5)	Safety, non-production activity collegiality
< 100	Brick laying	Ventilation	H&S |manager (P6)	Ability to experiment, Safety
< 100	Brick layer	Mortar mixer	Owner operator (P7)	Networking, Collegiality Production: safety
<100	Electrical contractor	Wire rack	Worker (P8)	Productivity safety
> 500	Utility provider	Anchor jack	Foreman /worker (P9)	Safety; non-production experimentation activity production
>500	Contractor (roads)	Stretching program	H&S manager (P10)	Safety, collegiality claim cost reduction
>500	Contractor (roads)	Alternative hammer	H& S Manager (P10)	Lighter but unsafe

4.5 FINDINGS

The selected interviews did not allow us to determine if welcoming environments attract and support champions or whether they influence workplaces to become innovative. Therefore, findings about the workplaces and champions are reported separately.

4.5(i) The innovations

In our original data set we examined twenty innovations but not all made it to more than an experimental try. The ten innovations selected for further analysis all illustrated some commitment by companies to implement them as evidenced by an investment of money and/or time.

Four newly created or recently modified innovations were identified. One company (P5) spent down-time creating a lifter for maintenance-hole covers which could lessen back and shoulder strain associated with dislodging a heavy metal cover (Figure 2). A large public utility (P9) modified an anchor jack to install anchors in ceilings (Figure 3). The anchor jack reduced neck, shoulder and arm strain associated with above head work. The workers of an electrical contractor (P8) independently requested a supplier to modify a wire reel to accommodate other changes. This tool limited the need to manually carry and manipulate bulky rolls of wire. Owners of a small company (P3) modified a tool used to secure drywall to become a tool to lay hardwood flooring without requiring workers to kneel repeatedly.

Figure 2: Maintenance hole cover filter

Figure 3: Anchor Jack

Readily available tools and/or programs were also identified. Two companies bought hydraulic ladder-lifts. These lifts hydraulically raised ladders on to the top of service vans and eliminated the need for drivers to lift the ladder and climb on the bumper of their vans (P1, P4). The owner-operator of a small paving company introduced a vibrating screed to mechanically finish paving surfaces (P2). The goal of the screed was to limit the need to manually smooth poured concrete and in turn reduce arm and back strain. The health and safety manager in a large construction firm brought their previous experience to the workplace and gradually introduced a stretching programme (P10). These programs have been widely introduced to prepare workers physically for a day of manual labor. The same company introduced a new type of lighter hammer which lessened the weight loads on workers' arms. The owner of a medium-sized company successfully introduced a silo-mixer (P7). This tool reduced the need to physically mix

large amounts of mortar for big jobs. Finally, in another medium-sized company (P6) that did stone restoration, there was an unsuccessful attempt to introduce a ventilation system. Workers at this firm were exposed to stone dust while preparing products for installation. The ventilation system would have removed the dust from most of the workplace, but it turned out to be too expensive when weighed against the amount of dust exposure. These examples all show effort and progress along the path to successful innovation.

4.5(ii) The Workplaces

These companies shared a common experience and survived economic downturns and managerial and functional changes. Most companies refocused their activities and redesigned their practices so they could thrive in changing circumstances. The larger companies suffered the least economic impact but required detailed business plans to determine the value of the change before it could be implemented. The narratives of the participants explain how these common characteristics set the stage for innovation.

Stability

For the purposes of this analysis, stable companies include those which have been in business for several years. That stability usually meant that there was financial "breathing room" for experimentation which was conducted apart from the normal course of business. In this data set, all the companies had retained most of their staff for a number of years and developed a collegial atmosphere.

In one case, the employer (P5) kept staff in the shop during the winter when outside work was unavailable. During that off-season, the staff created a maintenance-hole cover lifter which

reduced workers' exposures to physical loads (Figure 2). In another case, a large employer allowed the staff to work with a tool maker to refine an anchor jack to reduce work overhead while inserting anchors into concrete ceilings. The original tool was awkward and hard to move, but with the input of workers and supervisors the tool was refined (P9). In these two cases, the critical factor was the stability of the company. Stability meant that there were sufficient resources, including time to go outside the normal production process to find a solution for a recognized risk.

The manager of an electrical contractor (P8) reported that he had worked with the company for 22 years. That stable workforce was allowed to introduce new tools when they became available without significant study or discussion. For example, when the employer purchased a wire stand, the staff independently spoke to the supplier and requested that the supplier provide the wire on a compatible reel. The frontline workforce had sufficient confidence in their standing with the employer to act independently. This simple innovation decreased physical stress and improved productivity.

The company's stability provided "financial breathing room". For example, if the paving company did not have the available financial resources, it would have laid off all its employees during the winter shut down. But having some resources they were able to keep the innovator on staff to work in the shop during the winter and he eventually created the lifter. If that breathing room had been in question, there would not have been the resources to pay employees to experiment or obtain new tools. These stable companies which had been in business for several years, with a collegial atmosphere and a proven willingness to experiment, were identified as likely and willing hosts for innovation.

Collegiality

Another key characteristic of the willing workplaces was collegiality. Much of the literature describes workers in construction as having little connection to employers and often being engaged in acrimonious labor relationships (Weinstein et al., 2007; van der Molen, 2005; Lewchuk *et al.*2003). In contrast, another stream of research indicates that a collegial relationship between management and labor is an important factor in the innovation process (Yazdani and Wells, 2018). The following histories exemplify how a collegial atmosphere allows individuals to have the confidence to try and fail.

The owner of a privately owned bricklaying company (P7) valued collegiality and described the workplace as follows:

(P7) I try to keep the majority of the guys going. It just depends on the year. Winter's really tough in our trade, so it just depends on the type of work that's available at the time. A lot of my guys I keep at least half going through the winter for sure.

……They're pretty dedicated to us like we are with them too.

That participant had a history of providing consistent annual earnings for long-term employees and an interest in health and safety, which increased productivity as well as reduced the potential claim costs. Looking at both health and safety and production was a deciding factor in the decision to introduce innovations including a silo-mixer which mixed large volumes of mortar mechanically, which reduced physical strain and increased productivity.

Figure 4: Silo-mixer

In another company which was very large, the junior health and safety representative (P10) described the impact of collegiality in the following way:

We inherited an older [guy], he was in his sixties, carpenter superintendent. He recently had his hip replaced by the way. But he showed up on this program and he was very much a skeptic. And was not impressed with our corporate training program, 'cause it was new to him and it was quite alien. He had been in the carpenter trade for over thirty years. But nonetheless he had to participate because he was a superintendent. But I remember the first day demonstrating to him the exercises. . . The first time he had to try that he had to put his right hand on something, on a fence post he didn't have the balance. He couldn't do it unaided. Two weeks later he's doing it unaided…So right there I said to Jim look it, look what you've done you're not touching anything. You don't need to find balance that's going to benefit you on this program because the ground is uneven, you've got to step over things. So, at that moment I'd won him over and I don't have to worry about him as a superintendent who might undermine the Stretch don't Strain program.

The manager continued by stating that, "*He's a new ally and a champion to carry that on".* In this case, we saw how a collegial and safe environment allowed an older tradesperson to be persuaded to try something new and eventually become a champion.

The medium-sized electrical firm (P4) that purchased ladder-lifts had a workforce that had been together for several years. They had had no workplace injury claims resulting from installing ladders on the roofs of their vehicles. Even though there was no financial benefit resulting from reduced claims, the owners wanted to protect the health of long-term employees and purchased the lifts.

In this sample most companies that encouraged and adopted health and safety innovations had a long-term relationship with their employees, some having been with the employer for more than 30 years. The staff who participated in the interviews indicated that they were secure in their employment, which meant considerable, but not unlimited, protection against dismissal or demotion. This collegial relationship is an important characteristic of innovative workplaces and sets the stage for health and safety activity, in a sector which usually does not offer job security.

Flexibility

The following companies in our study provided the space to refine innovations. These companies recognized that successful change was often only possible when ongoing modifications were part of the process.

In one case (P6), a manager's original request to their executive for improved ventilation was rejected. Instead of giving up, they worked through the issue. As they explained:

P) I tried to get a local exhaust in here for the welders. But for the amount of time that we do welding, they look to the value. [They want to know if] there's another way to do it without having to go spending money on the machine. So there was a small amount of debate, but it wasn't as automatic as, yes or no. There was a discussion.

I) You came up with an alternative?

P) Yes.

I) So, it never was a no, altogether?

P) It was a no at that time. But the door is always open. I can always come up with it again and bring it to the table.

In this example the participant was sufficiently confident that bringing a new idea to management was an acceptable initiative. He also explained that the workplace was flexible and although the original idea was rejected, an alternative suggestion would be welcomed.

Again, the willingness to reverse a decision without adverse consequences is explained by this manager of a large contracting company (P10):

… there was what was deemed to be a great product. It's a hammer with a fiberglass handle, and a great rubber gripper. The hammerhead is held on there with some epoxy. In a hot heat environment that epoxy will melt and become kind of gooey allowing the hammerhead to fly off. Once we discovered this, we realized there's potential for serious injury…, we immediately contacted our purchasing department, and they got in touch with our distributors, and we have stopped buying that product.

The research team saw that employer flexibility, which includes respect for new ideas and experimentation, was critical. Not all new ideas are successful on the first try; however, the

ability to modify an innovation and try again can lead to success. We found that innovators worked in companies that allowed for mistakes and permitted people to spend time on activities that were not directly related to production.

4.5 (iii) The Champions

All the innovators in this sample were engaged in multiple social networks, which provided them with the opportunity to acquire social capital. Much like their companies, these innovators can also be described as flexible.

Social Network Involvement

To understand why certain individuals are champions we examined their willingness to travel in diffuse social networks. All these participants were engaged in the government organized construction health and safety association and most participated in trade specific organizations. Many were also engaged in community and social networks.

A manager (P8) also took advantage of the networking of the company's contingent workforce. They reported:

Having a migrant workforce is advantageous because you know what everyone else in the business is doing as well. You know, you're not like a factory where people come in and close the doors and do their own thing. Guys will tell you, 'At that company we do this,' and 'At this company we did it like that'. You get to know that for almost anything we're doing, there's different ways to do it, and there's different people who will do it differently for different reasons.

The owner/worker of a bricklaying company (P7) explained how a personal social network provided him with the information that led to the introduction of an innovation. He explained:

> *Actually, I received a phone call from a guy that I guess knew me years ago. We played hockey together years ago and he started selling this product [silo-mixer] …We tried it out for this big job that we had at a school that we did. And it worked great! It saved a lot of labor on the guys.*

The owner/operator (P3) of a small flooring company described his networking activity as follows:

> *Trade shows are something I started attending with my older brother who joined the company later and we came across a machine that was there to accommodate drywallers. We both looked at each other and had the exact same thought. Why not an extension to the machine and instead of using it on the ceiling, use it on the floors instead of bending done and screwing down the floor with one hand, with no glove…The benefits are incredible.*

These trades people took the time to go outside the immediate workplace and learn. They all took advantage of technical and social networks to gain additional knowledge, which they applied to their own workplace.

Ownership Of Social Capital

All the innovators in our sample had significant social capital and they expended it to create change. That capital included experiential knowledge gained from years on the job, positional/familial associations, and education.

An owner (P7) of a bricklaying company described his use of positional social capital:

I'm the fourth generation of the business. My great-grandfather brought it over from Europe, from Belgium, and my grandpa took over the business. My dad. Now me. So, it's just hard to try to convince somebody that's been doing it for that long that there is an easier way… I'm young, so for my father trying to get into the newer stuff, it's harder for him to justify it. But you know what, for me at my age, I'm like, 'let's try it'. I'm more willing to, at a younger age, to try something different to see if there is something better out there…He's good with me now because we have tried new stuff and it's all really worked out for us. So, he's more apt to adapt to something now.

The importance of experiential social capital was explained by a worker co-chair (P4) of the health and safety committee. They reported:

Corporate was very reluctant to hire [the management health and safety co-chair] because he comes from the field. He didn't come from the university background…

We [management and labor co-chairs] have greater success because we understand the nature of the business because we've done the installs. We've done the service. We've done the work that the people are complaining about. So, we can walk the walk, and talk the talk. And you get more respect by the people that you're working with to try and implement your programs due to the fact that it's not just corporate driven.

In large organizations, the health and safety manager (P10) described the decision-making chains in their bureaucracies. Social capital in these organizations was accrued from a

more formal bank--through education and training--rather than positional or experiential knowledge.

The health and safety representative (P10) in a large company explains the use of social capital in the form of academic knowledge and their perseverance:

Cost-benefit analysis is an easy business model which my superiors understand. It's just the way that I make the pitch. I kind of construct the idea, and definitely, if there's a huge cost savings there, one that can be measured easily in financial terms, it's going to be a green light.

In these cases, the beginning of the change process was dependent, in part, on the innovator's bank of social capital. Social capital created credibility among both workers and management and because their opinions were respected, innovators could open a change discussion. Even so, the expenditure of this capital was not, by itself, sufficient and often had to be supplemented with financial benefits to initiate change.

Flexibility

Only one of the participants, who was employed by a large company, moved up the career ladder from junior health and safety officer to health and safety director of an international company in a straight path. He was clearly an anomaly. In our study, most innovators experienced circuitous career paths, which reflect their adaptability and flexibility. While some people worked successively for several different companies in similar positions, other people worked for the same company but moved from production positions to health and safety positions.

The typical career path for these participants is described by this health and safety committee member(P4):

> *I started out many years ago in construction as an ironworker putting up the higher steel, higher rebar, and stuff like that. I fractured my neck…The one company that I had worked for in the past, said, '[Steve] can you use an engineer's transit?…From there I worked with them, and then a couple of years later I tore the cartilage out of my knee, so back again…So real estate felt like a good option…My original employer asked me to come back and do some work for them and do estimating…and then they said, 'We need somebody to actually start helping us with our safety.' …I started taking some courses and doing training with the Construction Safety Association and just on my own. I learned a lot about safety…Then I became the corporate safety manager.*

This type of career path involves several transitions, where social capital is gained from direct experience of injury, complemented by academic training.

The owner of a small company (P2) exhibited similar adaptability. They reported:

I started in 1987 with a drywall company… And then the recession hit, and I started diversifying…I did whatever I could get my hands on. And then it just grew from there.

Finally, the owner of a company (P7) reported their decision after hitting a career roadblock:

> *I went through for Law and Security to be a police officer and I graduated. And I went and did my co-op, my placement for my college. And that was it for me. I couldn't sit in*

the vehicle. I sat in the vehicle for two weeks and I said to my father, 'I think I wasted my money'… I just wasn't interested in it then.

The champions in this study are individuals who have confronted roadblocks and moved beyond them. They are not people who take a straight path. They had the ability and resources to learn and take another path to attempt change. They also accrued sufficient social capital from different platforms to influence change. Some employers have provided them with the independence, power, and budget to make new purchases or implement new practices. In other cases, the bureaucracy dictated the need for a business plan to persuade others of the value of the innovation. But the critical factor was always an opportunity to go outside the path of production and try something new.

4.5 DISCUSSION

These results led us to ponder what Weinstein et al. (2007) identified as a critical question for researchers outside the construction community: "What is the "appropriate entry point when attempting to introduce health and safety initiatives into the construction sector?" Specifically, we examined workplaces that provided a welcoming environment for health and safety innovation, and innovators who appeared to have skills to champion innovations. This analysis could help to focus future research by targeting specific workplaces and innovators.

Companies that are supportive of innovation and individuals willing to try new ideas are not driven solely by productivity imperatives (Dogherty et al., 2010). This finding contrasts with the current management fixation --lean production– which limits activity to only that which can add direct value to the product (Ismyrlis, 2021; Spencer & Carlan, 2008; Womack et al., 2007; Landsbergis, 2003). Welcoming work environments offer a level of security that allows the

innovator to feel sufficiently safe to spend time on experimentation. The environment also allows for contemplation, making mistakes, and taking chances. If these elements are missing and the personal consequences of failure are serious (e.g., dismissal), it is unlikely that the champions will be willing or able to try something new.

These innovators were engaged in social networks. Their work and interaction with colleagues, both in their own workplace and outside networks, exposed them to knowledge that would not have been available without that social interaction. A key to their innovativeness seems to be their willingness to acquire and share new knowledge. This knowledge enhances their confidence and allows them to persevere, a characteristic identified by Bandura (1989) as important for innovators. Ultimately perseverance, willingness to recognize a mistake, and then adapt are some of the characteristics of the people who can initiate change.

Although health and safety considerations can encourage innovation it may not be sufficient to ensure adoption (Yazdani and Wells, 2018). For example, a rebar tying tool that can unquestionably reduce physical strain has met with much resistance among rodmen, who are skilled tradesmen responsible for laying steel rods before concrete is poured. These workers rejected the innovation because it diminishes the value of their skill (Vi, 2006). On a more positive note, a small size and a midsize electrical firm adopted the hydraulic ladder-lift for proactive health and safety reasons alone (Kramer et al., 2009).

This research helps to provide a partial answer to the question, “what is the appropriate entry point?” The following characteristics provide partial answers:

- Availability of unscheduled time that allows for activities that may not have an immediate pay-out,
- A collegial atmosphere where managers and front-line staff can experiment and not be afraid to fail and
- Employees who are socially engaged and exposed to different approaches through their variety of networks have the ability to introduce new ideas.

Researchers aiming to innovate in health and safety should look for environments that share these characteristics. Future research should continue to examine the interaction between organizational structure and the people who operate within those structures. Of course, it is important to recognize that successful innovations often have a financial as well as a health and safety benefit to the employers and employees.

4.5 (i) Limitations

The major limitation in this work is the absence of a detailed investigation into failed innovations. Our conclusions may have been stronger if we could have contrasted successful innovations with unsuccessful innovations. However, the results, albeit limited, provide insight for potential applied researchers.

4.6. CONCLUSIONS

A good idea is not enough. Successful innovation is a social process, which is dependent on the idea, the real potential to reduce exposure to physical loads, the workplace context, and the champion. Each of these elements must share flexibility as a common characteristic for innovation to be successful. There must be the ability to tweak an innovation when it is

introduced into the workplace. The workplace must have sufficient respect for the workforce to allow members to try and to make mistakes without fear of reprisal. Finally, innovators need a sense of confidence and comfort, which allows them to try new ideas when opportunities arise.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 GENERAL FINDINGS

The transition of paid work from modernity to post-modernity has in part resulted in more gig workers, worker isolation, reduction in regulatory monitoring about exposures, modified return to safe work practices and modifications to benefits (Crawford et al., 2020). The extent of these changes is exemplified by a recent look at Google Scholar which identified over 17,000 research articles published since 2018 when the term “changing world of work” was searched. As an aside it is also relevant to recognize that the workplace changes have been even more evident because of the impact of the COVID-19 pandemic (Ng et al., 2021). The social process of occupational health research has been affected by the organization and structure of the world of paid work. That research now engages many social actors including academic researchers, employers, workers, unions, policy makers and manufacturers of tools. In this thesis I examine how the interaction of these actors influence the creation, dissemination, and implementation of knowledge in this changing world of work.

For occupational health research to be influential it is necessary to understand the context in which it operates. The class theories which describe a bifurcated world of the oppressed and oppressors, championed by Marx and Engels, can be used to explain the structured world of work in a modern context. In that world, which still operates, workers are employed usually by one employer for most of their working lives. The organization of work, limits understanding of or exposure to the entire production process (Braverman, 1974; Taylor, 1911) and accordingly limits workers’ opportunities to influence the occupation health and safety regime.

The workplaces in this thesis are in transition and have not completed the journey to post-modernity. In none of these studies are the workers assigned to stationary workplaces.[4] The relationship between workers and employers is often tenuous and not expected to be life-long, especially in the retail study. That tenuous relationship between workers and employers means that economic data documenting work-related lost time is not consistently available. The role of unions and their economic influence in these workplaces is also undergoing changes. Specifically, after the recession earlier in this century, unions found it necessary to be more focussed on job security and wages. Only after the recession did they again begin to deal aggressively with health and safety during contract negotiations. Although in these studies the work assignments were determined by the employers, developing the work processes was most often left to the workers. Furthermore, at least in this jurisdiction, neoliberal governments have been elected and now governments act more like advisors than regulators (Lewchuk, 2011; Tucker, 2009).

As a result of these changes the research process also changed. The retail study is predominately situated in a modern environment, which has a rigid power structure, limited worker control and only limited ability of workers to change to the work process. It does, however, illustrate the impact of workers as full research partners in the research process. The second study is situated in a complex workplace, which illustrates the development of knowledge by workers and the limits of implementation when there is incomplete enrolment of multiple actors (employers) in the research process. The final study exemplifies how knowledge can be

[4] Although the majority of full-time LCBO workers were assigned to one location, the majority of the participants were part-time and assigned to multiple locations.

created in fluid workplaces, more closely situated in the post-modern world in which there is a power sharing structure.

Each of these studies provides some insight into the changing paths of research and the accompanying knowledge creation. This analysis can provide guidance for future researchers and may provide insight into:

- who are the studiers (researchers),
- what is studied,
- how to study,
- how to disseminate the created knowledge, and
- how to mobilize what we learned.

The end of this research journey may ultimately be about workplaces following the Fourth Industrial Revolution (FIR). Those workplaces are described by Min et al (2019) in the following way:

> In FIR, nonstandard employment will be common. As a result, it is difficult to receive OHS services and compensation. Excessive trust in new technologies can lead to large-scale or new forms of accidents. Global business networks will cause destruction of workers' biorhythms, some cancers, overwork, and task complexity. The social disconnection because of an independent work will be a risk for worker's mental health. The union bonds will weaken, and it will be difficult to apply standardized OHS regulations to multinational enterprises

Future research will have to be designed to understand FIR workplaces that have completed the journey.

5.2 THE RESEARCH JOURNEY

When designing an approach, if the research team limits its thinking to a modern approach, it will fail to recognize the importance of the multiple forces at play during this period

of transition. For researchers to best understand the complex transitioning workplace I argue they should employ ANT and the complimentary work of Callon (1984) regarding the four movements. When that approach is employed, researchers problematize, create a shared interest, enrol all interested and affected parties, and finally mobilize the created knowledge. Unfortunately, I did not always follow that advice and so the following discussion illustrates how the research succeeded and also what research needs more work.

5.2(i) The studiers (researchers)

Occupational health outcomes are influenced by workers, employers, technical advances, costs, and regulations. For the research processes to be successful at least three groups of actors, including academics, workers, and employers should be part of the process. Like many qualitative researchers, who practice in a transitional environment, I provided a voice for workers in the research process. I was not successful in always engaging employers and that affected the final mobilization of the research results. Mobilization could have been encouraged if there was a clear financial benefit for employers like a reduction in WSIB premiums when there is an agreement to participate in a research initiative. It would also be beneficial if as Yazdani et al. (2015) argue that health and safety initiatives are an integral part of the business plan for all employers, not an afterthought following elevated rates of injuries.

The union representatives in the first study knew that there was a higher-than-expected rate of lost time injuries, but the exact causes of the injuries were not clear. Because there was not a collaborative workplace culture, there was very limited employer cooperation. That meant that there was no access to the data base to confirm the causes of injuries. However, by working

together with the academic researchers, that group of workers was able to design a research tool to isolate causes of the injuries and set the stage for preventative action in the future. When the results were reported to the employer there was not much interest in modifying work practices. I attribute this disinterest, in part, to the lack of employer input in the collection of data. There were also significant staffing changes at the managerial level and this study was not considered a high priority. If I were to do it over again, I think that the economic advantages could have been more vigorously addressed during private employer meetings and that could have encouraged their input.

The plumbers believed the repetitive crimping was the source of their pain. However, there was no data to validate their concerns. As in the retail study, we (the academics) entered into a plan with the plumbers and their union and did not spend any energy at the initial stages of the research plan to engage the employers. Accordingly, the contractors did not see any benefit to them to warrant additional expenditures for different tools. During this research process the employers did not see themselves as participants, and therefore were not anxious to adopt some of our recommendations. We were, however, able to collect significant quantitative data because the workers/union provided us with entrance into the workplace. Not only did we learn from these visits, but we were also able to develop a level of trust and collegiality with the union activists. That relationship also provided us with invitations to present findings at union organized events. Finally, the workers provided the academics with a good understanding of the organization of work and the opportunities to disseminate information and influence work practices.

In the third study the workplaces enjoyed more collaborative environments. All of the workplace parties participated by either modifying work practices or providing the time to try new ideas. As a result of this more inclusive research team, there was a greater willingness to adopt the research results.

Developing a research team is a critical step in the research process. That development process is just as fluid as the work practices in post-modernity and requires flexibility on the part of the initial research team. In a post-modern environment when knowledge and power are shared it is necessary to include all the players in the final research design to improve the possibility of the adoption of research results.

If in both the retail and plumbing studies the research teams had been more inclusive, the results might have been persuasive, and we may have seen a more immediate adoption. I am not, however, convinced that this flaw was fatal to the research process. It simply means that we must do more work at the end stage to persuade the adoption of results. The knowledge created without the employers still provides insight into possible improved working conditions.

5.2 (ii) What to study

For research to be impactful it is necessary to understand the injury, as well as its cause and finally how to avoid the injury. In these studies, the occupational injury and etiological hazard and/or risk were not always immediately apparent. This process of investigation of the frequency of injuries, the source of injuries and possible solutions is problematization or the first step of knowledge creation.

Because the existing forms of knowledge predate the beginning of any research process, it is helpful to consider the forms of knowledge to also understand the problematization process. Many authors have identified different forms of knowledge, (Park 1993, Hall et al. 2016; Kramer and Cole, 2003). Each form is critical when attempting to improving the health and safety environments and are:

Instrumental knowledge: (also called structural or problem solving) is based on research findings or the experience of workplace parties including workers, which can be used to design a new policy, program or procedure (i.e., the introduction of a new tool).

Strategic knowledge: (also called tactical or symbolic) is used to justify a change of a course of action following the creation of instrumental knowledge (i.e., changes in work organization like the reduction of part-time staff).

Conceptual knowledge (also called political or enlightened) creates structural change which goes beyond the immediate workplace (i.e., the introduction of a new government regulation).

Each of these forms of knowledge are components of occupational health research and are critical to the completion of the research process.

Modern workplaces, which are often large-scale assembly lines with controlled environments, are dependent on employers to dictate instrumental knowledge or standard work practices. That work organization provides little opportunity for workers to explore or use their indigenous knowledge to modify the work process. As a consequence of this rigid organizational structure, most often data about exposures, accidents, and lost time is collected from company

records and require permission from employers. That collection process makes it possible to identify work processes, which result in high rates of injuries through quantitative analysis (Aronson et al.,1994; Eisen &Tolbert ,1992; Kusiak et al. 1991)

In this jurisdiction, research during modernity was initially the result of public pressure because of the workers' concerns over of elevated cancer rates resulting from exposure to asbestos and mining risks. That pressure led to the 1975 Royal Commission on the Health and Safety of Workers in Mines, which in turn led to multiple epidemiological studies of the health of miners (IDSP, 1994). In addition to quantitative incidence data, employers also had and still have the authority to allow researchers like hygienists to quantify the exposures in the workplace. Worker representatives did participate in the development of the research initiative; however, their voices were rarely part of the quantitative data analysis. The quantitative research process did and does allow the employer to identify weaknesses in its work processes and sets the stage for corrections. The research results also set the stage for unions, workers, and activists to begin to bargain for safer workplaces and compensation for injured workers. Finally, it set the stage for the state to develop policies for the compensation of illnesses like cancer and COPD.

In any workplace the people who do and did the work have access to instrumental knowledge about how to do the job and how to make simple modifications to make the task easier. With or without permission from employers, workers know where to position their tools for easy access and they often bring their own tools which make the job easier. In transitioning workplaces, workers have additional power to modify work practices and can take independent steps to improve work. That power and or independence sets the stage for the development of strategic knowledge which can result in changes to the work process. We also saw with access to

additional knowledge, workers were able to become activists and pursue political goals in the form of joint committees and the right to refuse unsafe work.

The study of the retail workers provides a good example of broad-based knowledge creation. Although the full-time workforce was the driver of the research initiative, it did not abandon the part-time workforce. Full-timers encouraged part-time participation and included resources to capture the part-time experience. Because of new data collection techniques, including the union's ability to use publicly available computer software, the full-time workforce, with assistance from academic researchers, was able to collect data.

These technological advances (publicly available survey tools) allowed the workforce to exercise some power in the process of data collection without the specific authorization from the employer. In addition to participating in quantitative data collection, the full-time workforce insured that the voices of workers were heard in the development of the study design and gave the workers an opportunity to provide qualitative data. Without worker input, the survey would not have properly documented exposure because of the split shifts of part-time workers. Additionally union health and safety representatives now have access to the new survey when conducting ongoing regular surveillance of the workplace risks. This study exemplifies the creation of all three forms of knowledge. The survey results have formed the foundation of ongoing discussions with the employer about possible immediate improvements, an example of instrumental knowledge. By providing a platform for workers' voices we created a better survey and the foundation for evidence-based health and safety programmes to strategically improve the relationship between workers and employers as cocreators of knowledge. Finally, the workers and the union were introduced to their ability to create knowledge and share power in the research process, a role

which goes beyond fixing immediate problems. Because conceptual knowledge is still being developed this research process is not complete, but in this transitioning workplace we can see the beginning of a power sharing process.

The plumbers' study also highlights the creation of different forms of knowledge. In contrast to modern work activities, plumbers are often assigned different tasks and are able to exert some control over the completion of the task. In this case the workers identified issues arising out of the new work process – plastic piping. Furthermore, during the research process the union staff came to learn about research techniques, and subsequent instrumental and strategic knowledge creation. Of equal importance was the opportunity for academic researchers to learn about the workplace.

The final study looking at the innovation process gave us the opportunity to observe knowledge creation in non-traditional workplaces. Although there were some modern companies in this study's sample, every company operated in a flexible environment, something more common in a post-modern economy. The study focussed on skilled tradespeople who have always had an opportunity develop their own work practices. These participants identified occupational risks and gave health and safety researchers an opportunity to observe the use of instrumental knowledge to create occupational heath knowledge. The skilled trades people not only used their knowledge to modify existing tools but to also design new tools. Because they were not subject to the strict controls of modern workplaces, they used the opportunity to go beyond everyday activities and improve their work practices.

These three studies illustrate how workplaces which are flexible and in transition provide opportunities for input from different players using different methods. The collection of

alternative forms of knowledge allows workplaces to value all of the actors and in turn rely on the actors to participate in knowledge creation.

5.2 (iii) How to study (Research Methods)

In transitioning workplaces, the creators of knowledge include not only traditional academic researchers and the owners of the means of production (employers) but also the also the workers who carry out work activities. Participatory Action Research (PAR) has become critical to knowledge creation during the transition to post-modernity. Because workplaces are smaller, PAR offers the use of indigenous knowledge to identify technical issues and the use of low-cost tools and local solutions (Kogi, 2006; Brown, 2005). That indigenous knowledge can be more concentrated than data from large data banks but just as useful. For example, in the innovation study we saw how the value of stretching programmes was passed on from the employer to employee and finally to other employees. In the retail study, the role of the union was critical in the data collection process. Not only did the union provide resources for the health and safety representatives to participate but it also encouraged the membership to participate in the survey and study.

As PAR was gaining acceptance, qualitative research methods were also gaining acceptance (Park, 1993; Guba & Lincoln, 2004; Moir, 2005). In each of these research studies we not only identified quantitative exposure risks but also heard workers' voices to understand the issues around the organization of their workplaces. These combined research processes allowed us to gain a greater understanding of how the workplaces functioned. They also provided academic researchers with better research tools to focus the data collection. As a

consequence of the combined research methods, we had a pathway to dissemination as the worker/researcher participants actively shared the results of their work.

In the final study we used secondary analysis to allow us to dig deeper into our previous findings. Not only is this research process economical, but it allows external researchers to move closer to the final mobilization stage. In that study by learning what worked we could apply the same practices to new research initiatives.

Research methods studying the post-modern world must also be fluid. If researchers are rigid about interview schedules or data collection processes, they may miss important information. When multiple actors are engaged, researchers hear multiple voices and can create more complex and useful knowledge. Using both methodologies resulted in top-down knowledge and bottom up knowledge creation. It meant that sometimes we had to sit back and reconsider our course of action.

5.2 (iv) The dissemination of knowledge

The dissemination of knowledge is affected by the context in which the transfer occurs, the audience to be addressed and the content of the knowledge (Kramer et al., 2013; Carlan et al., 2012; Kramer et al., 2009). Traditional/modern workplace research was most frequently disseminated through academic journals, which were addressed to other academic researchers and, on occasion, policy makers. Those journals were not readily available to workplace parties until the internet became a common forum. In the 1980s and ‘90s when joint health and safety committees came into their own, we saw the research results being made available to workplace

parties, workers, and unions (Storey, 2008; Palmer, 1992) because of negotiations between unions and employers.

As the workplace and its context became less structured, researchers identified the need to study the dissemination process. The idea of workers reading written academic papers was and is unrealistic (Ngo et al., 2017). In transitioning workplaces other forms of dissemination have become popular because traditional health and safety committees are not as prominent or available to gig workers. In the alternative social networks provide the venues for people with social capital to be key transmitters (Carlan et al., 2012). In each of these studies the dissemination of research is most effective when social networks are the environment in which dissemination occurs.

The research team in the retail study included workers from the inception of the project. The union arranged committee meetings and were not only actants in disseminating the results of the research but also encouraged multi-party participation in the development of the research. Of even more importance these meetings provided an opportunity for health and safety representatives to meet, some for the first time, and form additional networks, which set the stage for the dissemination to front line workers. Of course, we have to also recognize the publication of the study results in a peer reviewed journal was also an effective method of sharing results. The published research paper has been cited in other articles on other subjects because of the survey development process.

The plumbers' study illustrated multiple forms of dissemination. In the first instance the indigenous knowledge of plumbers using the new process, identified health hazards to academic

researchers. During our research, the academic researchers introduced new Generation I and II crimpers to the frontline plumbers. During our focus group, several contractors were also introduced to the hydraulic crimpers for the first time. The publication of this paper in a peer reviewed journal was also an important dissemination activity because it set the stage for policy makers to consider the potential for recognition of work-related MSDs.

The innovation study clearly identified the value of social and professional networks with respect to the dissemination of knowledge. This finding confirmed the previous results of our research with respect to ladder racks and other innovative practices, that social and professional networks are an important forum for the dissemination of knowledge (Kramer et al., 2009). Workplace parties participate in these networks and gain social capital because of their participation. Workers who acquired more social capital were more influential in the workplace and more successful in disseminating knowledge.

The construction sector is an important milieu in which to study dissemination in transitionary workplaces. An innate characteristic of the construction sector is multiple worksites, which engage multiple trades, who are transitory. When workplace parties engage in multiple social networks, they provide knowledge in an accessible (practical) format. The focus groups held with union workers and independent contractors also provided knowledge which would not have been previously available. Finally, the formal academic research process was also important because it could lead to the development of conceptual or policy change.

5.2 (v) Mobilization or implementation of knowledge

From my perspective the implementation of knowledge is a critical element in the completion of the research process in at least two important ways. In the first instance, the implementation of knowledge can facilitate improvements to work practices and, secondly, can influence the development of government policy concerning health and safety regulations and compensation policies.

The practical implementation of health and safety research is often dependent on an economic benefit for the employer (Carlan et al., 2022; Wells & Yazdani, 2021; Tompa et al., 2007). For example, there is evidence that structured modern workplaces have benefited from the financial awards of ergonomic improvements. As Hendrick (1996) wrote:

> Ergonomics offers a wonderful common ground for labor and management collaboration; for invariably, both can benefit – managers, in terms of reduced costs and improved productivity; employees, in terms of improved safety, health, comfort, usability of tools and equipment, including software; and improved quality of work life.

The growing prominence of small or gig employers can preclude the identification of financial benefits associated with the introduction of ergonomic tools. Very often these firms do not have WSIB coverage, or their transient workers are not with them long enough to establish claim reduction as a benefit of improvements. As an example, the hydraulic crimper was not adopted by plumbing contractors because no financial benefit was identified. Therefore, we have to look beyond immediate economic benefits to encourage change for the sake of safety.

Unfortunately, because of constant staff changes at the management level, we were not successful in engaging the employer in initial stages of the retail study. This issue confirms the need to recognize all the actors in the workplace and the need to engage them to be able to

successfully implement research results when developing a research plan. However, I do not think that unwillingness on the part of an important actor (employers) should shut down the research. The building of a complete health and safety network is a process. It may not be complete, but as Latour wrote "in post-modernity the social is always changing" and the potential for employer participation may be possible in the future.

Notwithstanding the limited implementation in these studies, we did identify some examples of health and safety improvements as a result of participation in the research process. Small companies, which could be described as participants in the gig economy, championed improvements which we identified. For example, in the case of independent plumbers, manual crimpers were abandoned, and hydraulic crimping tools were chosen which increased productivity and prevented MSDs. The study of innovators illustrated the value of ergonomic tools created by the implementation of indigenous knowledge. In collegial workplaces, characterized by small contingent workforces, the manhole lifter and anchor jack were introduced and accepted. These tools improved working conditions without an immediate economic benefit. In these cases, the indigenous knowledge of the workforce was applied without fanfare to improve fluid workplaces. It also allowed companies to maintain a stable reliable workforce, which in itself is an economic benefit.

The ability to mobilize newly created knowledge in the modern world may appear more efficient but mobilization may be less effective. That environment allows the researchers to continue to be guided and in part limited by the power exerted by the owners of means of production.

In the alternative, ANT recognizes the power in the transitioning workplace comes from multiple sources including workers who have the instrumental knowledge required to improve working practices. Another mobilizing force in the transitioning world is advancing technology, which is available to both employers and workers. That additional actant – the advancement of technology - has opened the door to not only to the creation of knowledge but also its dissemination and impact.

Looking beyond these studies, my work in the construction sector the indicated that the implementation of knowledge by workplace parties resulting from academic publishing was very limited. I frequently asked tradespeople if they ever googled health and safety issues on their own time. The resounding consensus was no. However, academic research was raised in meetings with construction health and safety associations as an important component of the development of government regulations. The members of the committees would ask for data to support their position to modify regulations concerning exposures. Academic researchers add a special component to the knowledge creation process. But for them, these papers probably would not have been submitted for publication in peer reviewed journals. Those publications, which can be described as conceptual knowledge, gave the research the status necessary to influence government policy makers and advance healthier workplaces.

Finally, relying on my experience as a senior government employee I am disappointed to see how little peer reviewed research made it into the policy. As Chair of a statutory policy organization only three of 21 research papers made it into policy providing compensation for occupational diseases. For example, in 1994, the ODP recommended that Schedule 3 of the Workers' Compensation Act be amended research to include lung cancer as a possible outcome

for hard rock miners. This recommendation was supported by nearly 20 years of academic research but has not yet affected policy. As an adjudicator, I was only occasionally provided with current academic research as support for a claim. Furthermore, I am unable to recall any cases when the treating physicians relied on any published research when discussing the etiology of a worker's disability. It is disappointing that the research paid for in large part by the government was not rigorously applied by the government in adjudicating claims.

The second leg of the implementation of knowledge is political change brought about by a new activism. Twenty years ago, in 1997, Von Krogh and others challenged researchers (knowledge creators) to develop knowledge activists. Those authors saw knowledge activists as catalysts of knowledge creation, as connectors of knowledge creation efforts and merchants of foresight. This analysis is consistent with the more recent thoughts of others who have considered the implementation of knowledge. In their earlier work, Hall et al. (2006) recognized that knowledge activists were characterized by the wide-ranging base of their knowledge and the focus on the underlying causes of disabilities. Recently Hall et al. (2016) advanced the discussion of political health and safety knowledge activists. Specifically, they found that political knowledge resulted in changes that went beyond the introduction of instrumental knowledge.

The retail study shows that the road from the development of technical knowledge creation to political knowledge activism is not linear, but it exists. In the first instance, union representatives realized that they have more power when they help create documented technical knowledge and they have access to that knowledge. When that knowledge is strategically used it has the potential to advance the development of proactive participatory

ergonomic programs - a conceptual/political goal. The fact that technical knowledge has not yet resulted in structural change, which would include collaborative proactive ergonomic programs, confirms Hall's conclusions that political (institutional) knowledge activism is critical. The union participants, in this case, now have a broader network of health and safety specialists and have gained technical and strategic knowledge during this process. Historically, the union in this workplace has used significant political knowledge to negotiate good working conditions and fair wages. There is now an opportunity to move health and safety issues to a political platform and bargain for systemic collaborative health and safety initiatives.

Although the research has helped to create knowledge, there are barriers to change resulting from this new knowledge. A major stumbling block identified by Yazdani and others (2017, 2016) is the negative impact of the absence of management's commitment to integrate health and safety into its business plans. Those researchers found that many individual ergonomic initiatives are implemented only on a short-term basis. Whereas business management frameworks that include ergonomic practices are continuously revisited, improved, and sustained. The short coming may be overridden if the state intervenes to promote organization-wide MSD programmes.

This evidence shows us that researchers in post-modern environments have to look beyond the reduction of claims costs as an incentive for employers to participate. Support from social network members may be more important than other forms of dissemination to encourage the implementation of different forms of research results. It is also important to recognize that the knowledge shared in the grey environment including trade magazines and trade shows has

the potential to successfully encourage the implementation of research knowledge. Furthermore, the manufacturers that design new industrial processes could also have a proactive role in prevention if the state were to introduce an incentive programme like Prevention by Design.

5.3 AGENT OF CHANGE ACTIVITIES

In this thesis I argue that research is a social process, which encompasses the creation, dissemination, and implementation of knowledge. The three studies included, as well as my professional activities provide some insight into my participation as a change agent. I want to acknowledge, however, that my role would only have been possible with the collaboration with my research partners.

With respect to the creation of knowledge, the journey to post-modernity has opened the door for more importance to be granted to the role of workplace parties. In Ontario since the 1970s and the Ham Report, workers became more engaged in occupational health and their participation is evident in this research. In each of these research processes, workers were either initiators of the study and/or research partners. My role as the academic was to introduce standard accepted research practices and to identify how workers could be engaged in knowledge creation. With the retail workers I was able to introduce a validated physical load survey which formed the foundation of the survey to be used by these workers to create their own study. In the plumbers' study I engaged the union in the participation processes and led it to follow the standard practices to encourage participation, which gave the results professional credence. In all my efforts, I have encouraged workers to describe their work processes and share their knowledge with academic researchers. For example, but for the workers voices, we would not have known for example, that there was a subpopulation of piece-work plumbers who crimped

400 times per day. The final paper allowed me to take an overview of multiple initiatives to identify common themes that encouraged knowledge creation about the processes of innovation.

Because the workers were actively engaged in the creation of knowledge, their role in disseminating knowledge became more significant. Workers who were full partners in the research process were more knowledgeable about study results and willing to facilitate the dissemination of knowledge. Each of the health and safety officers presented their work at union-initiated conferences, monthly union meetings and in the grey literature. I was also invited and participated in many conferences outlining our research findings as well as successes and barriers to research implementation. I think that a paper I co-authored on the role of social networks in the dissemination of knowledge is my most significant academic work. Published in a traditional peer reviewed journal this article was the repeatedly cited by other academics. I think it provided academic researchers some insight into alternative forms of knowledge transfer and translation that could improve the impact of their work.

Finally, I think that when workers are part of the process they are more likely to influence the product/knowledge of the process. In the plumbers' study after the focus group with employers an employer took a real interest in the hydraulic crimper and investigated its application. The introduction of the anchor jack to the workplace partners set the stage for collaboration, modification, and subsequent implementation of the tool. In another life when I had to decide on entitlement to workers' compensation benefits I can confirm that when workplace parties are engaged in the application of research they can improve its adoption. For example, when the union was involved in cancer research in the mining industry it identified a serious error in the data collection process that ended up in the study underestimating the true

risk. Many members of the data set were part of a cost center but had no exposure to possible carcinogens. That data problem resulted in reduced identified cancer rates and limited prevention initiatives. When it was resolved, and the true risks were known then appropriate prevention activities were instituted.

In summary when workers are involved in study design, in my opinion the design is more complete. When workplace parties are engaged in the research process they have more confidence in the results and are more willing the dispense and act upon the results.

5.4 CONCLUSIONS

Work related injury costs are a major government expenditure. According to its 2020 Annual Report, the WSIB covers 5.3 million people in approximately 325,000 workplaces across Ontario. In 2020 the Board paid $3,000,000,000 in benefits and invested $30,000,000,000 in future costs. These costs do not include other costs associated with Ministry of Labour expenditures. In addition to injury costs, there are costs associated with replacing injured workers, reemployment costs, and costs affecting productivity. This type of expenditure and its impact on the citizens and economy of Ontario warrant a coordinated effort to insure we use what we know to spend these resources wisely.

Modern workplaces allow for large epidemiological investigations which have set the stage for important changes to work practices. Without this research, we would not have identified the causes of carpal tunnel or the adverse effects of exposures to vibration. The new fluidity of workplaces has necessitated alternative forms of data collection and opened the door to allow workers' voices to be heard. It has also given workers an entry into the research process

and has provided academics with a better understanding of the workplace. This interaction has improved the dissemination of research results and, in turn, the implementation of knowledge.

The transitioning workplaces highlighted in this thesis illustrate a shift in research process, as a consequence of the changing power of workers, the organization of work and the available research tools. In all three cases we have seen a more iterative research process, where workers and their representatives are engaged with academic researchers as partners. In each case we see the workers as active partners in the knowledge creation processes. The dissemination of the research results is also more fluid in the transitioning workplace and social networks are important arenas for knowledge dissemination. Finally, we can see how changes in work practices – the implementation of research - are less cumbersome in the fluid post-modern workplace.

In my opinion in transitioning workplaces the research process, especially around MSDs, requires a greater role for government. There is a gap between knowledge creation and implementation particularly when it comes to transitional workplaces. Agencies continue to work in research, prevention and compensation silos and do not aggressively share their knowledge. The scattered nature of transitional workplaces requires the government to be a comprehensive clearing house, which identifies the newly created knowledge and the implementation of that knowledge.

5.5 IDEAS FOR THE FUTURE

- A proactive role in evaluating the health and safety risks before the introduction of new tools and practices (Prevention by Design) (Che et al., 2021; Hare et al., 2006).
- A proactive role in the inclusion of health and safety in other regulated processes like building codes and factory design.
- The integration of research, regulations and compensation under a common authority which can facilitate the path from knowledge creation to implementation.
- A committed inclusion of workers' voices in the research process.
- The integration of health and safety in all apprenticeship programmes.

References

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Abma T., Cook T., Rämgård M. (2017). Social impact of participatory health research: collaborative non-linear processes of knowledge mobilization. *Educational Action Research, 25, 489–505.*

Adler, P.S. and Kwon, S.W. (2002). Social capital: Prospects for a new concept. *Academy of management* review, 27(1), 17-40.

Albers JT, Merlino LA, Anton D, Rosecrance JC, Kong YK. (2006). Use of epidemiological data to prioritize construction ergonomic hand-tool exposure evaluations. *16th World Congress on Ergonomics of the International Ergonomics Association:* Maastricht the Netherlands.

Alsharef, A., Albert, A., Jaselskis, E. and Bhandari, S. (2020), November. Construction Safety Training: Barriers, Challenges, and Opportunities. In *Construction Research Congress 2020: Safety, Workforce, and Education* (pp. 547-555). Reston, VA: American Society of Civil Engineers.

Argyris, C. and Schön, D.A. (1997), Organizational learning: A theory of action perspective. *Reis*, (77/78), 345-348.

Aronson, K. J., Tomlinson, G. A., & Smith, L. (1994). Mortality among fire fighters in metropolitan Toronto. *American journal of industrial medicine*, *26*(1), 89-101.

Aronsson G. (1999) Contingent Workers and Health and Safety. *Work, Employment and Society*.,13(3), 439-459

Bandura, A. (1989). Human agency in social cognitive theory. *American psychologist*, *44*(9), 1175.

Barrett, M. (1999). *Imagination in Theory: Culture, Writing, Words, and Things*. NYU Press.

Beck, U., Bonss, W., Lay C. (2003). The Theory of Reflexive Modernization Problematic, Hypotheses and Research Programme. *Theory, Culture and Society* 20(2),1-33.

Beck, U., *Risk society: Towards a new modernity* (Vol. 17). Sage.

Benach J, Vives A, Tarafa G, et al. What should we know about precarious employment and health in 2025? Framing the agenda for the next decade of research. *International Journal of Epidemiology* 2016; 45: 232–238.

Benach J., Muntaner C., Benavides F., Amable M., Jodar P., (2002). A New occupational Health agenda for a new work environment. *Scandinavian Journal of Work Environment and Health* 28(3), 191-196.

Berg, B. (2004). *Qualitative Research Methods.* Boston: Pearson Education Inc.

Berger, P., Luckmann, T., (1991). *The social construction of reality: A treatise in the sociology of knowledge*. Penguin UK.

Bernard BP, Putz-Anderson V. (1997). Musculoskeletal disorders and workplace factors; a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. *National Institute for Occupational Safety and Health, US Department of Health and Human Services.*

Bishop, L. and Kuula-Luumi, A. (2017), Revisiting qualitative data reuse: A decade on. *Sage Open, 7(1).*

Black, A.J. (1989). Setting up a Microcomputer in a small Occupational Health Department, *Occupational Medicine*, Volume 39, Issue 4, Pages 147–151, https://doi.org/10.1093/occmed/39.4.147

Blayse, A. M., & Manley, K. (2004). Key influences on construction innovation. *Construction innovation*, *4*(3), 143-154.

Blumer, H. (1986). *Symbolic interactionism: Perspective and method*. Univ of California Press.

Borg, G. (1998). *Borg's Perceived Exertion and Pain Scales.* Stockholm: Human Kinetics.

Braverman, H. (1974). *Labor and Monopoly Capital.* New York: Monthly Review Press.

Bresnen, M., Edelman, L., Newell, S., Scarbrough, H., & Swan, J. (2005). Exploring social capital in the construction firm. *Building Research & Information*, 33(3), 235-244.

Building Trades Council of Ontario. (2021) Personal Communications

Burawoy, M., Blum, J. A., George, S., Gille, Z., & Thayer, M. (2000). *Global ethnography: Forces, connections, and imaginations in a postmodern world*. Univ of California Press.

Burgess-Limerick, R. (2018). Participatory ergonomics: Evidence and implementation lessons. *Applied ergonomics*, *68*, 289-293.

Callon, M. (1984). Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay. *The sociological review*, *32*(1_suppl), 196-233.

Campbell-Kelly, M. (2001). Not Only Microsoft: The Maturing of the Personal Computer Software Industry, 1982–1995. *Business History Review*, *75*(1), 103–145. doi:10.2307/3116558

Carlan, N. A., Kramer, D. M., Bigelow, P., Wells, R., Garritano, E., & Vi, P. (2012), Digging into construction: Social networks and their potential impact on knowledge transfer. *Work*, 42(2), 223-232.

Carlan, N., Szymanski, T., Van Zetten, J., Hilbrecht, M., & Bigelow, P. (2022). The Path from Survey Development to Knowledge Activism: A Case Study of the Use of a Physical Loads Survey in a Retail Workplace. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, *32*(1), 65-76.

Carroll, W. (1997). Social Movements and Counter hegemony: Canadian Contexts and Social Theories. In W. Carroll (Ed.), *Organizing Dissent* (pp. 3-38). Toronto: Garamond Press.

CAW Health and Safety Department. (2006). *OCCUPATIONAL HEALTH AND SAFETY* (MWF) www.metalworkingfluid.com/mwf/docs/CAW FACT.

Charmaz, K. (2017). Constructivist grounded theory. *The Journal of Positive Psychology*.

Che Ibrahim, C. K. I., Belayutham, S., Manu, P., & Mahamadu, A. M. (2021). Key attributes of designers' competency for prevention through design (PtD) practices in construction: a review. *Engineering, Construction and Architectural Management*, *28*(4), 908-933.

Chia, R. (1995). From modern to postmodern organizational analysis. *Organization studies*, *16*(4), 579-604.

Clarke, R.D., (1982). Worker Participation in health and Safety in Canada. *International Labour Review 121(2):199-206.*

Clarke, S.P. and Clarke, S. (2000) Secondary Analysis: Theoretical, Methodological and Practical Considerations. *Canadian Journal of Nursing Research 32(3),* 109-129.

Cole D., Theberge N., Dixon S., Rivilis I., Neumann P., Wells R. (2009). Reflecting on a program of participatory ergonomics interventions: A multiple case study. *Work* 34 (2), 161-178.

Conklin, J., Kothari, A., Stolee, P., Chambers, L., Forbes, D., & Le Clair, K. (2011). Knowledge-to-action processes in SHRTN collaborative communities of practice: a study protocol. *Implementation Science*, *6*(1), 1-11.

Conway, J. (2004). *Identity, place, knowledge: Social movements contesting globalization.* Halifax: Fernwood Press.

Cooke, L., Blismas, N. (2012). *Designing for construction workers health and safety: A case study of socio-material complexity.* Construction Management and Economics 30(5), 367-382

Cornwall A, & Jewkes J. (1995). What is participatory research*? Social Science and Medicine*; 41, 1667–1676.

Corti, L., Thompson, P., & Seale, C. (2006), Secondary analysis of archived data. *Qualitative Research Practice:* Concise Paperback Edition, SAGE Publications Ltd, London, 297-313.

Cotterell, P., & Morris, C. (2011). The capacity, impact and challenge of service users' experiential knowledge. In *Critical perspectives on user involvement* (57-69). Policy Press.

Crawford, J. O., Berkovic, D., Erwin, J., Copsey, S. M., Davis, A., Giagloglou, E., Woolf, A. (2020). Musculoskeletal health in the workplace. *Best practice & research clinical rheumatology, 34*(5), 101558.

Creswell, J. (2009). *Research Design Qualitative, Quantitative, and Mixed Methods Approaches.* Thousand Oaks: Sage Publications Inc.

Cummings G.G., Estabrooks C.A., Midodzi W.K, Wallin L.& Hayduk L. (2007), Influence of organizational characteristics and context on research utilization. *Nursing research*, 56(4 Suppl): S24-39.

Cuny-Guerrier, A., Savescu, A., & Tappin, D. (2019). Strategies to commit senior subcontractor managers in participatory ergonomics interventions. *Applied ergonomics*, *81*, 102878.

Davis, N., & Hayashi, C. (2016). World Economic Forum. *What is the Fourth Industrial Revolution.*

Demers, P. A. (2020). Using Scientific Evidence and Principles to Help Determine the Work-Relatedness of Cancer. *Toronto, ON: Occupational Cancer Research Centre, Ontario Health.*

De Witt, A, de Boer J., Hedlund, N., Osseweijer P. (2016). A new tool to map the major worldviews in the Netherlands and USA, and explore how they relate to climate change. *Environmental Science and Policy;* 63, 101-112.

Denzin, N. &. Lincoln, Y. (1994) *Handbook of Qualitative Research*. Thousand Oaks: Sage Publications.

Dillman D A, Smyth J D, Christian L M. (2009). Internet, mail, and mixed-mode surveys: The tailored design method (3rd ed.). Wiley & Sons Hoboken, N.J.

Dixon S, Theberge N, & Cole D. Sustaining management commitment to workplace health programs: the case of participatory ergonomics. *Relations Industrielles/Industrial Relations*; 2009; 64, 50–74.

Dixon, S., Theberge, N., Cole, D. (2009) Sustaining Management Commitment to Workplace Health Programs: The Case of Participatory Ergonomics. *Relations Industrielles/Industrial Relations* 64(1), 50-74.

Dogherty, E. J., Harrison, M.B., and Graham, I. D. (2010), Facilitation as a role and process in achieving evidence-based practice in nursing: A focused review of concept and meaning. *Worldviews on Evidence-Based Nursing Linking Evidence to Action*. *Second Quarter,* 76-89.

Donovan, M., Khan, A., Johnston, V. (2017) The Effect of a Workplace-Based Early Intervention Program on Work-Related Musculoskeletal Compensation Outcomes at a Poultry Meat Processing Plant. *Journal of Occupational Rehabilitation* 27 (1),24-34.

Eakin, J. M., Cava, M., & Smith, T. F. (2001). From theory to practice: a determinants approach to workplace health promotion in small businesses. *Health Promotion Practice*, 2(2), 172-181.

Eisen, E., and Tolbert, P. (1992). Mortality Studies of Machining Fluid Exposure in the Automobile Industry. *American Journal of Industrial Medicine, 22,*809-824.

Farjoun, M. (2010). Beyond dualism: Stability and change as a duality. *Academy of management review*, *35*(2), 202-225.

Ferreira, A. M., Souleles, N., & Savva, S. (2020). Social design, innovation and ergonomics: reflections on education, transdisciplinarity and new blurred models for sustainable social change. In *Advances in Social and Occupational Ergonomics: Proceedings of the AHFE 2019 International Conference on Social and Occupational Ergonomics, July 24-28, 2019, Washington DC, USA 10* (pp. 37-48). Springer International Publishing.

Flood, R. L., & Romm, N. R. (2018), A systemic approach to processes of power in learning organizations: part I–literature, theory, and methodology of triple loop learning. *The Learning Organization.*25(4), 260-272.

Foley M, Silverstein B, Polissar N, et al. (2009). Impact of implementing the Washington state ergonomics rule on employer reported risk factors and hazard reduction activity. *Am Journal of Industrial Medicine*; 52, 1–16.

Forde M. S., Punnett L, Wegman DH. (2005). Prevalence of musculoskeletal disorders in union ironworkers. *Journal of Occupational and Environmental Hygiene*.: 2 (4),203-212.

Foucault, M. (1980). *The History of Sexuality.* New York : Vintage Books .

Franklin Associates (2011). Peer-Reviewed Life Cycle Inventory For The Production And Use Of Installed Residential Piping Systems For Three House Layouts. *Franklin Associates, A Division of ERG (Eastern Research Group),* Overland Park, KS, USA.

Gallagher, S., Roy, A., Domeracki, S. J., Mohrmann, T., Missar, V., Jule, J., & DeWitt, R. (2021). The low-wage essential worker: Occupational concerns and needs in the COVID-19 pandemic—A round table. *Workplace Health & Safety*, *69*(4), 154-160.

Giddens, A. (1982). A reply to my critics. *Theory, Culture & Society*, *1*(2), 107-113.

Gilkey, D. P., Keefe, T. J., Bigelow, P. L., Herron, R. E., Duvall, K., Hautaluoma, J. E., Sesek, R. (2007). Low back pain among residential carpenters: ergonomic evaluation using OWAS and 2D compression estimation. *International Journal of Occupational Safety and Ergonomics*, *13*(3), 305-321.

Glimskar B., & Lundberg, S. (2013). Barriers to Adoption of Ergonomic Innovations in the Construction Industry. *Ergonomics in Design*, 21(4), 26–30.

Goffman, E. (1969). *Strategic Interaction.* Oxford: Basis Blackwell

Goldenhar, l., LaMontagne, A., Katz, T., Heaney, C., Landsbergis, P. (2001). The Intervention Research Process in Occupational Safety and Health: An Overview From the National Occupational Research Agenda Intervention Effectiveness Research Team. *Journal of Occupational and Environmental Medicine* 43, 616-622.

Gramsci, A. (1971). Section III The Philosophy of Praxis. In *Selections from the Prison Notebooks.* New York: International Publishers.

Gray, G. C. (2009). The responsibilization strategy of health and safety: Neo-liberalism and the reconfiguration of individual responsibility for risk. *The British Journal of Criminology*, *49*(3), 326-342.

Greenberg, G. N. (2002). Internet resources for occupational and environmental health professionals. *Toxicology*, *178*(3), 263-269.

Greenhalgh, T. (2010). What is this knowledge that we seek to "exchange"? *Milbank Quarterly*, 88(4), 492-499.

Guba, E. &. Lincoln, Y. (2004). Competing Paradigms in Qualitative Research: Theories and Issues (17-39). In Hess-Biber, L. (Ed.), *Approaches to Qualitative Research* Cambridge: Oxford University Press.

Habermas, J., & Ben-Habib, S. (1981). Modernity versus Postmodernity. *New German Critique, 22*, 3–14.

Hafeez, H., Abdullah, M. I., Riaz, A., & Shafique, I. (2020). Prevention of occupational injuries and accidents: A social capital perspective. *Nursing inquiry*, 27(4), e12345.

Hall A, Forrest A, Sears R, Carlan N. (2006). Making a difference: knowledge activism and worker representation in joint OHS committees. *Industrielles/Industrial Relations 61*.

Hall A., Oudyk J., King A, (2016). Identifying knowledge activism in worker health and safety representation: a cluster analysis. *Am J Ind Med*: 59, 42–56.

Hall, B. (1981) 'Participatory Research, Popular Knowledge, and Power: A personal reflection', *Convergence*, 14(3), 6–17.

Hall, B. L. (1992). From margins to center? The development and purpose of participatory research. *The American Sociologist*, *23*(4), 15-28.

Harding, S. (1991). *Whose Science? Whose Knowledge?* Ithica: Cornell University Press.

Hare, B., Cameron I, Roy D A. (2006). Exploring the integration of health and safety with pre-construction planning. *Engineering, Construction and Architectural Management*; 13(5): 438-450.

Harris PA, Taylor R, Minor B. L., (2019). The REDCap consortium: building an international community of software partners. *J Biomed Inform*.103208.

Harris PA, Taylor R, Thielke R,.(2009). Research electronic data capture (REDCap) – A metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*; 42: 377–381.

Heaton, J. (2008). Secondary analysis of qualitative data: An overview. *Historical Social Research/Historische Sozialforschung*, pp.33-45.

Heidarimoghadam, R., Mohammadfam, I., Babamiri, M., Soltanian, A. R., Khotanlou, H., & Sohrabi, M. S. (2022). What do the different ergonomic interventions accomplish in the workplace? A systematic review. *International Journal of Occupational Safety and Ergonomics*, *28*(1), 600-624.

Helfrich, C. D., Damschroder, L. J., Hagedorn, H. J., Daggett, G. S., Sahay, A., Ritchie, M., & Stetler, C. B. (2010), A critical synthesis of literature on the promoting action on research implementation in health services (PARIHS) framework. *Implementation Science*, 5(1), pp.1-20.

Hendrick, H. W. (1996, October). The ergonomics of economics is the economics of ergonomics. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 40, No. 1, pp. 1-10). Sage CA: Los Angeles, CA: Sage Publications

Hilyer, B., Leviton, L., Overman, L., Mukherjee, S. (2000). A Union-Initiated Safety Training Program Leads to Improved Workplace Safety. *Labor Studies Journal*, 24 (4), 53-66.

Holifield, R. (2009). Actor-Network Theory as a Critical Approach to Environmental Justice: A Case against Synthesis with Urban Political Ecology. *Anipode, 41*(4), 637-658.

Hosmer DW, Lemeshow S, Sturdivant R. (2013). Applied logistic regression. Wiley.
http://www.caw.ca/whatwedo/health&safety/factsheet/hsfssubstanceno31.asp.

Industrial Disease Standards Panel. (1994). Report to the Workers' Compensation Board on Lung Cancer in the Hardrock Mining Industry.

Irwin, S. (2013). Qualitative secondary data analysis: Ethics, epistemology and context. *Progress in Development Studies*, *13*(4), 295-306.

Ismyrlis, V. (2021), Lean and Kaizen: The Past and the Future of the Methodologies. In Lean Manufacturing. *IntechOpen*.

Ison, T. G. (1989)*Workers' Compensation in Canada [2nd Edition]*. Toronto, ON: Butterworths.

Jackson, A. (2005). The Unhealthy Canadian Workplace . In A. Jackson, *Work and Labour in Canada: Critical Issues* (pp. 55-74). Toronto: Canadian Scholars Press.

Jarvis, D. (2007). Theorizing risk: Ulrich Beck, globalization and the rise of the risk society. *Lee Kuan Yew School of Public Policy. http://www. spp. nus. edu. sg/docs/rr/RR3% 20Beck.*

Johnston, M. P. (2017). Secondary data analysis: A method of which the time has come. *Qualitative and Quantitative Methods in Libraries*, *3*(3), 619-626.

Kitson, A. L., Rycroft-Malone, J., Harvey, G., McCormack, B., Seers, K., & Titchen, A. (2008), Evaluating the successful implementation of evidence into practice using the PARiHS framework: theoretical and practical challenges. *Implementation science*, 3(1), pp.1-12.

Khan, N. (2021). Contrasting Modernity And Postmodernity With A Particular View To The Fault-Lines Within Social Science Research. *Journal of Sociology*, *5*(1), 29-34.

Kogi, K. (2006). Advances in participatory occupational health aimed at good practices in small enterprises and the informal sector. *Industrial Health*, *44*(1), 31-34.

Kramer DM, & Cole DC. (2003). Sustained, intensive engagement to promote health and safety knowledge transfer to and utilization by workplaces. *Sci Commun; 25: 56–82.*

Kramer, D. and Wells, R. (2005). Achieving Buy-In: Building Networks to Facilitate Knowledge Transfer. *Science Communication, 26*(4), 428-444.

Kramer, D., Bigelow, P., Vi, P., Garritano, E., Carlan, N., & Wells, R. (2009). Spreading good ideas: A case study of the adoption of an innovation in the construction sector. *Applied Ergonomics*, 40(5), pp.826-832.

Kramer, D.L., Bigelow, P., Carlan, N., Wells, Garritano E. Vi P., Plawinski, M. (2010) Searching for needles in a haystack: Identifying innovations to prevent MSDs in the construction sector. *Applied Ergonomics* 41(4): 577-584.

Kramer, D. M., Wells, R. P., Carlan, N., Aversa, T., Bigelow, P. P., Dixon, S. M., & McMillan, K. (2013). Did you have an impact? A theory-based method for planning and evaluating knowledge-transfer and exchange activities in occupational health and safety. *International journal of occupational safety and ergonomics*, 19(1), pp.41-62.

Kuhn, T. (1971). The structure of scientific revolutions. In *Foundations of the Unity of Science* (pp. 54-275). Chicago: University of Chicago

Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sorensen F, Anderson G, Jergensen K.. (1987). Standardized Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon*:18 (2), 33-237.

Kusiak, R. A., Springer, J., Ritchie, A. C., & Muller, J. (1991). Carcinoma of the lung in Ontario gold miners: possible aetiological factors. *Occupational and Environmental Medicine*, *48*(12), 808-817.

Landsbergis, P., Cahill, J. S. (1999), The Impact of Lean Production and Related News Systems of Work Organization on Worker Health. *Journal of Occupational Health Psychology*, 4(2), pp.108-130.

Landsbergis, P. (2003) The changing organization of work and the safety and health of working people: a commentary. *Journal of occupational and environmental medicine* 45 (1), pp.61-72.

Lanoie P, & Tavenas S. (1995). Cost and benefits of preventing accidents: the case of participatory ergonomics. *CIRANO Scientific Series* 1995 Montreal.

Latour, B. (1999). On recalling ANT. *The Sociological Review, 47*(S1), 15-25.

Latour, B. (2005). *Reassembling the social: An introduction to actor-network-theory*. Oxford university press.

Lay, A., M., Saunders, R., Lifshen, M., Breslin, M., LaMontagne, A., Tompa,E. (2015) Individual, occupational and workplace correlates of occupational health and safety vulnerability in a sample of Canadian Workers. *American Journal of Industrial Medicine* 59 (2): 119-128.

Levenstein, C., & Wooding, J. (1999). At the Point of Production. *New York: Guilford*.

Lewchuk, W., Robb, A., & Walter, A. (1996). The Effectiveness of Bill 70 and Joint Health and Safety Committees on Reducing Injuries in the workplace: The case of Ontario. *Canadian Public Policy, 22*(3):, 225-243.

Lewchuk W. Clarke M, de Wolff A. (2011*). Working Without Commitment: The health effects of precarious employment*. McGill-Queen's University Press Montreal

Lewchuk, W., De Wolff, A., King, A., & Polanyi, M. (2003), From job strain to employment strain: Health effects of precarious employment. *Just Labour*.

Lewchuk, W., de Wolff, A., King, A., & Polanyi, M. (2003). From Job Strain To Emploment Strain: Health Effects of Precarious Employment. *Just Labour*, 23-35.

Li, S., Fan, M., & Wu, X. (2018), Effect of social capital between construction supervisors and workers on workers' safety behavior. *Journal of construction engineering and management*, 144(4), 04018014.

Liao, Y., Loures, E. R., Deschamps, F., Brezinski, G., & Venâncio, A. (2018). The impact of the fourth industrial revolution: a cross-country/region comparison. *Production*, *28*.

Lingard H, Blismas N, ,Cooper H. (2009) The model client framework: Resources to help Australian Government agencies to promote safe construction. *International Journal of Managing Projects in Business;*. 2 (1): 131-140.

Loisel, P., Buchbinder, R., Hazard, R., Keller, R., Scheel, I., Van Tulder, M., Webster, B. (2005). Prevention of work disability due to musculoskeletal disorders: the challenge of implementing evidence. *Journal of occupational rehabilitation*, *15*(4), 507-524.

Lund, F., Naidoo, R. (2016). The Changing World of Work. *New Solutions 26(2) 145-54.*

MacEachen E., Lippel K., Saunders R., Kosny A., Mansfield L., Carrasco C., Pugliese D. (2012). Workers' Compensation Experience Rating Rules and the Danger To Workers' Safety in the Temporary Work Agency Sector, *Policy and Practice in Health and Safety, 10(1)* , 77-95,

MacNevin, L. (2020). Designing PEX Plumbing Systems to Optimize Performance and Efficiency -A presentation by the Plastics Pipe Institute, Irving, TX. Available at: https://plasticpipe.org/pdf/designing-pex-plumbing.pdf

Majima, S., Moore, N. (2009). Rethinking Qualitaive and Quantitative Methods. *Cultural Sociology*, *3*(1), 203-216.

Mansfield L, MacEachen E, Tompa E, Kalcevich C, Endicott M, Yeung N. (2012). A Critical Review of Literature on Experience Rating in Workers' Compensation Systems, *Policy and Practice in Health and Safety*;10:1, 3-25.

Marsden, O., Aigbavboa, C. Thwala, W., (2021). An Effective Strategy for Safety Management and Enhanced Productivity in Construction Industry. In *International Conference on Applied Human Factors and Ergonomics* (pp. 86-91). Springer, Cham.

Marx, K. (1986). The German Ideology . In C. Arthur, *German Ideology.* Moscow: :Progress Publisher.

Matthews RA, & Gallus JA. (2005). Initial development of the employee perception of participatory ergonomics questionnaire. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*; 49, pp.1478–1483.

McCormack B, Kitson A, Harvey G, Rycroft-Malone J, Titchen A, & Seers K. (2002), Getting evidence into practice: the meaning of context. *Journal of Advanced Nursing*, 38(1), 94-104.

McShane, B. B., Gal, D., Gelman, A., Robert, C., & Tackett, J. L. (2019). Abandon statistical significance. *The American Statistician*, *73* (sup1), 235-245.

Melucci, A. (1996). *Challenging Codes: Collective Action in the Information Age* . Cambridge: Cambridge University Press.

Merlino LA, Rosecrance JC, Anton D, Cook TM. (2003). Symptoms of musculoskeletal disorders among apprentice construction workers. *Applied occupational and environmental hygiene*; 18(1), 57-64.

Messing, K., Neis B.and Dumais L. (Ed.), (1995). *Issues in Women's Occupational Health Invisible*. Charlottetown, gynergy books

Methner M, McKernan J, Dennison, J. (2000). Occupational Health and Safety Surveillance Task-Based Exposure Assessment of Hazards Associated with New Residential Construction. *Applied Occupational and Environmental Hygiene;* 15 (11), 811-819.

Min, J., Kim, Y., Lee, S., Jang, T. W., Kim, I., & Song, J. (2019). The fourth industrial revolution and its impact on occupational health and safety, worker's compensation and labor conditions. *Safety and health at work*, *10*(4), 400-408.

Moir S. (2005). Ideological influences on participatory research in occupational health and safety: a review of the literature. *New Solutions*; 15, 15–28.

Molen, H. D, Koningsveld E, Haslam R, Gibb A. (2005). Ergonomics in building and construction: Time for implementation. *Applied Ergonomics*: 36(4), 387-389.

Morgan, G. (1986). Images of Organization. Newbury Park: Sage Publications.

Ng, M. A., Naranjo, A., Schlotzhauer, A. E., Shoss, M. K., Kartvelishvili, N., Bartek, M., Silva, C. (2021). Has the COVID-19 pandemic accelerated the future of work or changed its course? Implications for research and practice. *International Journal of Environmental Research and Public Health, 18*(19), 10199.

Ngo, B., Yazdani A., Carlan N., Wells, R, (2017). Lifting Height as the Dominant Risk Factor for Low-Back Pain and Loading During Manual Materials Handling: A Scoping Review, *IISE Transactions on Occupational Ergonomics and Human Factors*, 5:3-4, 158-171, DOI: 10.1080/24725838.2017.1338633.

Nielsen, K., Randall, R., & Christensen, K. B. (2010), Does training managers enhance the effects of implementing team-working? A longitudinal, mixed methods field study. *Human Relations,* 63(11), 1719-1741.

Oakman, J., Rothmore, P., & Tappin, D. (2016), Intervention development to reduce musculoskeletal disorders: Is the process on target? *Applied Ergonomics*, 56, 179-186.

Ontario Workplace Safety and Insurance www.wsib,on,ca accessed 20 October 2020.

Owen, J. P. (1995|) Assessing the use of computers in industrial occupational health departments, *Occupational Medicine*, Volume 45, Issue 2, , Pages 105–108, https://doi.org/10.1093/occmed/45.2.105

Palmer, B. (1992). *Working Class Experience* . Toronto: McClelland & Stewart Inc.

Park P. (1993). *Voices of Change.* West Port Connecticut: Bergin & Garvey.

Petersen, D., Minkler, M., Vásquez, V. B., Baden, A. C. (2006). Community-Based Participatory Research as a Tool for Policy Change: A Case Study of the Southern California Environmental Justice Collaborative. *Review of Policy Research, 23*(2), 339-354.

Polanyi, M., McIntosh, T., Kosny, A. (2005, June). Understanding and improving the health of workers in the new economy: A call for a participatory dialogue-based approach to health research. *Critical Public health, 15*(2), 103- 119.

Polanyi, M., Tompa, E. (2004). Rethinking Work-health models for the new global economy: A qualtitive analysis of emerging dimensions of work. *Work, 23*, 3-18.

Prisecaru, P. (2016). Challenges of the fourth industrial revolution. *Knowledge Horizons. Economics*, *8*(1), 57.

Quinlan M, Mayhew C, & Bohle P. (2001). The global expansion of pre- carious employment, work disorganization, and consequences for occupational health: a review of recent research. *Int J Health Serv;* 31, 335–414.

Quinlan, M., Mayhew, C., Bohle, P. (2001). The Global Expansion of Precarious Employment, Work Disorganization and Occupational Health: A Review of Recent Literature . *International Journal of Health* 31(2),335-414.

Raiden, A. B., & Dainty, A. R., (2006). Human resource development in construction organizations: an example of a "chaordic" learning organization? *The Learning Organization*, 13(1),63-79.

Ramalho, R., Adams, P., Huggard, P., & Hoare, K. (2015, August). Literature review and constructivist grounded theory methodology. In *Forum: Qualitative social research* 16 (3), 1-13.

Rhebergen, M. D., Hulshof, C. T., Lenderink, A. F., & van Dijk, F. J. (2010). An online network tool for quality information to answer questions about occupational safety and health: usability and applicability. *BMC medical informatics and decision making*, *10*(1), 1-11.

Rip, A. (2022). The importance of post-modern science policy. In *Smart Policies for Societies in Transition* (pp. 48-58). Edward Elgar Publishing.

Rivilis, I., Van Eerd, D., Cullen, K., Cole, D. C., Irvin, E., Tyson, J., & Mahood, Q. (2008). Effectiveness of participatory ergonomic interventions on health outcomes: a systematic review. *Applied ergonomics*, *39*(3), 342-358.

Robertson, R. (1992). Globality and modernity. *Theory, Culture & Society*, *9*(2), 153-161.

Rogers Everett, M. (2003) *Diffusion of Innovation. 5th ed.* New York: Free Press.

Romano J. (2006). If Copper Pipes Are Too Costly .... *The New York Times*. Retrieved 2011-07-09. http://www.nytimes.com/2006/09/03/realestate/03home.html.

Rose J.B., (1980). *Public Policy, Bargaining Structure and the Construction Industry* Butterworth, Toronto.

Rose L. (2007). Work With Press Jointing Machines For Pipe Working: An Ergonomic Analysis. in: C. Berlin and L-O. Bligård (Eds): Proceedings of the 39th Nordic Ergonomics Society Conference, Oct 1-3, 2007, Lysekil, Sweden. http://www.nordiskergonomi.org/nes2007/CD_NES_2007/papers/A58_

Rosecrance JS, Sesek R. (2007). Low Back Pain Among Residential Carpenters: Ergonomic valuation Using OWAS and 2D Compression Estimation. *Int J Occup Safe Ergon*.:13 (3), 305-321.

Rosecrance, JC, Cook T M, Anton DC, Merlino L A. (2002). Carpal tunnel syndrome among apprentice construction workers. *Am J Ind Med.*: 42(2), 107-116.

Rosencrance JC, Cook TM, Zimmerman C L. (1996). Work-related musculoskeletal symptoms among construction workers in the pipe trades. *Work*: 7:13-20.

Rubin, H. &. R. I. (1995). *Qualitative Interviewing.* Thousand Oaks: Sage Publications.

Russell, B. (1999). *More with Less Work Reorganization in the Canadain Miining Industry* . Toronto : University of Toronto Press.

Rycroft-Malone J, Harvey G, Seers K, Kitson A. McCormack B, & Titchen A., (2004). An exploration of the factors that influence the implementation of evidence into practice. *Journal of Clinical Nursing,* 13, 913-924

Schneider S. (2001). Musculoskeletal Injuries in Construction: A Review of the Literature. *Appl Occup Environ Hyg.*: 16 (11), 1056- 1064.

Schneider S, Susi P. (1994). Ergonomics and Construction: A Review of Potential Hazards in New Construction. *Am Ind Hyg Assoc J*: 55(7), 635-49.

Selsam, H., Goldway. D. (1970). *Dynamics of Social Change, A Reader in Marxist Social Science.* New York: International Publishers Co., Inc.

Shin S, Won-gyu Y, Kim T. (2012). Effects of Different Overhead Work Conditions on the Neck and Shoulder Muscles. *J Phys Ther Sci*.: 24(2): 197-199.

Selikoff, I. J., Churg, J., & Hammond, E. C. (1984). Asbestos exposure and neoplasia. *Jama*, *252*(1), 91-95

Shin S, Won-gyu Y, Kim T. (2012). Effects of Different Overhead Work Conditions on the Neck and Shoulder Muscles. *J Pys Ther Sci.* 24(2), 197-199.

SiIverstein, M. P., Marmot, M., Maizlish, N., Mirer, F. (1988). Mortality Among Bearing Plant Workers Exposed to Metalworking Fluuids and Abrasives. *Journal of Occupational Medicine, 30*(9), 706-714.

Silverstein B, Foley M, & Pollisar N. (2004). Impact of implementing the Washington State ergonomics rule. *Final Report 73-1-2004 SHARP Technical Report Department of Labor and Industries.* Washington State.

Smith, B. (1981). Black Lung: The Social Production of Disease. *International Journal of Health Services, 11*(3), 343-359.

Spencer, D., Carlan, N. (2008). The Complexities of the Automotive Industry: Positive and Negative Feedbacks i the Production Sysytems. *Candaian Journal of Sociaology, 33*(2), 265-290.

Sprague, J., Zimmerman M. (2004). Overcoming Dualisms: A Feminist Agenda for Sociological Methodology. *In* Approaches to Qualitative Research, Sharlene Nagy Hess-Biber and Patricia Leavy, eds., Cambridge: Oxford University Press. Pp. 39-61.

Statistics Canada. (2020) Employment by Class of Worker Table 14 -100-0027-01

Stetler, C.B., Legro, M.W., Rycroft-Malone, J., Bowman, C., Curran, G., Guihan, M., Hagedorn, H., Pineros, S., & Wallace, C.M. (2006), Role of "external facilitation" in implementation of research findings: A qualitative evaluation of facilitation experiences in the Veterans Health Administration. *Implementation Science,* 1 (23).

Storey, R. (2008). "Their only power was moral": The Injured Workers' Movement in Toronto 1970-1985. *Social history, 41(81), 99*-113.

Storey, R., & Tucker, E. (2006). All that is Solid that Melts into Air . In V. Mogensen, *Worker Safety Under Siege* (pp. 157-185). New York : M.E. Sharpe .

Swidler, A., Arditi, J. (1994) The New Sociology of Knowledge. *American Review of Sociology 20 305-29.*

Tarcisio AS, Costella M, De Macedo GL. (2008). Method for Assessing Health and Safety Management Systems from the Resilience Engineering Prospective. *Proceedings of the Third Resilience Engineering Symposium*. Antibes-Juan -les-Pins France.

Taylor. F. (1911) *The Principles of Scientific Management*. London: Harper and Brothers Publishers.

Tesh, S. N. (2000). *Uncertain Hazards.* Ithica: Cornell University Press

Tompa, E., Scott-Marshall, H., Dolinschi, R., Trevithick, S., & Bhattacharyya, S. (2007). Precarious employment experiences and their health consequences: towards a theoretical framework. *Work*, *28*(3), 209-224.

Tompa, E., Trevithick, S., & McLeod, C. (2007). Systematic review of the prevention incentives of insurance and regulatory mechanisms for occupational health and safety. *Scandinavian Journal of Work, Environment & Health*, *33*(2), 85–95.

Tourraine, A. (1988). *Return of the Actor: Social Theory in Post-industrail society.* Minneapolis: Univerity of Minnesota Press.

Trelease, R. B. (2016). From chalkboard, slides, and paper to e-learning: How computing technologies have transformed anatomical sciences education. *Anatomical sciences education*, *9*(6), 583-602.

Tucker, E. (2003). Diverging trends in worker health and safety protection and participation in Canada, 1985-2000. *Relations Industrielles/Industrial Relations*, *58*(3): 395-426.

Tudiver, N. (1999). *Universities for Sale.* Toronto: James Lorimer and Company Ltd.
Underhill E, & Quinlan M. (2011). Beyond statutory enforcement –alternative approaches to improving OSH in the temporary agency sector. *Policy and Practice in Health and Safety*; 9(2).

Urry, J. (2000). *Sociology Beyond Societies*. Routledge Taylor Francis Group: London

Usher, R. (2005). Telling a story about research and research as story-telling: Postmodern approaches to social research. In *Understanding Social Research* (pp. 32-46). Routledge.

van der Molen HF, Lehtola MM, Lappalainen J, Hoonakker PLT, Hsiao H, Haslam R, Hale AR, Verbeek JH. (2007), Interventions for preventing injuries in the construction industry. *Cochrane Database of Systematic Reviews 2007*, Issue 4. Art. No.: CD006251. DOI: 10.1002/14651858.CD006251.pub2.

van der Molen, H.F., Sluiter, J.K. and Frings-Dresen, M.H., (2005). Behavioural change phases of different stakeholders involved in the implementation process of ergonomics measures in bricklaying. *Applied Ergonomics*, *36*(4), 449-459.

Van Eerd, D., Cole, D., Irvin, E., Mahood, Q., Keown, K., Theberge, N., Cullen, K. (2010). Process and implementation of participatory ergonomic interventions: a systematic review. *Ergonomics*, *53*(10), 1153-1166.

Van Winckle, D., Taylor, C., & Velzer, V. (2010). Cost justification for ergonomics program. *Taylor Ergonomics Incorporated*.

Verma, D. (1996). Occupational Health and Safety Initiatives and Trends in Canada, In Particular in Ontario. *Annals of Occupational Hygiene* 60(4), 477-485.

Vi, P., (2006). A field study investigating the effects of a rebar-tying machine on trunk flexion, tool usability and productivity. *Ergonomics,* 49 (14), pp.1437-5.

Village J, Ostry A. (2010). Assessing attitudes, beliefs and readiness for musculoskeletal injury prevention in the construction industry. *Appl Ergon*. 4, 771–778.

Von Krogh G, Nonaka I, & Ichijo K. Develop knowledge activists! (1997). *European Management Journal,* 15, 475–483.

Vosko, Leah F. (2006). *Precarious employment: Understanding labour market insecurity in Canada*. McGill-Queen's Press-MQUP.

Walters, V., Haines, T. (1988). Workers' Use of Knowledge of the 'Internal Responsibility System': Limits to Participation in Occupational Health and Safety. *Canadian Public Policy XIV (4): 411-423.*

Waterson, P., & Dingwall, R. (2016). Health and safety in a changing world. *Policy and Practice in Health and Safety*, *14*(1), 1-6.

Weber, M. (1958). Science as a Vocation. In Gerth and Mills (Ed.), *Max Weber: Essays in Sociology* (pp. 129-156). New York: Oxford University Press.

Weiler, Paul. (1980*). Reshaping workers' compensation for Ontario*. Ministry of Labour, Toronto..

Weinstein MG, Hecker SF, Hess JA, Kincl L. (2007). Roadmap to Diffuse Ergonomic Innovations in the Construction Industry: There is Nothing So Practical as Good Theory. *Int J Occup Environ Healt*h:13(1), 46-55.

Wells, R., (2009). Why have we not solved the MSD problem? *Work*, 34(1), 117-121.

White, J. (1966). *Karl Marx and the Intellectual Origins of Dialectical Materialism*. Springer.

Wolford, R. (1996). Intervention Research in Construction: A Hypothetical Case Study of Painters. *American Journal of Industrial Medicine*, 29, 431-434.

Womack, J. P., Jones, D. T., & Roos, D. (2007). *The machine that changed the world: The story of lean production--Toyota's secret weapon in the global car wars that is now revolutionizing world industry*. Simon and Schuster.

Wood E., (1997). Modernity, postmodernity or capitalism? *Review of International Political Economy:* 4 (3), 539-560

Workplace Safety Insurance Board (2012). EIW Lost Time Injury database (compiled as by March 2013).

Xue, X., Zhang, R., Yang, R., & Dai, J. (2014). Innovation in Construction: A Critical Review and Future Research. *International Journal of Innovation Science*, 6(2), 111–126. https://doi.org/10.1260/1757-2223.6.2.111

Yazdani, A., Neumann, W. P., Imbeau, D., Bigelow, P., Pagell, M., & Wells, R. (2015). Prevention of musculoskeletal disorders within management systems: A scoping review of practices, approaches, and techniques. *Applied ergonomics (51*), 255-262.

Yazdani A, Bigelow P, Carlan N. (2016). Development and evaluation of a questionnaire to document worker exposures to mechanical loading at a workplace level. *IIE Trans Occup*; 4, 38–53.

Yazdani A, Hilbrecht M, Imbeau D. (2017). Informants' perspectives: management commitment, training, and worker participation in the prevention of musculoskeletal disorders. *IIE Trans Occupation*; 5: 172–184.

Yazdani, A., & Wells, R., (2018), Barriers for implementation of successful change to prevent musculoskeletal disorders and how to systematically address them. *Applied Ergonomics*, 73, 122-140.

Young, D., Borland, R., & Coghill, K. (2010). "An actor-network theory analysis of policy innovation for smoke-free places: understanding change in complex systems." *American Journal of Public Health*, 100 (7), 1208-1217.

Yung M, Bigelow P, Hastings D.M, Wells R. (2014) Detecting within and between day manifestations of neuromuscular fatigue at work: an exploratory study. *Ergonomics*: 57 (10), 1562-1573.

Zoller, H. M. (2003). Health on the line: Identity and disciplinary control in employee occupational health and safety discourse. *Journal of Applied Communication Research*, *31*(2), 118-139.

Appendices
Appendix I

The Path from Survey Development to Knowledge Activism: A Case Study of the Use of a Physical Loads Survey in a Retail Workplace

(i) Background
(ii) Process
(iii) Invitation letter to employer
(iv) Survey
(v) Follow-up Letter
(vi) Final Report

(i) BACKGROUND

In 2015, I was approached by the Union's Provincial Health and Safety Officer (PHSO) to explore a study of the union's retail workers. They were having higher than expected appeals before the Workplace Safety and Insurance Board for MSD claims. The conduct of this research was prolonged and delayed because the union staff changed, the employer's heath and safety director changed three times and there was never a formal acknowledgement of the study by the employer. Notwithstanding the long process, the results of the study have been added and continues to be added by the Union to the agenda of the Joint Provincial Joint Health and Safety Committee meetings eight times. The employer has never agreed to discuss the findings or implications. However, the union health and safety officers now have a validated survey with guidelines for their monthly workplace inspections. This provides a basis upon which to open a discussion of specific physical loads that should be addressed as a preventative measure to limit exposures and injuries in the future.

(ii) PROCESS

Multiple meetings were held over the 18 months with the Union's provincial health and safety committee. The union representatives voted and agreed to undertake a survey of the workforce to document the physical load exposure. The Union agreed to help fund the study and compensate representatives for lost time. The research team decided not to include the employer in the planning process because it had not been cooperative in previous initiatives. Accordingly, the attached letter was sent to the employer to notify them of the study.

A study was designed based on the CRE-MSD's physical load survey. A draft survey tool was designed and tested with some participants. Together with the PHSO changes were made. I introduced the survey to the local H&S representatives at three meetings -Oshawa, Toronto, and Windsor. Collectively 150 union health and safety representatives attended.

Because we did not want to rely on employer resources the survey was sent to staff from lists maintained by local union activists. We did not keep track of the number of surveys which were dispensed. Based on the input from the H&S representatives and with input from REDCap from the University the final survey was launched. A copy of the survey is attached. Through out this process we were assisted by an undergraduate student Rosemary Ku who used this work as her undergraduate thesis.

During this process I met with the bipartite provincial health and safety committee on two occasions. In addition to the primary goal of introducing the project to the appropriate officers, we hoped to engage the employer. In spite of evidence of significant potential savings supported by evidence from a similar employer this employer expressed no interest.

A final report, which is attached was submitted to the Provincial Health and Safety Committee. Unfortunately, or fortunately, I was appointed as a Vice-Chair to WSIAT. As a consequence, in keeping with government ethics guidelines I was prohibited from continuing to conduct any activities with labour or management alone. The Union PHSO did however present the findings to the Annual RSI Day session. Shortly after the PH&SO retired. The union representatives and I did work together recently and produced a paper jointly authored and published in *New Solutions*.

(iii) INVITATION LETTER

October 2, 2015 Via e-mail: Alkarim.kanji@lcbo.com

Alkarim Kanji

Manager, Corporate Safety Services

Co-chair LBED Provincial Health and
Safety Committee Liquor Control Board
of Ontario

Dear Mr. Kanji:

I am writing to inform you that OPSEU has been invited by the University of Waterloo's Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD) to test a survey tool that helps workers identify physical load hazards in their workplaces. The CRE- MSD's Survey of Physical Loads at Work is funded by a research grant from the Workplace Safety Insurance Board.

OPSEU members at the LCBO have physically demanding jobs that often cause debilitating conditions leading to temporary and permanent impairment. Hundreds of our members are suffering from injuries sustained during the course of their job. We are participating in the CRE-MSD project in order to build the capacity of our health and safety representatives to identify hazards and prevent musculoskeletal disorders (MSDs). As you know, Section 8 (10) of the Occupational Health and Safety Act gives health and safety representatives the power to identify situations that may be a source of danger or hazard to workers and to make recommendations to the employer.

will ask members in a number of pilot locals to complete the CRE-MSD online survey at home, considering each shift in their worksite. They will answer

questions about the various kinds of loads on their members' bodies. Lifting, pushing, pulling, carrying, climbing, and awkward body movements are among the risk factors for musculoskeletal disorders. A report will be produced for each worksite identifying the number of people who are exposed to potential hazards.

Provincial Committee members will then use the information compiled about hazards to create Physical Demands Descriptions (PDDs) for the work they do. Committee members will be guided in the development of the PDDs by the Occupational Health Clinics for Ontario Workers' Physical Demands Handbook. The PDDs will be a critical tool for joint health and safety committees and health and safety representatives to identify hazards and prevent MSDs.

We will be very happy to share the findings of the CRE-MSD survey with you. We hope we can count on the employer's co-operation as health and safety representatives in the pilot locals complete the online survey in the coming weeks.

Yours sincerely,

Rob Mithrush

OPSEU Co-chair LBED Provincial Health and Safety Committee

Denise Davis

Survey of Physical Loads at Work

Dear workers, union representatives and supervisors:

We are a research team, based at the University of Waterloo that is developing and validating a new kind of survey. The survey is designed to help Ontario workplaces and the Health and Safety System better understand physical loads at work.

We are asking for your name and/or email address so we can follow up in a couple of months to determine if you made any changes to your work as a result of the survey. If you do not feel comfortable providing us with that information, you can still access the survey and may find it beneficial.

The data is collected via REDCap software which is being widely used by clinical researchers for secure data collection and storage. The data will be stored on the REDCap server which is hosted at the University of Waterloo. The server is protected by UW's firewall and according to strict security and access control policy. Only authorized researchers with Research Ethics Approval can view data.

If you have any questions about this project or how to fill out this survey please contact: Niki Carlan, Project Coordinator at 519-xxxx or ncarlan@uwaterloo.ca.

HOW TO FILL OUT THIS SURVEY

We would like you to estimate how often you do the activities described. In the survey to follow, we have included some pictures of tasks that could fit each question, however these are only examples.

The survey is designed to be completed by a worker. There is another version of this survey that can be used by joint health and safety committee members during routine audit activities. If you find an area where there is high exposure to physical loads you may want to alert the JHSC so they can do a formal hazard identification or risk assessment.

When completing the survey estimate the work being done today. We anticipate a good sample of participants so we should capture slow and busy days.

This survey was developed by adapting and modifying many of the questions in the Washington State Survey (Foley M, Silverstein B, Polissar N, and Neradilek B. (2009) Impact

of implementing the Washington State ergonomics rule on employer reported risk factors and hazard reduction activity. American Journal of Industrial Medicine 52(1): 1-16.)

Ethics Statement

Participation in this study is voluntary. There are no known or anticipated risks to the company or to the workers as participants. You may decline to participate or you can withdraw at any time, and you can refuse to answer any question. Your withdrawal at any point will not have a negative impact on your relationship with our organizations or your company.

The researchers will keep the information you provide confidential. The name of your organization will not appear in any article, documentation or reports and will be referred to by number only in final documents. With your agreement, anonymous quotations may be used but attributed only to a general title (manager, worker health and safety representative) and in ways that ensure you cannot be identified. These assessments and notes will be maintained in a locked filing cabinet, in room LHI 3711, at the University of Waterloo for a period of four years (the period of time necessary for review and publication of research articles) and then destroyed.

To help us assess the effectiveness of the tool, please provide us with your organization and your contact information for analysis and follow-up interviews.
A. Please select where you are doing the survey: At Work ○ At Home ○
B. Can we contact you in a couple of months to determine if the survey results have affected your workplace? Yes ○ No ○
C. What is your position in your organization?
D. Please select the shift of the survey: Day ○ Afternoon ○ Night ○

E. How long is your shift today?

- 1 hour
- 2 hours
- 3 hours
- 4 hours
- 5 hours
- 6 hours
- 7 hours
- 8 hours
- 9 hours
- 10 hours

Section 1
Lifting / pushing / carrying / climbing

Question 1: Today how often did you carry loads more than a few steps (loads greater than 10 kg or 25 lbs.)?

Examples: lifting crates from table to table more than a few feet apart, carrying construction material to site, moving furniture, moving carcasses.

- Never
- Occasionally
- Once/shift
- 2~9 times/shift
- 10~100 times/shift
- More than 100 times/shift

Question 2: Today how often did you push or pull loads more than a few steps: wheeling more than 100kg (225lbs) or dragging more than 35kg (75lbs) ?

Examples: pushing trolleys, carts, and wheeled cages, material handling, drag or slide objects on the floor or table.

- Never
- Occasionally
- Once/shift
- 2~9 times/shift
- 10~100 times/shift
- More than 100 times/shift

Question 3: Today, how often did you lift or lower 23kg or 50 lbs., or more unassisted?

Examples: lifting cement bags, using a vaculift to lift retail products, heavy boxes of paper, lifting heavy mattresses.

- Never
- Occasionally
- Once/shift
- 2~9 times/shift
- 10~100 times/shift
- More than 100 times/shift

Question 4: Today, how often did you lift or lower 40kg (80lbs), or more unassisted?

Examples: jack leg drill in mining, lifting construction materials, unloading trucks, lifting piano (not people).

Never

2~9

More

- Occasionally
- Once/shift
- times/shift
- 10~100 times/shift
- than 100 times/shift

Question 5: Today, how often did you lift or reposition people unassisted?

Examples: lifting or transferring people into a wheelchair or toilet or bed, repositioning a person in bed.

- Never
- Occasionally
- Once/shift
- 2~9 times/shift
- 10~100 times/shift
- More than 100 times/shift

Question 6: Today how often did you climb more than 8 steps on stairs or a ladder?

Never

2~9

More

- Occasionally
- Once/shift
- times/shift
- 10~100 times/shift
- than 100 times/shift

Section 2
Loads related to awkward positions

Question 7: Today how often did you bend forward with few pauses?

Examples: tying rebar on the ground, working on a low table, working with limited headroom, filling deli counters.

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 8: Today how often did you work with one or both hands above shoulder level with minimal loads in the hands with few pauses?

Examples: Painting overhead, installing wiring in the ceiling, sanding dry wall, garage mechanic working on the underside of car.

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 9: Today how often did you lift or lower objects above the shoulders?

Examples: Installing overhead ductwork, loading boxes on or off high shelf.

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 10: Today, how often did you work with your neck in an awkward position with few pauses?

Examples: viewing a monitor placed off to the side, working cash looking up when painting a ceiling, holding a phone to your ear with your shoulder.

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 11: Today, how often did you hold a fixed position of the upper body with few pauses?

Examples: microscopic work, soldering small parts, packaging, inserting electronic components, sewing

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 12: Today how often did you kneel or squat?

Examples: Laying tile flooring, carpeting, landscaping, scrubbing floors

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Section 3
Loads related to repetitive hand and arm use

Question 13: Today, how often did you perform repetitive movement of whole arm more than twice per minute?

Examples: Packing boxes, planting trees, feeding parts into a machine, mopping floors, cleaning wall with a cloth, wiping off tables, using an axe, opening and closing machine, weighing.

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 14: Today, how often did you move your hand, wrist, or forearm?

Examples: Scanning groceries, chopping vegetables, packing small object, dealing cards, sing a manual screwdriver

.

Occasionally

Never

Up to 2 hrs

2~4 hrs

4~8 hrs

More than 8 hrs

Question 15: Today how often did you use a key board or mouse intensively?

Examples: Data entry, word processing, computer graphics.

Never

Up to 2

2~4 hrs

4~8 hrs

More than 8 hrs

Occasionally

hrs

Section 4
Loads related to the use of force

Question 16: Today how often did you pinch grip small objects between thumb and finger continuously or with few pauses?

Examples: Inserting small parts, using a dental tool, pipefitting, pinch

.

Occasionally

- Never
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 17: Today how often did you use your whole hand to grasp objects continually or squeeze objects repeatedly?

Examples: Using caulking gun, using pliers to tie rebar, pruning, holding knife in meatpacking, use hand tool, carry suitcase or bucket by handle.

.

Occasionally

- Never
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question18: Today how often did you grasp objects while wearing heavy gloves or gloves that get in the way?

Examples: Handling cold product in freezer, meat cutting, maintaining live power lines.

Never

. Occasionally

Up to 2 hrs

2~4 hrs

4~8 hrs

More than 8 hrs

Question 19: Today how often did you use your knees as a hammer more than once/minute?

Examples: knee kicker for carpet installation, loading skids, breaking boxes, making beds.

.

Never

Occasionally

Up to 2 hrs

2~4 hrs

4~8 hrs

More than 8 hrs

Section 5
Loads related standing, sitting and vibration

Question 20: Today how often did you stand with infrequent walking?

Examples: cashier, bank teller, machine operator, retail.

.

Occasionally

- Never
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 21: Today how often did you sit not in vehicles?

Examples: monitoring video screens, computer work, small parts assembly.

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 22: Today how often did you sit in or drive on-road vehicles only?

Examples: Ride in or drive cars, buses, transport truck, pickup.

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 23: Today how often did you sit or stand on vibrating surfaces machines or off-road vehicles?

Examples: Forklifts, off road vehicles, construction vehicles, logging trucks, earth graders, forestry machinery, vibrating platforms.

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 24: Today how often did you work in the cold?

Examples: Outside workers, cold store or refrigeration workers.

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Section 6
Loads related to hand arm vibration

Question 25: Today, how often did you use or grasp high** vibration tools or objects? moderate.

Example: use a hand wood sander, floor polisher, zamboni or floor cleaner, power drill, wizard knife.

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Question 26: Today, how often did you use or grasp moderate** vibration tools or objects?

**Moderate is less than 8 hour energy equivalent frequency weighted acceleration value of 2.5m/s2."

Example: use a chain saw, pneumatic chipper, hammer drill (or rotary hammer), grinder.

- Never
- Occasionally
- Up to 2 hrs
- 2~4 hrs
- 4~8 hrs
- More than 8 hrs

Thank you for participating and finishing the survey!

(v) FOLLOW-UP LETTER

Dear xxx,

This e-mail is to invite you to participate in a follow-up interview regarding the Physical Loads at Work Survey that you have previously completed. At that time you indicated that you would be willing to participate in an interview.

To reintroduce ourselves, we are a group of researchers from the School of Public Health and Health Systems at the University of Waterloo validating the surveys potential to help workplaces and the Health and Safety System better understand physical loads at work. This research is being led by Dr. Philip Bigelow (Principal Investigator), Niki Carlan (Research Associate), Rosemary Ku (Student Investigator) and Terri Aversa (OPSEU Health and Safety Officer). We anticipate that the results of these surveys will provide an opportunity for Health and Safety Committees to initiate discussions and reduce workplace injuries. In addition to its value as a health and safety tool this research is being conducted as Rosemary Ku Honour's Thesis.

Your Involvement

This follow-up interview will include questions regarding your role as a health and safety representative, the utility of the survey and accompanying report, including the ease with which it could be completed, and your actions following the use of this tool.

The interview will last approximately 30 minutes and will conducted via telephone.

Please indicate a date and time from the list below, so that we can contact you for a follow-up interview. We will also need your phone number.

Interview Dates:

Saturday, April 2nd: anytime between 8AM – 8PM

Sunday, April 3rd: anytime between 8AM – 8PM

Monday, April 4th: anytime between 8AM – 8PM

Please note, participation in this study is voluntary and there are no known or anticipated risks to you as a participant in this study. If you decide not to participate in the interview process it will not have any effect on your relationship with your union or employer. You may decline to answer any of the interview questions if you do not wish to answer. Furthermore, you may decide to withdraw from this study at any time by advising the researcher. All information you provide is considered completely confidential. Your name or any other personal identifying information will not appear in any type of documentation from this study; however, with your permission anonymous quotations linked to position or title may be used. Notes, tapes or electronic data collected during this study will be retained for 7 years in a secure location and then

destroyed. Only researchers who are directly involved in this project will have access to the data.

Contact Information

If you have any questions regarding this study, or would like additional information to assist you in reaching a decision about participation, please contact Philip Bigelow pbigelow@uwaterloo.ca (519-xxx), Niki Carlan at ncarlan@uwaterloo.ca/ (519)-xxxx or Rosemary Ku at xx

I would like to assure you that this study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee. However, the final decision about participation is yours. If you have any comments or concerns resulting from your participation in this study, please Dr. Maureen Nummelin, the Director, Office of Research Ethics, at 1-519-888-4567, Ext. 36005 or maureen.nummelin@uwaterloo.ca.

Thank you for your consideration. I look forward to speaking with you in the near future.

Sincerely,

Rosemary Ku

(vi) FINAL REPORT

Report on Physical Loads Survey of LCBO Employees

Prepared by: Niki Carlan PhD Candidate, CRE-MSD

Supported by the University of Waterloo and OPSEU

Table of Contents

Survey Results

428 Respondents

Summary of Findings

During the interviews with members and comments made during focus groups organizational concerns were often raised. Some participants identified very good relations with store managers. Other participants indicated that managers were reluctant to discuss organizational issues like extensive part-time work which could adversely affect job rotation. In other words, it was a mixed bag when trying to assess the safety climate.

The exposures identified in different classes of stores were significant. The age of facility, the pattern of business and the availability of staffing resources were all factors in identifying exposure to physical loads. Each of these elements may have to be addressed on a store-by-store basis. It would make sense to evaluate individual facilities if a preventive ergonomic plan was to be implemented.

The five most frequent physical loads exposures identified were:

- Standing with infrequent walking
- Carrying loads of greater than n 25 lbs. more than a few steps
- Push/pull loads more than 225 lbs.
- Perform respective movement of whole arm more than n 2x /minute
- Move hand wrist forearm more than 10x / minute.

There are mechanical solutions readily available to reduce these exposures, including check out design, scanning equipment, shelving design and packaging sizing.

The participation in this survey was much greater than previous applications. There was a reluctance on the part-time workers to participate. It would appear possible to identify a clearer picture of exposure to physical load exposure if management would be willing to endorse the survey.

Background and Brief Literature Review

Primary goals and focus of CRE-MSD are to work with workplace parties to limit exposure to physical loads and accordingly prevent musculoskeletal disorders and disabilities. We recognize that one of the barriers to MSD prevention is the lack of resources including limited access to tools and knowledge necessary to implement change. To develop tools necessary to identify exposure to Physical Loads CRE_MSD has created a Physical Loads Survey (PLS).

Although the survey was initially modelled on the work of researchers in Washington State, the PLS was modified through participatory action research and now is quite distinct from the Washington State survey. The Washington State research was seminal as it introduced the assessment of the prevalence and magnitude of exposures to physical loads based on the entire

workplace as the unit of observation. By engaging a knowledgeable workplace party to complete the survey to estimate physical loads across their workplace, the survey findings were representative of exposures to employees across the State. At the time a State-wide ergonomic rule was being introduced and included an extensive phase-in period with demonstration projects and development of training material. Following and during the phase-in a reduction in both exposures to physical loads and of MSD-related injuries were observed using their workplace level assessment tool. When the ergonomic rule was subsequently repealed those improvements did not continue (Foley at al. 2009). The research demonstrated not only the potential impact of a State-wide approach to MSD prevention, but also the utility of a population-based survey of workplace physical loads. Our research builds on this and in addition to the PLOS being a valid tool for benchmarking physical loads within workplaces, it has been designed and refined to be easily used be workplace parties in Ontario as a first step in implementing voluntary MSD prevention initiatives.

Findings from the original Ontario study indicated good to moderate agreement between JHSC representatives and the ergonomist. This indicates that valid results can be achieved by having H&S representatives complete the risk assessment survey, with or without management workers and/or professional consultations (Yazdani et al., 2016). The advantages of this approach are twofold. One, the survey can be utilized by H&S representatives to supplement MSD-related prevention recommendations to the employer. Second, the survey increases H&S representatives' role in the decision-making process, which in turn increases the probability that new ergonomic interventions will be accepted by workers (National Research Council, 2001).

The PLS can be seen as a piece of participatory ergonomics. Wilson and Haines (1997) have defined PE as the "involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes to achieve a desirable goal". We have chosen a PE approach which recognizes workers as the stakeholders within an organization who are most familiar with the work processes; therefore, they are the ones most suited to identify a comprehensive list of workplace risks and hazards (Dixon & Theberge, 2011).

PLOS has the potential to provide knowledge (a resource) of excess exposure to physical loads for small and medium size companies which are interested in limiting physical loads but have limited resources to create knowledge themselves. Since current MSD risk assessment tools are predominantly utilized at the individual of workstation level, this survey does fill a current gap within the system (van der Beek & Frings-Dresen, 1998; Yazdani, 2015).

There are several critical elements to the knowledge transfer process. That process includes the need to identify the knowledge to be shared, the validation of that knowledge, the identification of the audience and the expected outcomes of that transfer activity. Knowledge development and translation can be defined as an "iterative and dynamic process in which relevant research information is created, synthesized, disseminated and exchanged through interactive engagement with decision makers and knowledge users to improve outcomes, provide more effective services and products and strengthen the use of evidence in decision making, practice, planning and policy" (Van Eerd et al., 2011). Clearly the engagement between the researchers and the six

unions within the previous study can be regarded as the beginning of a workplace knowledge transfer (KT) process.

For the most part, we have identified Joint Health and Safety Committees as the audience. In Ontario, JHSCs are mandated for workplaces employing more than 20 employees. For workplaces that employ 1 to 5 employees, a JHSC is only required if a designated substance is present in the workplace. For workplaces that employ 6 to 19 workers, a least one H&S representative is required (Yassi & Lockhart, 2012). The presence of either a H&S representative or JHSC is important because their work can have a significant impact on reducing the risk of workplace injuries, illnesses and even death. To ensure all identified risks and hazards are minimized within the workplace, full cooperation between workers and management is required (Dixon & Theberge, 2011). This is advantageous because there is an abundance of literature indicating that this participatory ergonomic approach increases the chances that an ergonomic intervention will be accepted in the workplace (Cole et al., 2009).

Workplace discussions and routines are important because health and safety routines and business management frameworks should not be viewed as two separate entities (Yazdani, 2015). Yazdani et al. (2016) found that the majority of ergonomic initiatives were implemented on a short-term basis; whereas, business management frameworks were continuously revisited, improved, and sustained. Implementing an initiative within the business framework of an organization would therefore increase the potential sustainability of an initiative.

This survey has the potential to create as well as transfer knowledge. Kramer and Cole (2003) described three forms of the use of knowledge, which are critical to improved health and safety environments:

> **Conceptual use"** (also called "enlightenment" or "indirect" use) is determined when the research findings are used to gradually change and frame the understanding of an issue;
>
> **Instrumental use:** (also called "structural", "problem solving", or "direct" use) is indicated when the research findings are used to design a new policy, program or procedure; and
>
> **Strategic use"** (also called "political", "tactical" or "symbolic" use) is indicated when research is used to justify a course of action already decided upon.

This Study

The Liquor Control and Licencing Board (LCBO) is an important employer under the Ontario Government umbrella. There are about 300 stores and multiple warehouses. The volume of activity is significant. For example, the warehouse in London moves (in and out) 2.4 million bottles of liquor (wine and spirits) monthly. OPSEU has approximately 130,000 members in total. The LBED unit is a significant component and has about 6,000 members. These 6000 members account for about 20% of all MSD WSIB appeals.

We were approached by Terri Aversa the OPSEU provincial health and safety officer to introduce the physical loads survey to the LBED membership. Previously when approached during the roll out of preliminary research, management of LBED declined to participate.

We have taken this opportunity to pilot the electronic versions of the study. This is a good cross section of ABCD stores (A being the largest and D the smallest).

Building on previous research activities which developed a Physical Loads Survey (PLS), this is a case study, employing Participatory Action Research principles. The purpose of this study is to assess the use of survey data in making workplace change.

The research process.

This is the fourth stage of a research process and documents the path from the original development of a survey to the use of survey results by workplace parties. The union's interest in the rollout of the survey is piqued because of disproportionate rates of workers' compensation claims among these retail workers. According to union records the retail staff composed 6.1% of its membership and filed 19.22% of the union workers' compensation claims during the last 10 years. With the on-line version and because of the championship of an original participant in the PLS development, a union health and safety staff officer, the revised on-line survey will be broadly introduced. That application is the basis of this case study.
The survey which was ultimately designed addressed these issues:

- Carry Loads,
- Trunk Flexed,
- Lift > 23 kg,
- Lift People,
- Hand Above Shoulder,
- Repetitive Arm,
- Power Grasp,
- Computer Use,
- Standing,
- Driving Off-Road,
- Kneel/ Squat, and
- High Vibration.

The research team is mix of union health and safety representatives, researchers from the university and colleagues with technical skills to revise the survey. The research team considered the reliability of the revised on-line survey. Would the survey still be able to accomplish the original goal of producing a report on a **workplace** physical loads exposure? Because the majority of workers in this environment had similar job titles and performed similar activities it was decided that the original goal would be achieved by surveying multiple workers on their own experiences with respect to the frequency of exposure. It is

arguable that multiple reports from individual workers engaged in the same activities should provide a good overview of workplace exposure.

With financial support from the union the research team (academic researchers and union health and safety staff) attended four meetings with local health and safety representatives to introduce the survey. It was interesting to note that the groups of H&S representatives had not previously met as groups so was an opportunity for them to express concerns and network.

The survey was introduced by the union to its membership by email. The union also agreed to send out multiple email reminders to its membership encouraging participation. The University agreed to offer prizes for randomly chosen survey participants. Sufficient numbers of workers responded to allow for a detailed report on the extent of physical loads exposure.

Respondents were also asked to participate in a short qualitative interview following completion of the survey. A selective sample representing different groups of respondents (management, casual, warehouse and full-time employees) were interviewed.
The union arranged that I was able to present findings at the Joint Health and Safety Committee (JHSC) meeting. Following that presentation, a written report addressing the issues of importance to JHSC will be provided to the committee.

Qualitative Results
Below are some samples of comments made during the interviews.

1) In the London warehouse most if not all of the liquor is delivered by non LBED employees. These skids to be sent out to are prepared by non LBED employees. They are short term employees who rarely have training in the packing. For whatever reason skids are often sent to stores which are packed too high and not properly wrapped. As a consequence these skids are difficult if not dangerous to unpack.
2) Job rotation is often identified on the roosters but is often not possible. The number of part-time employees makes it difficult to organize. Rotation is often hindered because of the high per cent age of workers on modified duties because of work and non-worker related issues.
3) Some part time employees are reluctant to participate in surveys. They are rightly or not concerned that their shifts may be altered or reduced.

Quantitative Results

The response rate was:

- 428 responses (71 casual, 37 managers, 13 warehouse, 307 CSRs) .
- about 75% from 8-hour shift
- more women than men
- all job classifications including management
- most from day shift

The five most frequent physical loads exposures identified were:

- Standing with infrequent walking
- Carrying loads of greater than n 25 lbs more than a few steps
- Push/pull loads more than 225 lbs.
- Perform respective movement of whole arm more than n 2x /minute
- Move hand wrist forearm more than 10x / minute.

The results of full time Customers Service Representatives are reproduced on the following pages.

Each graph contains the responses collected from <u>307</u> subjects in the "<u>CSR</u>" group.

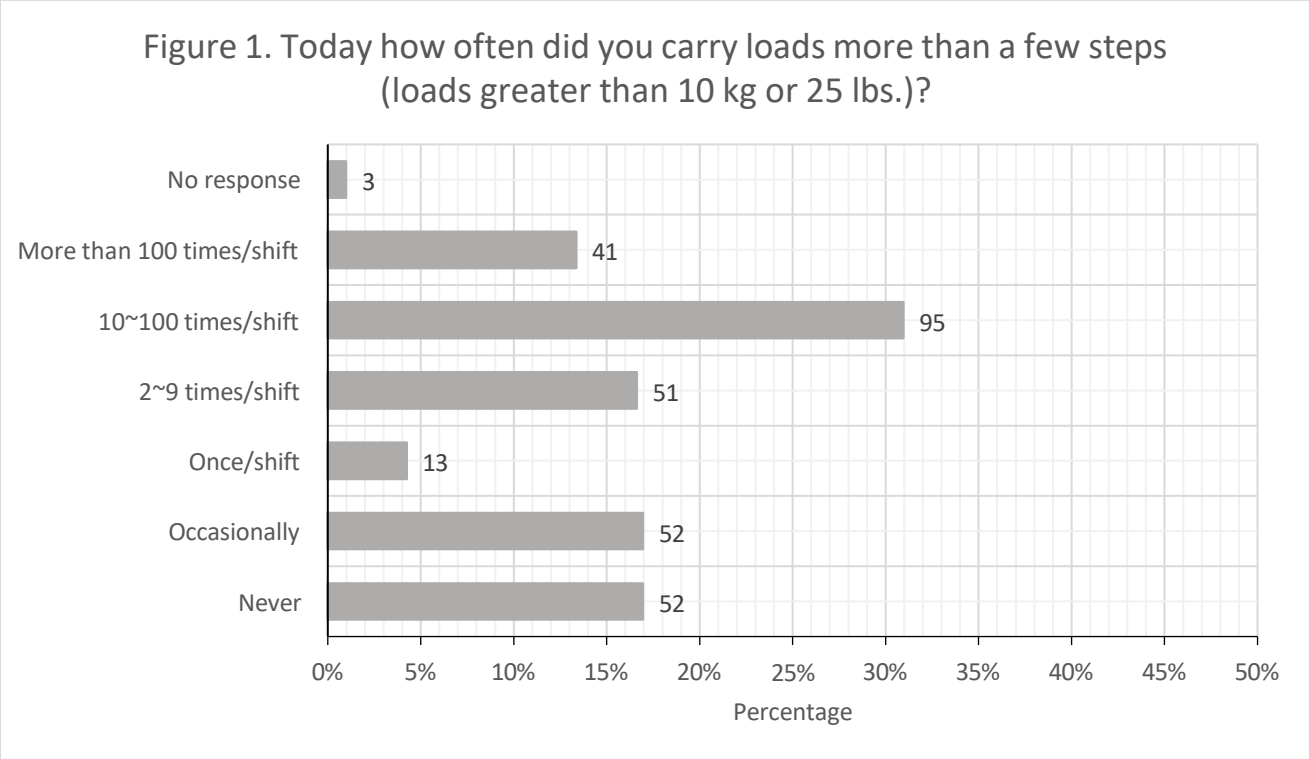


Figure 2. Today how often did you push or pull loads more than a few steps: wheeling more than 100kg (225lbs) or dragging more than 35kg (75lbs)?

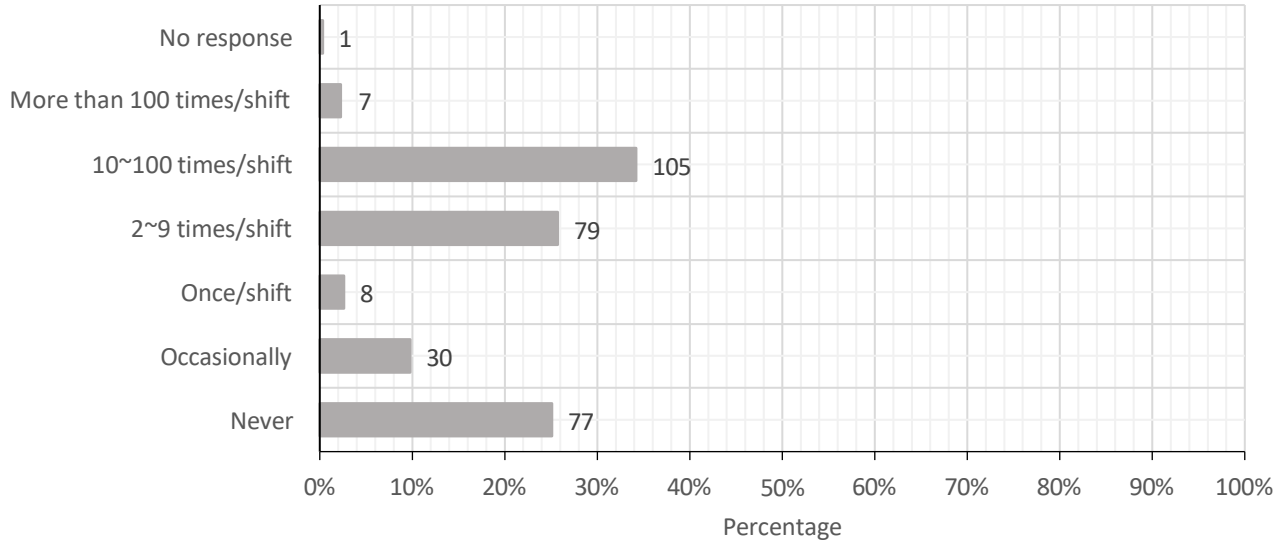


Figure 3. Today, how often did you lift or lower 23kg or 50 lbs., or more unassisted?

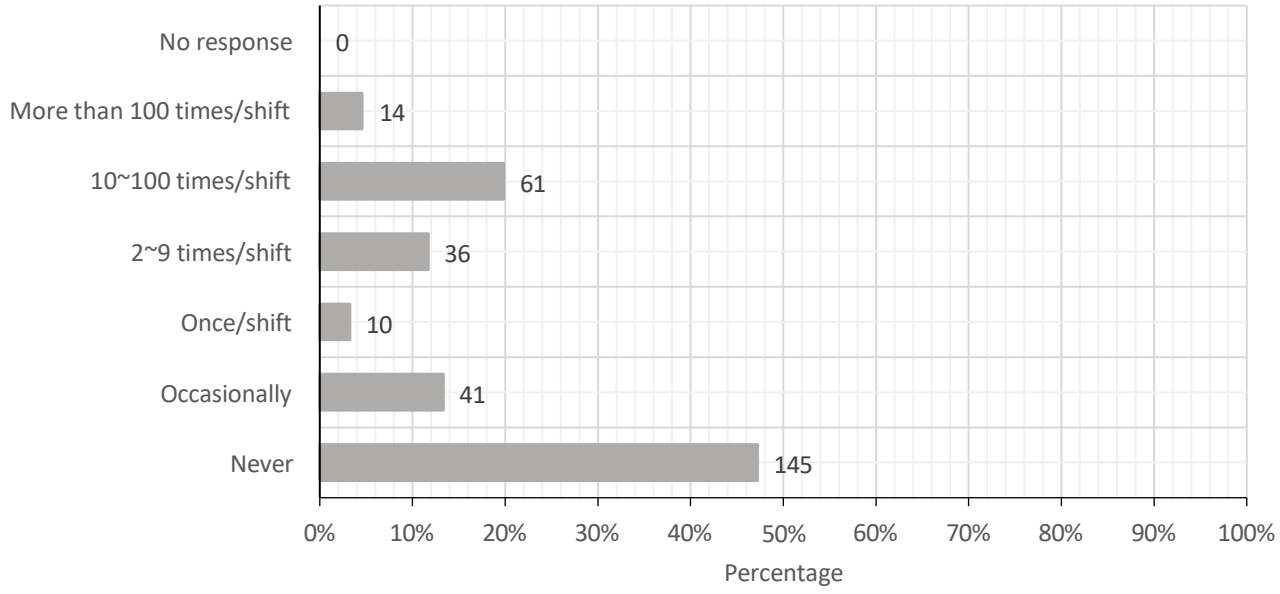


Figure 4. Today, how often did you lift or lower 40kg (80lbs), or more unassisted?

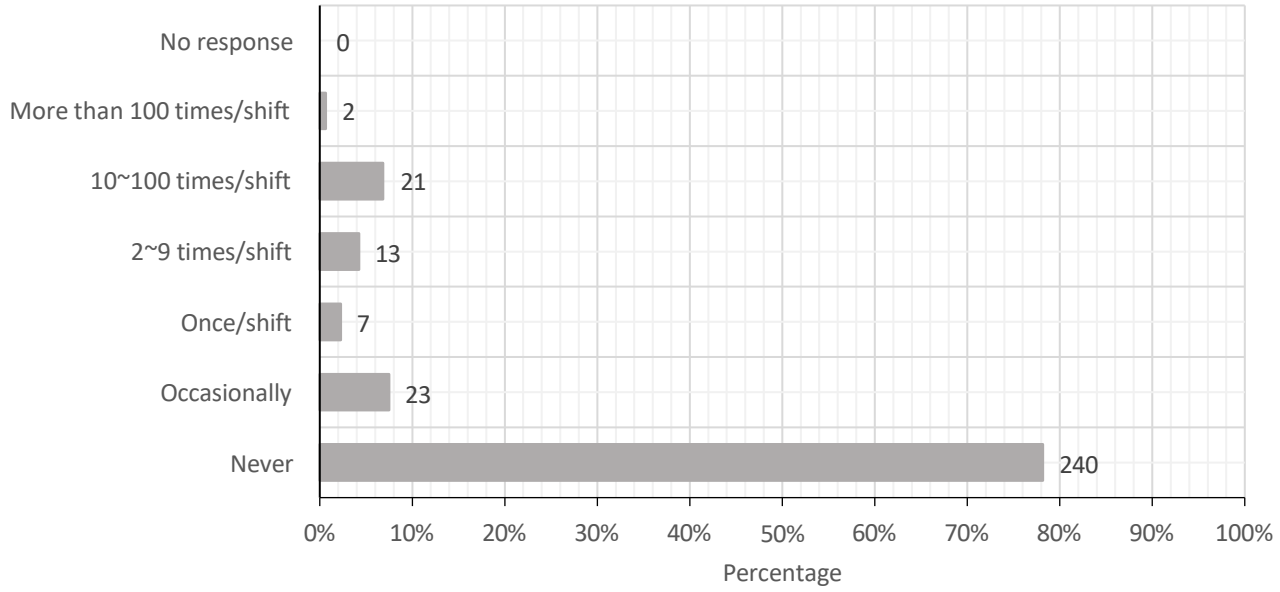


Figure 5. Today, how often did you lift or reposition people unassisted?

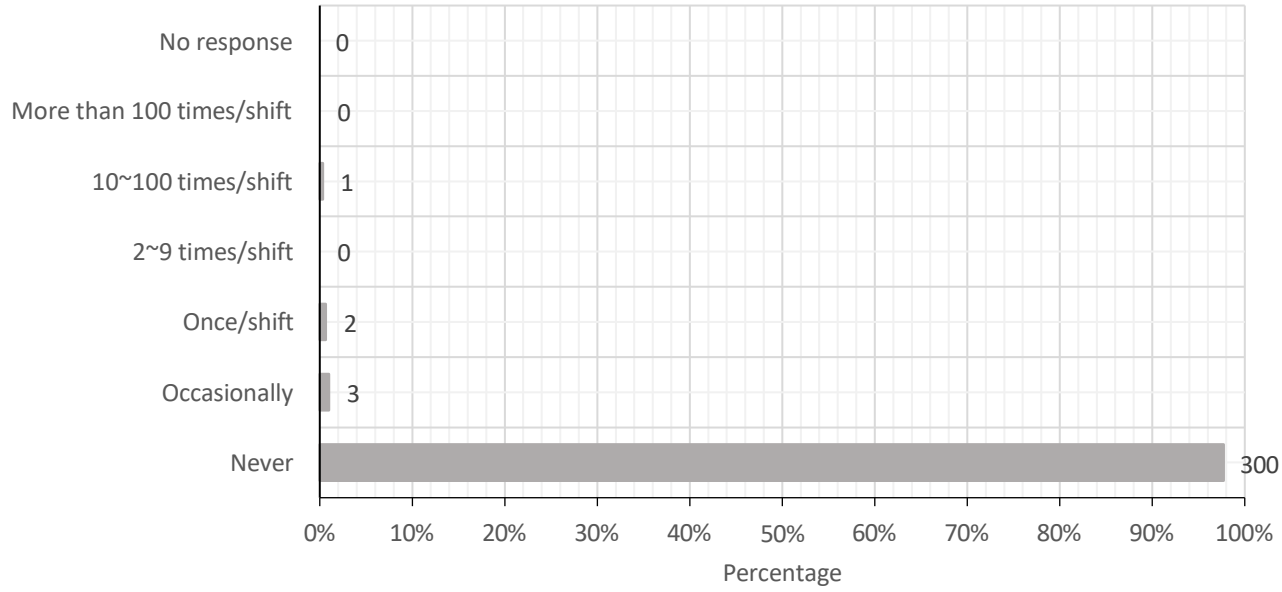


Figure 6. Today how often did you climb 8 or more steps on stairs or ladder?

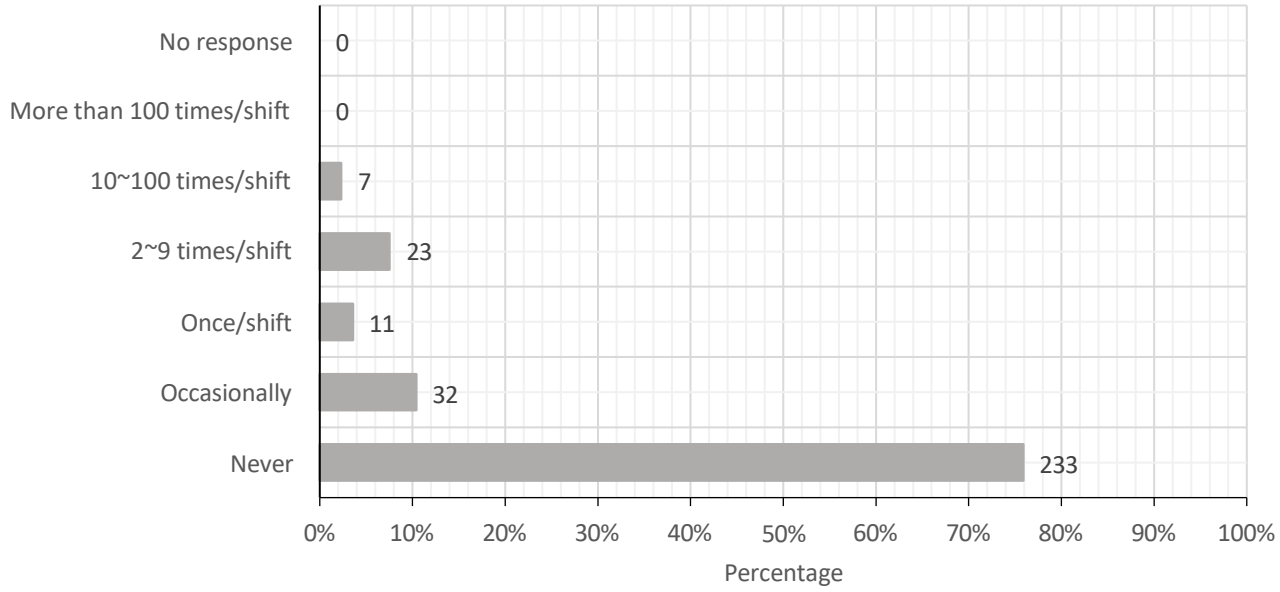


Figure 7. Today how often did you bend forward with few pauses?

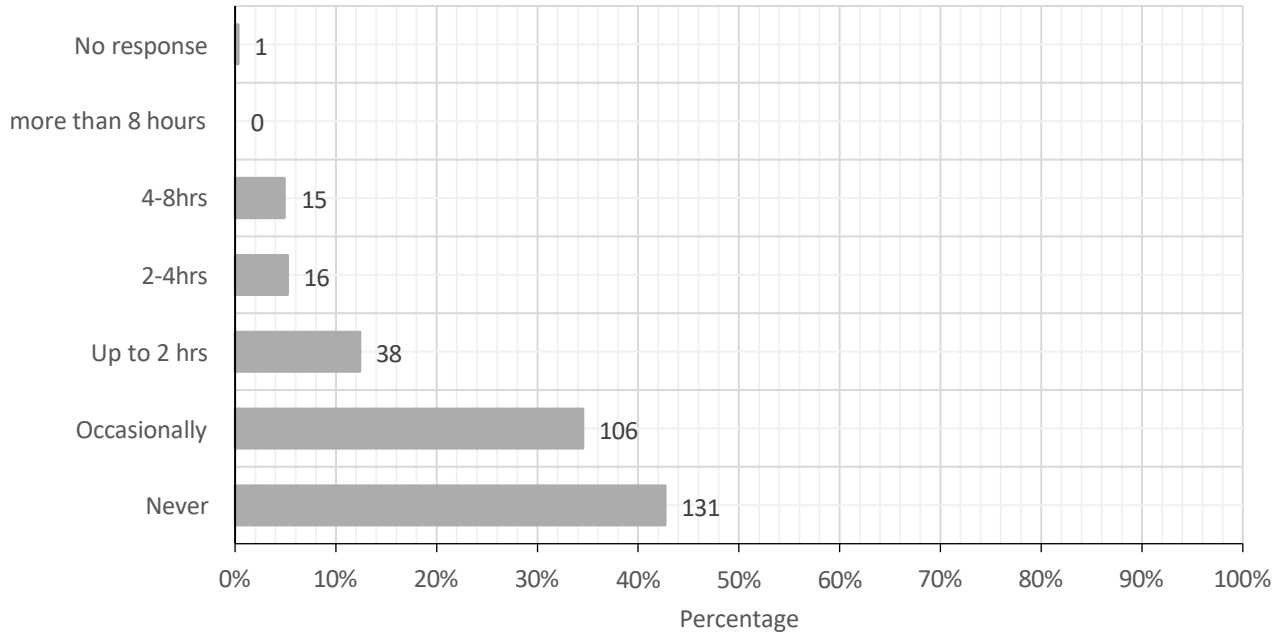


Figure 8. Today how often did you work with one or both hands above shoulder level with minimal loads in the hands with few pauses?

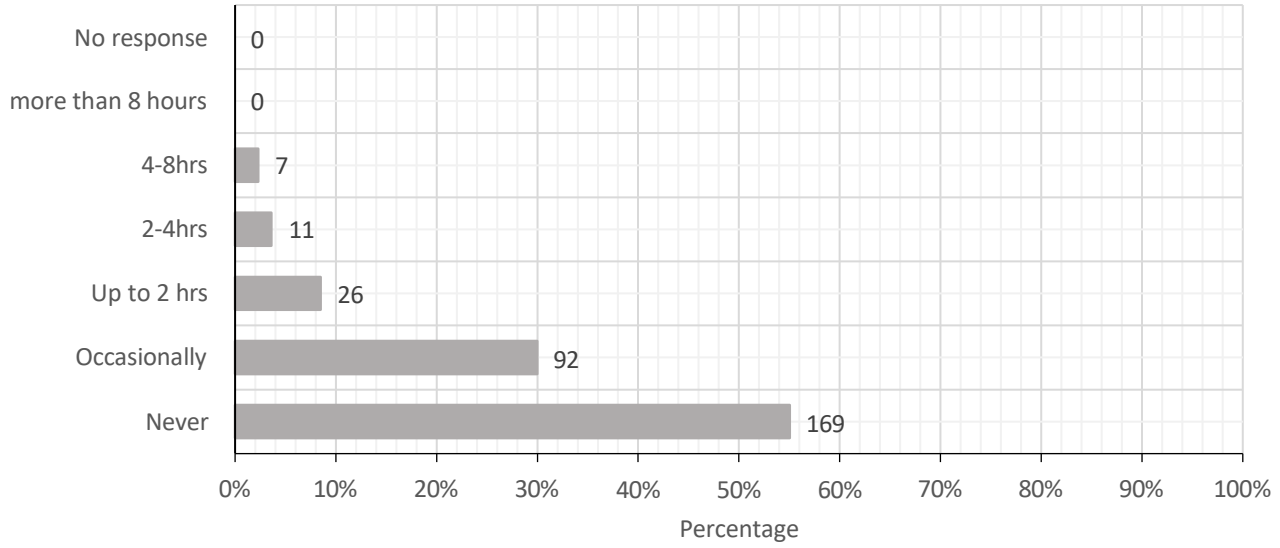


Figure 9. Today how often did you lift or lower objects above the shoulders?

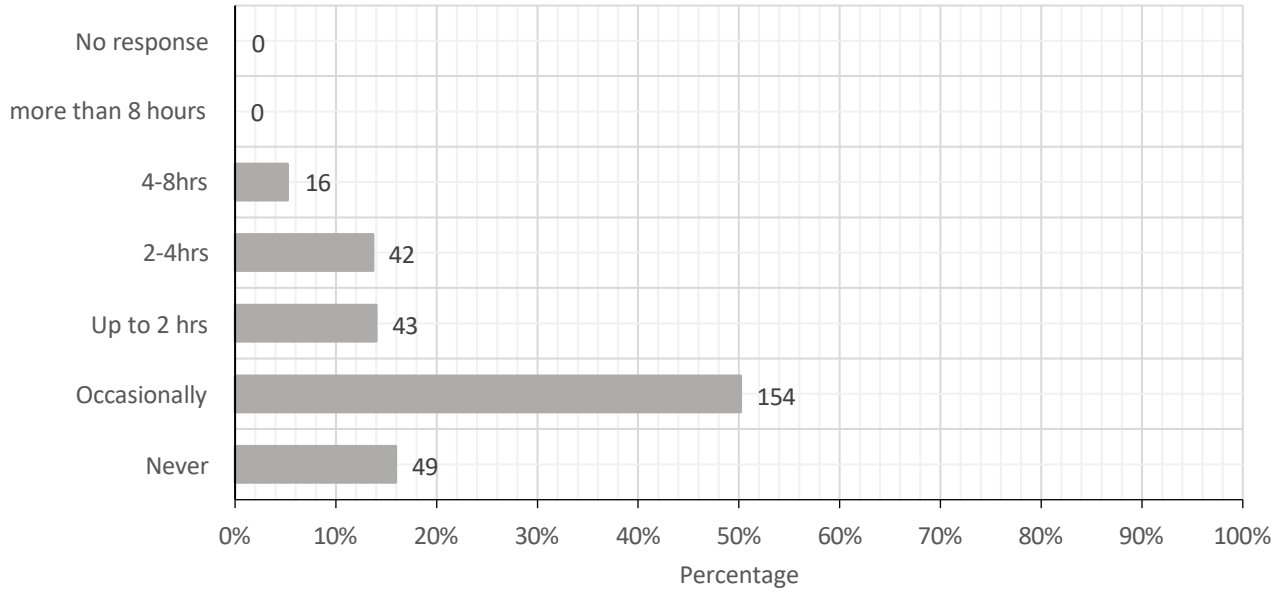


Figure 10. Today, how often did you work with your neck in an awkward position with few pauses?

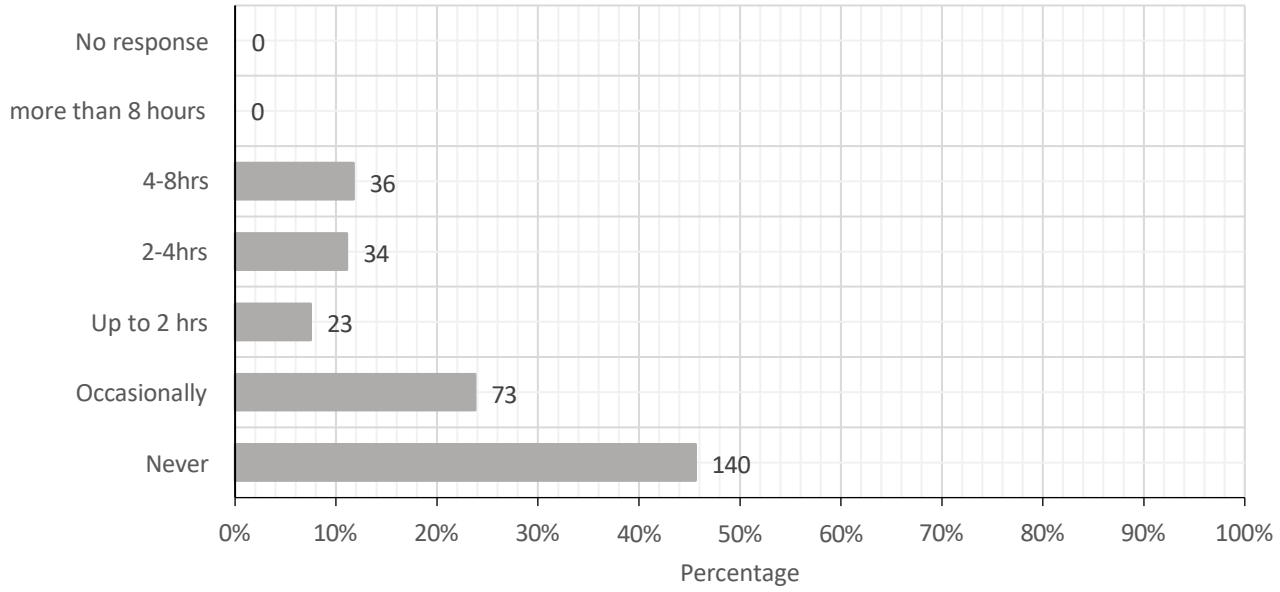
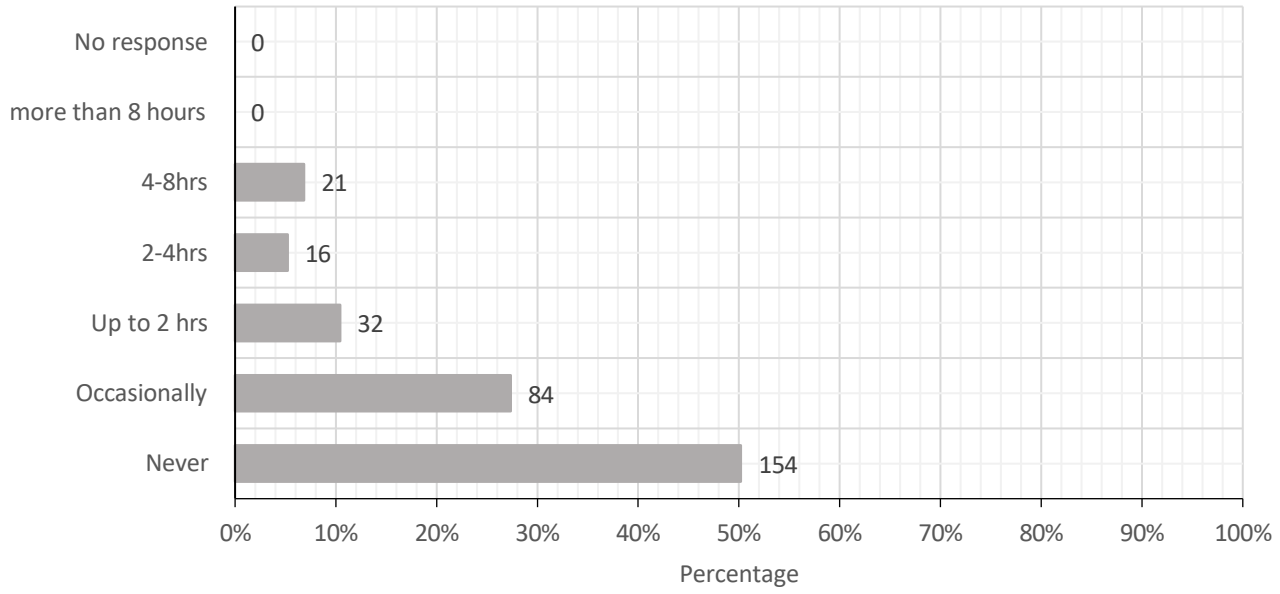


Figure 11. Today, how often did you hold a fixed position of the upper body with few pauses?



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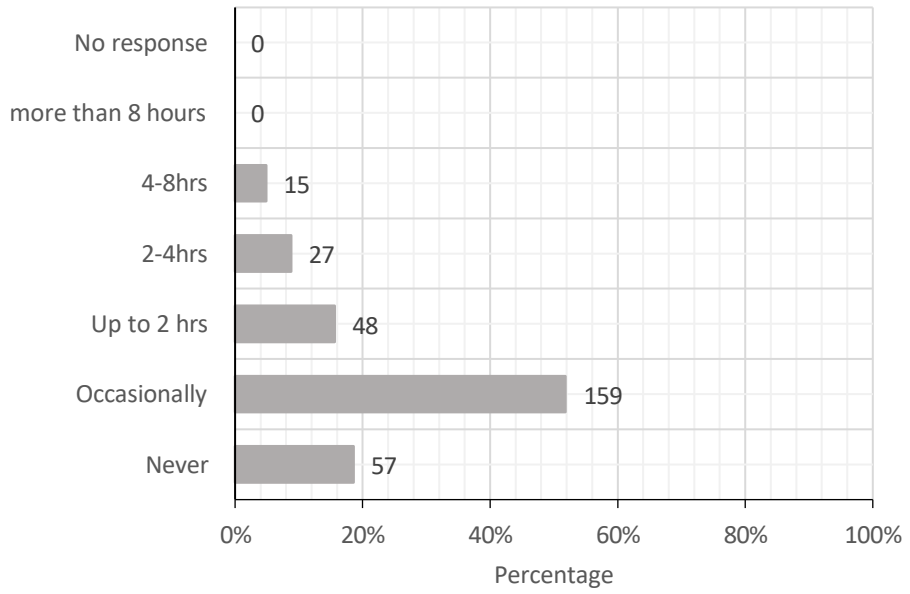


Figure 13. Today, how often did you perform repetitive movement of whole arm more than twice per minute?

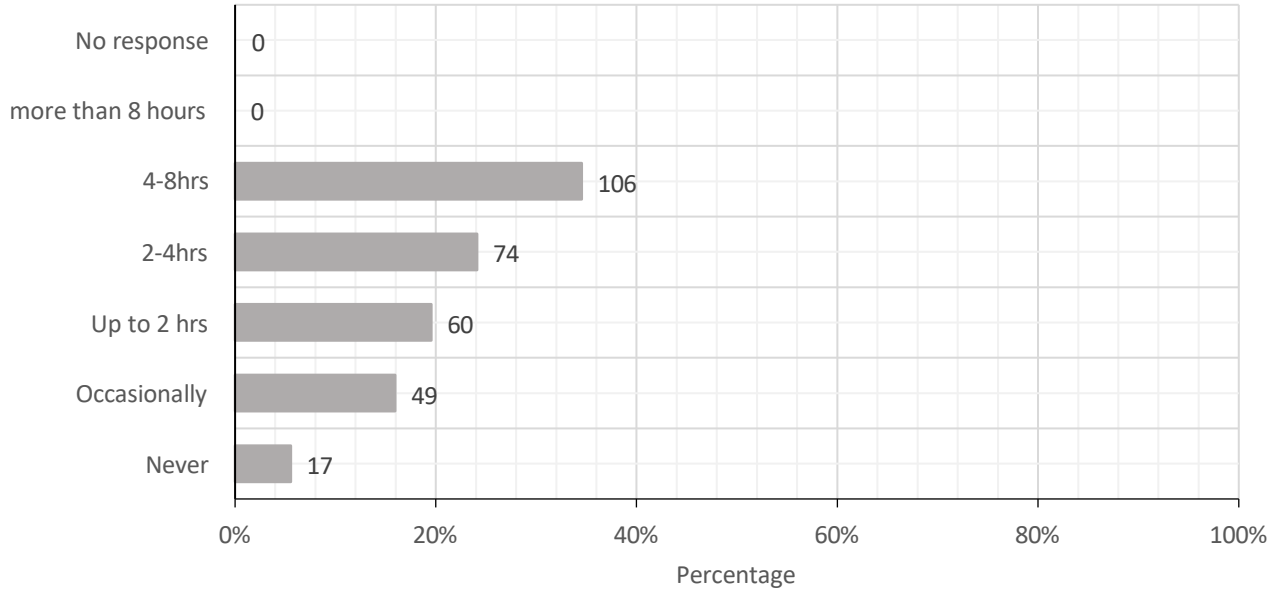
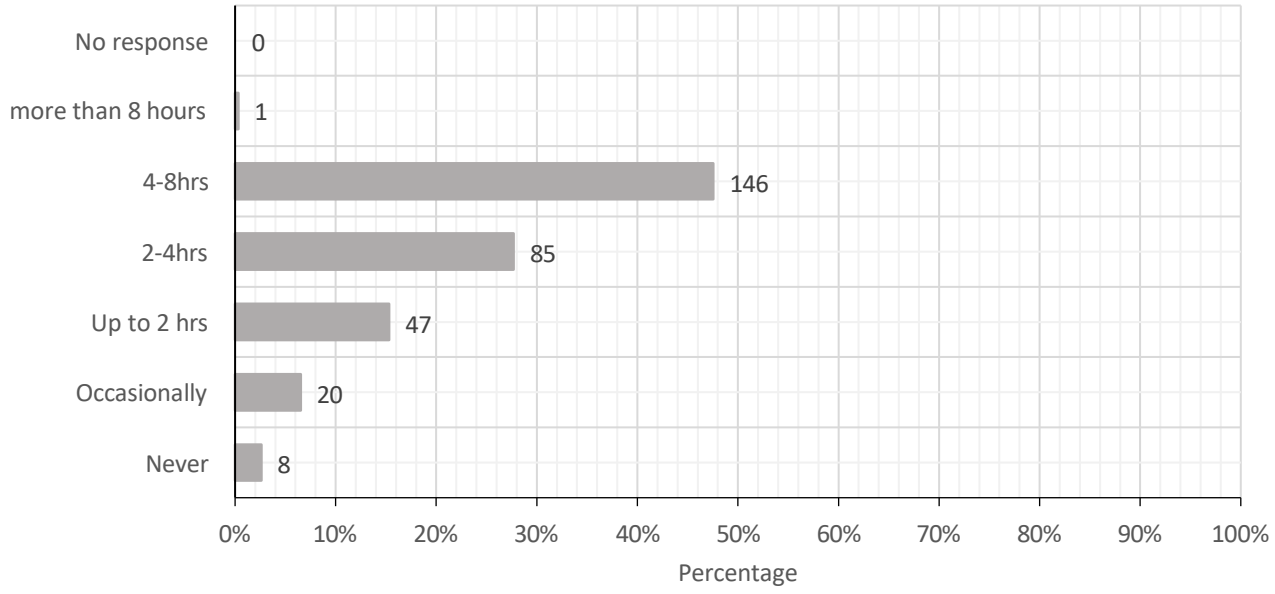


Figure 14. Today, how often did you move your hand, wrist, or forearm more than 10 times per minute not typing?



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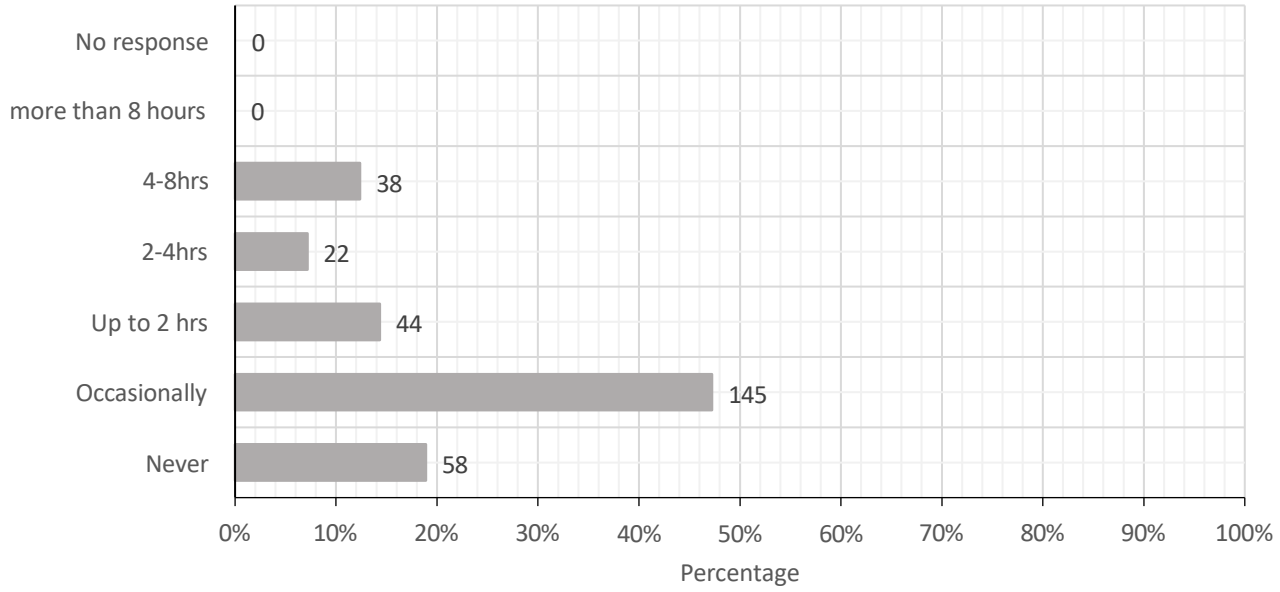


Figure 16. Today how often did you pinch grip small objects between thumb and finger continuously or with few pauses?

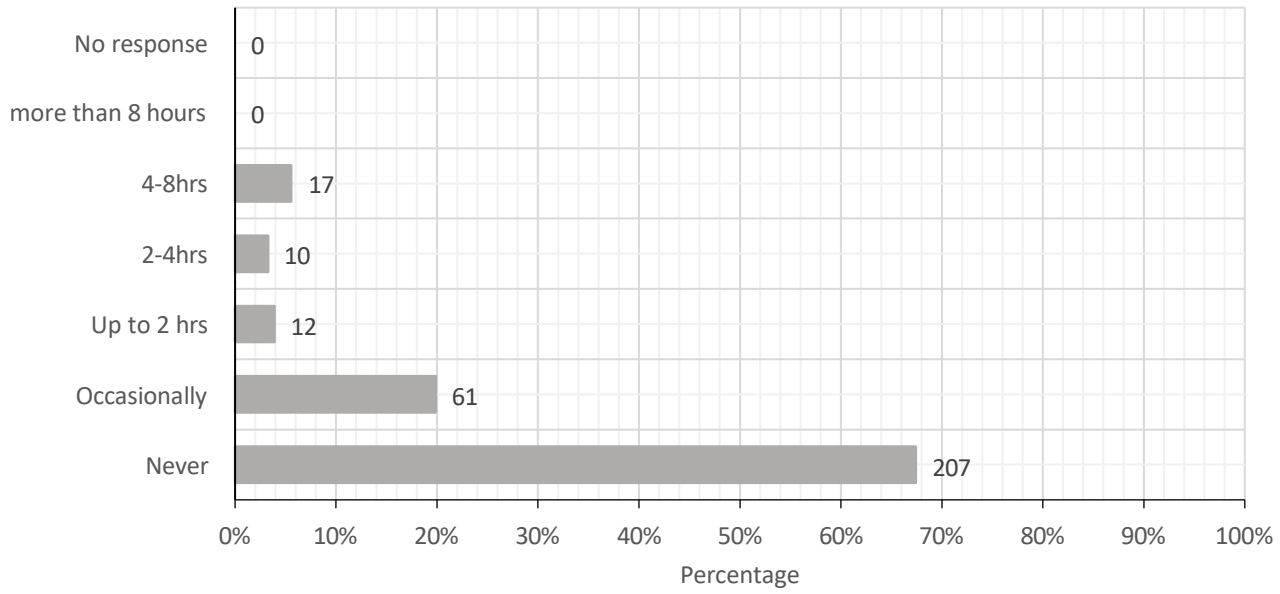


Figure 17. Today how often did you use your whole hand to grasp objects continually or squeeze objects repeatedly?

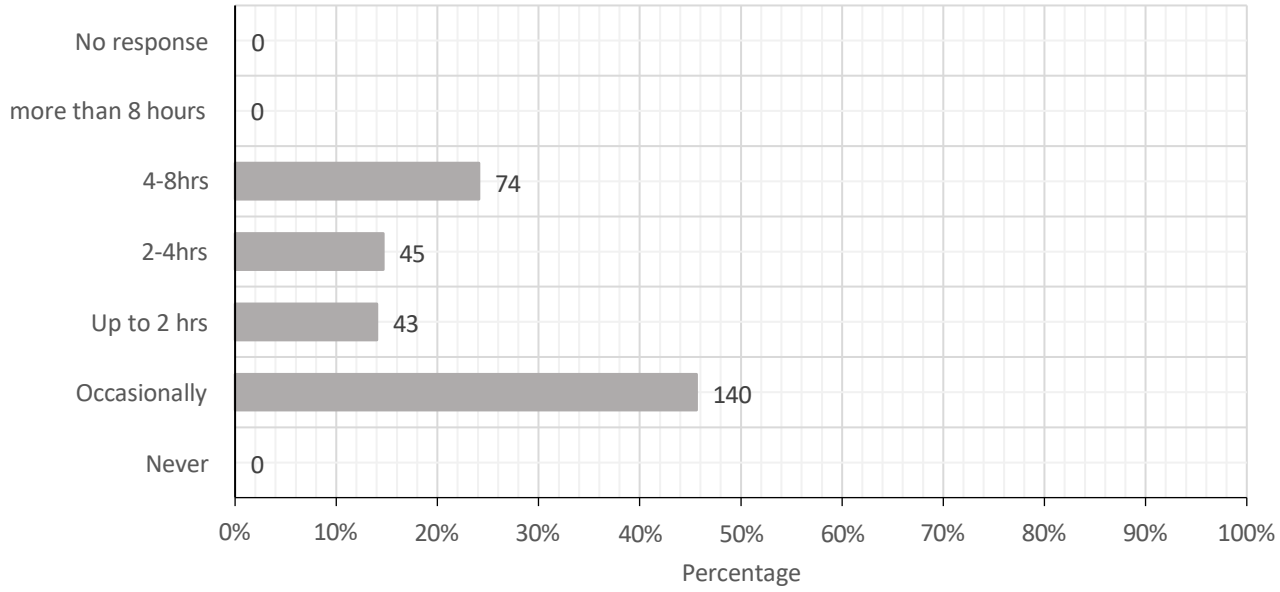


Figure 18. Today how often did you use your hand as a hammer to pound objects?

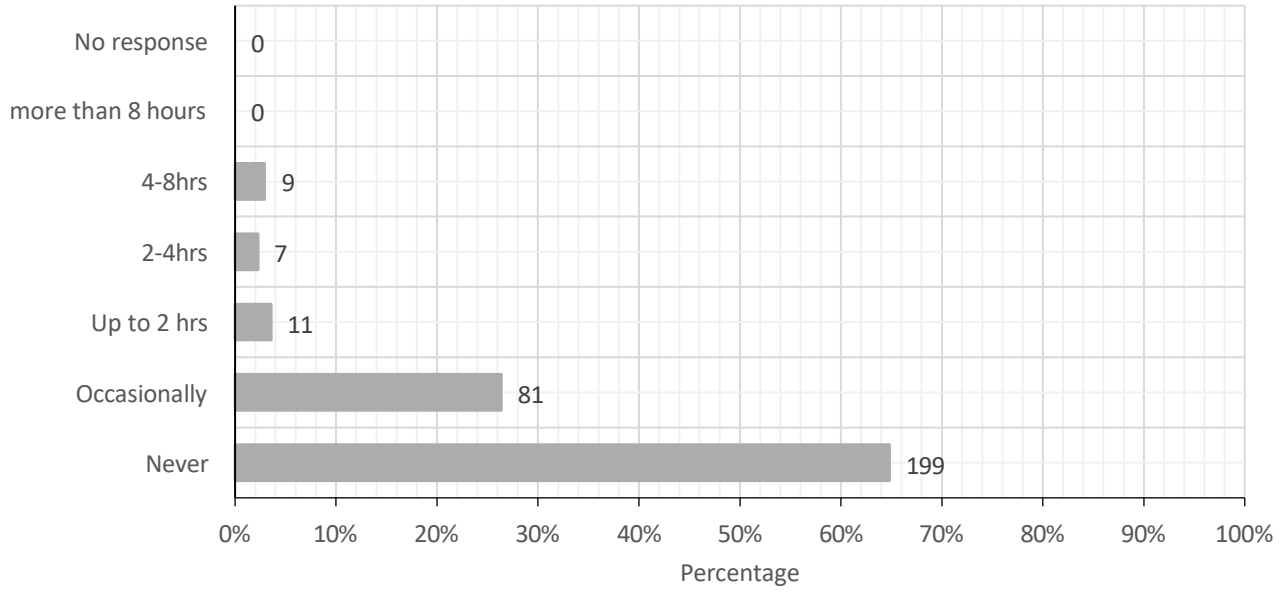


Figure 19. Today how often did you grasp objects while wearing heavy gloves or gloves that get in the way?

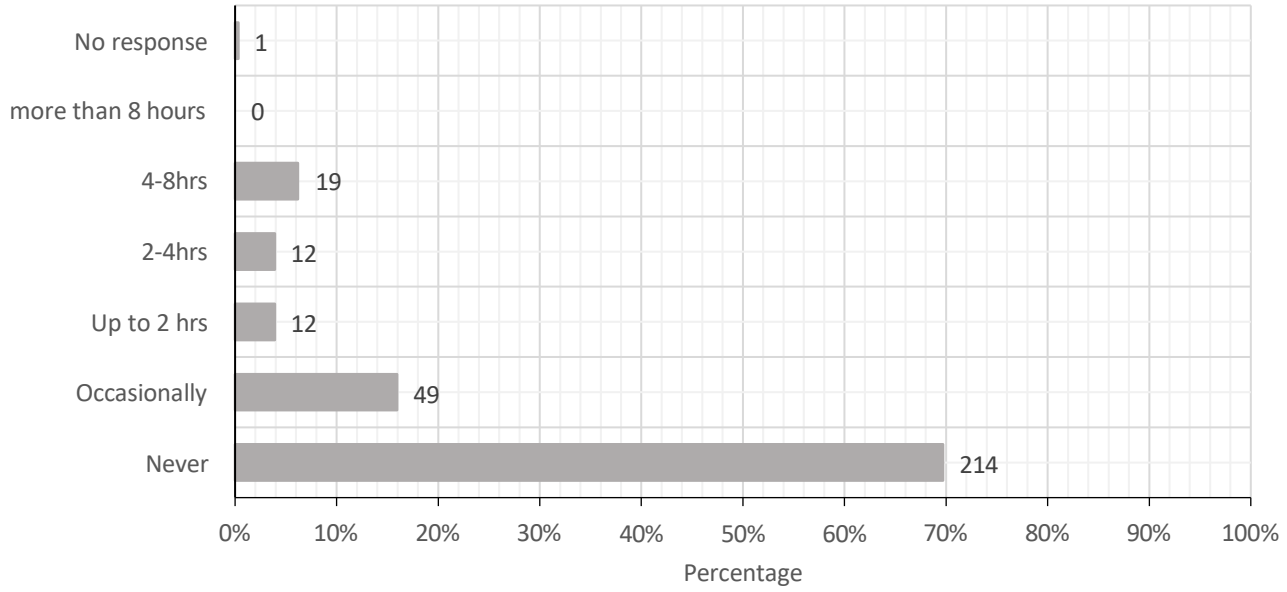


Figure 20. Today how often did you use your knees as a hammer more than once/minute?

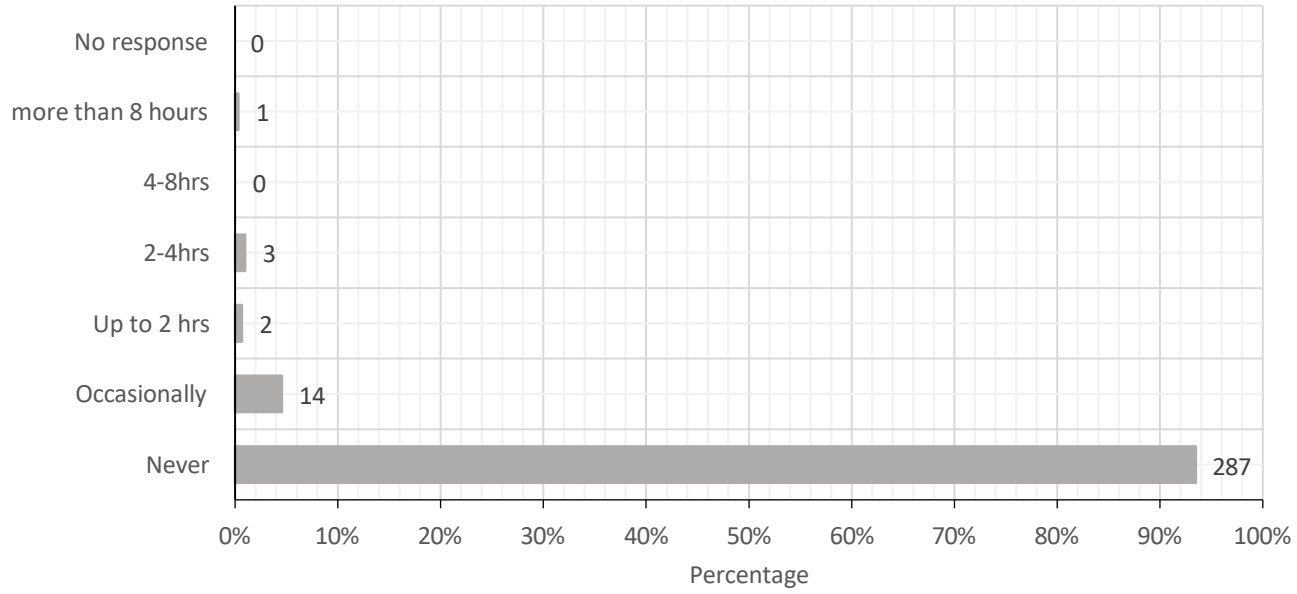


Figure 21. Today how often did you stand with infrequent walking?

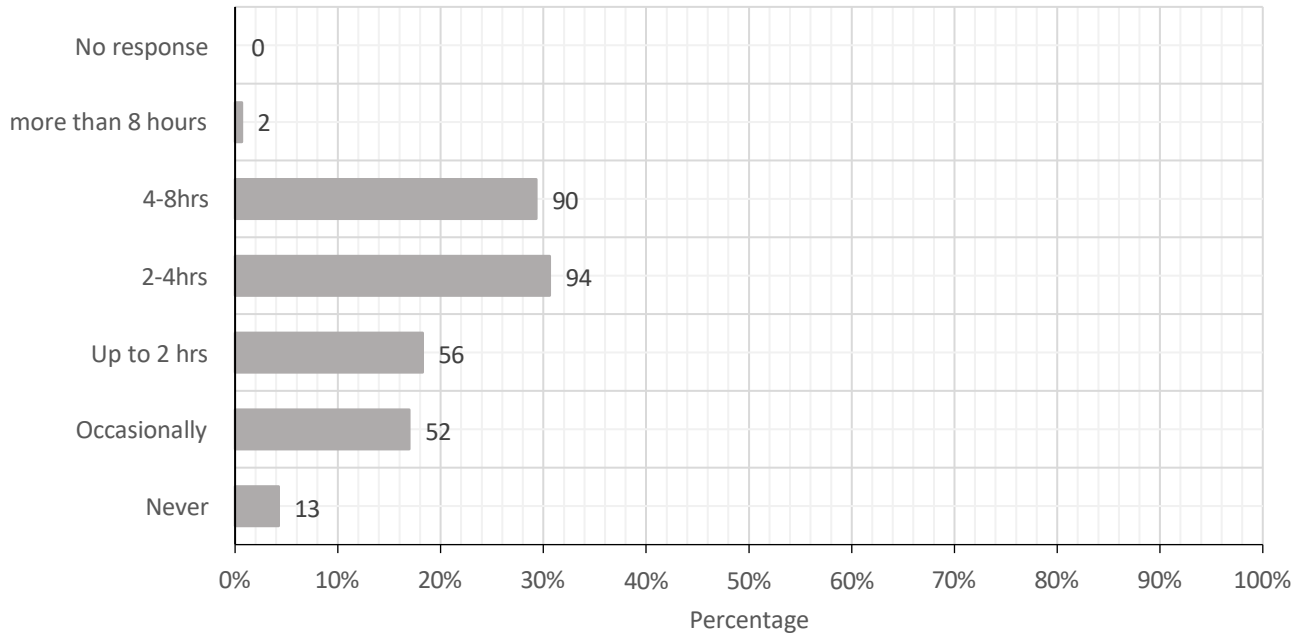


Figure 22. Today how often did you sit not in vehicles?

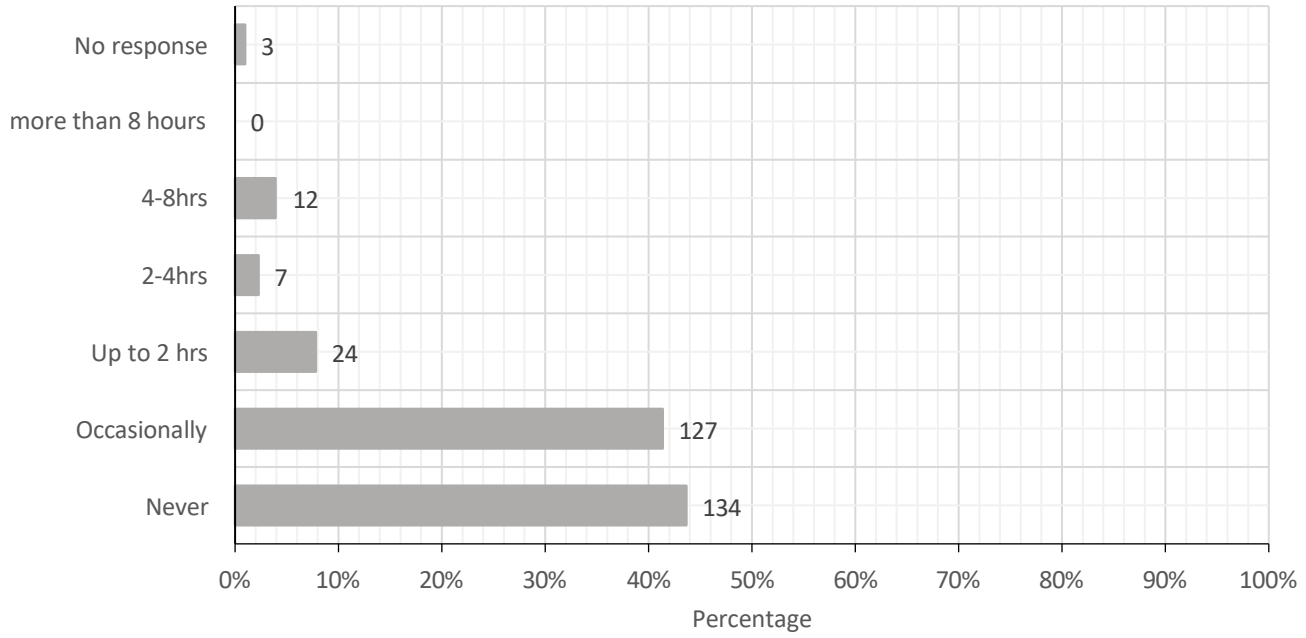


Figure 23. Today how often did you sit in or drive on-road vehicles only?

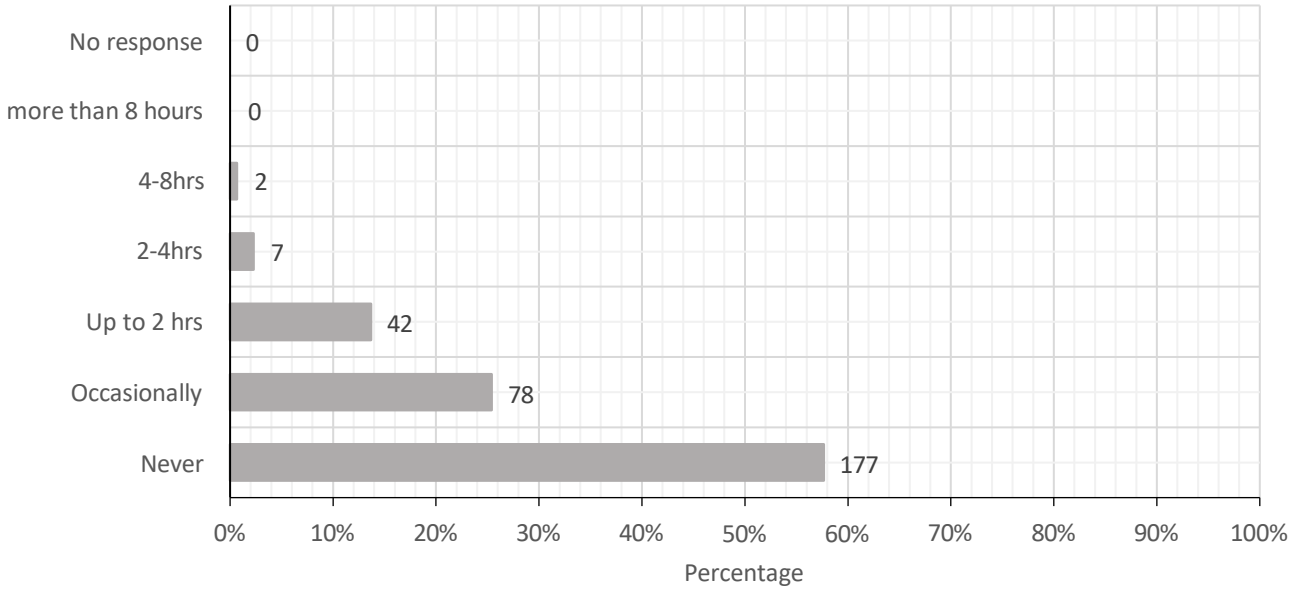


Figure 24. Today how often did you sit or stand on vibrating surfaces machines or off-road vehicles?

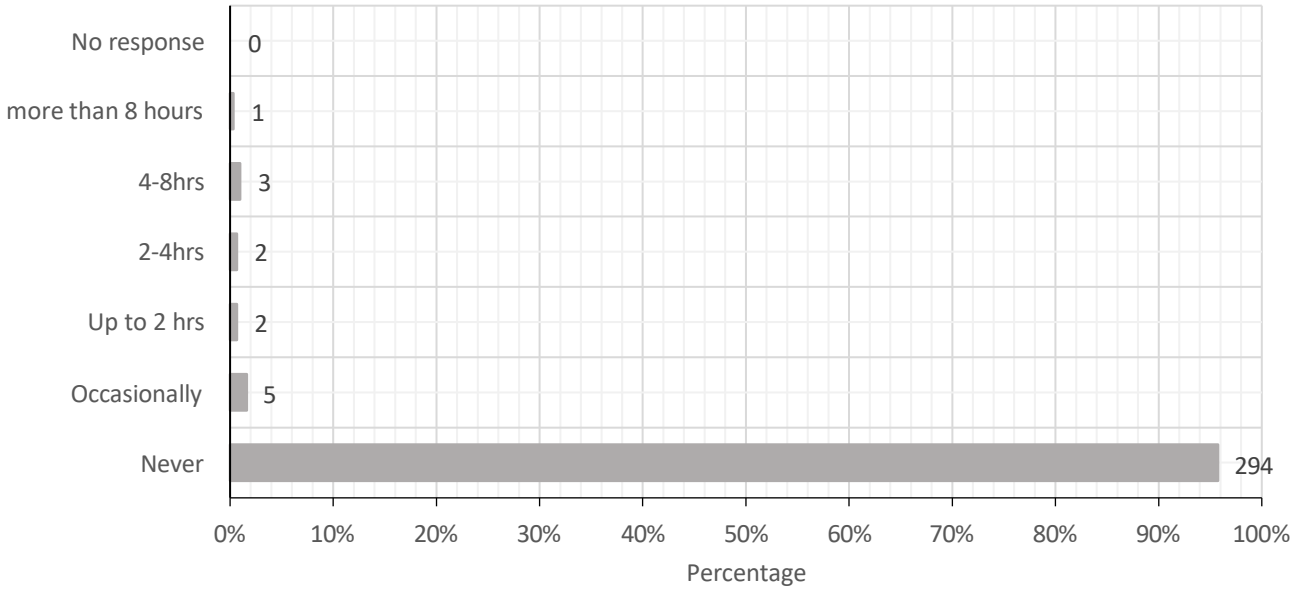


Figure 25. Today how often did you work in the cold?

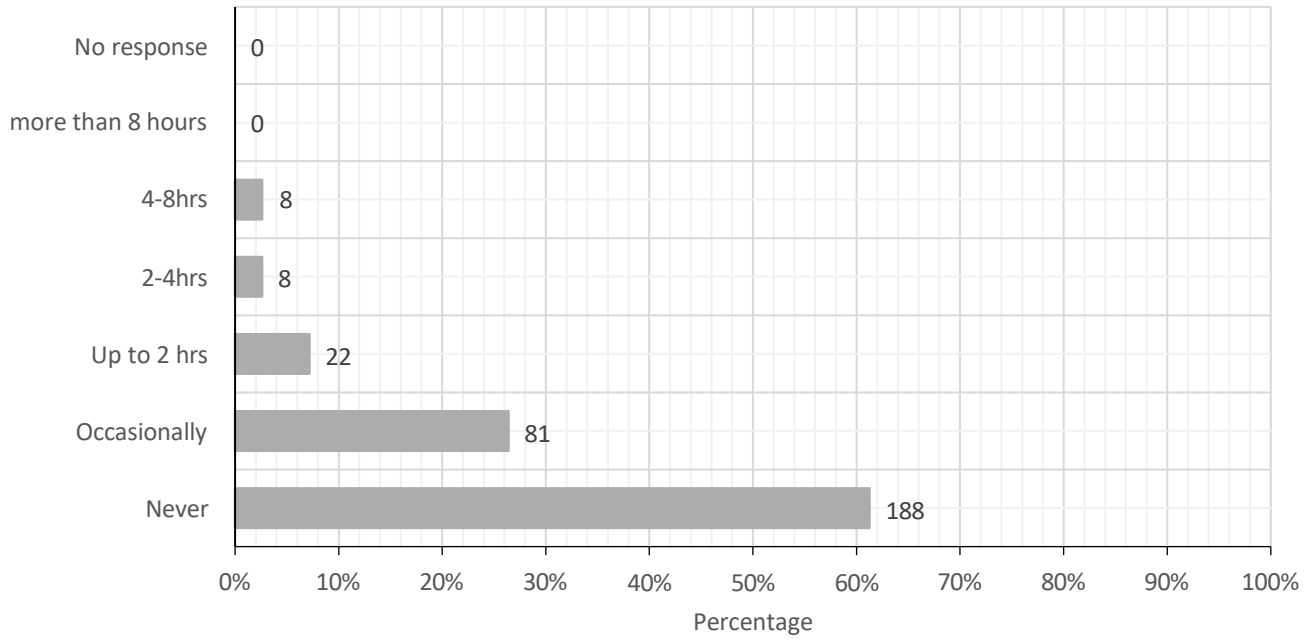


Figure 26. Today, how often did you use or grasp high** vibration tools or objects?

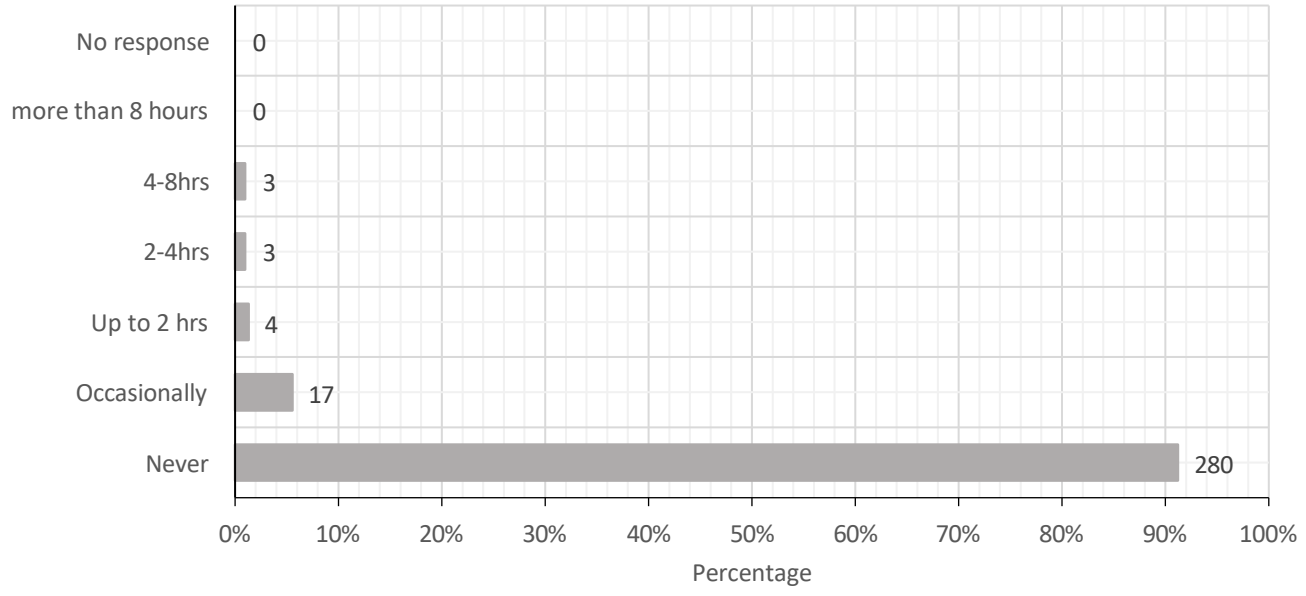


Figure 27. Today, how often did you use or grasp moderate** vibration tools or objects?

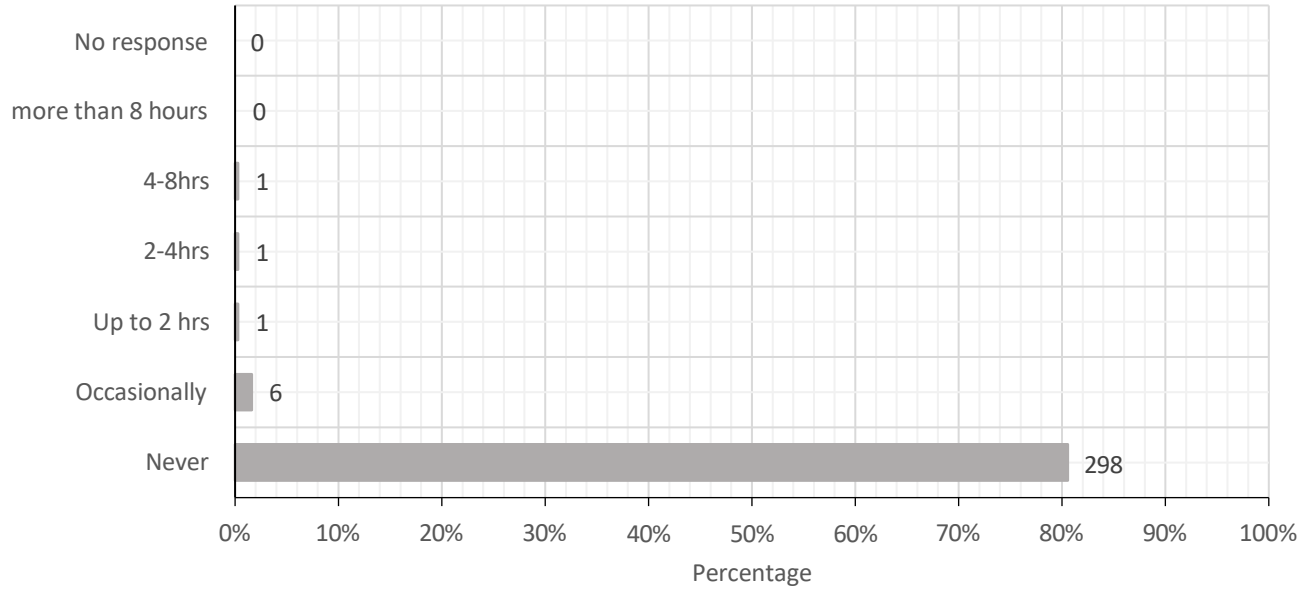
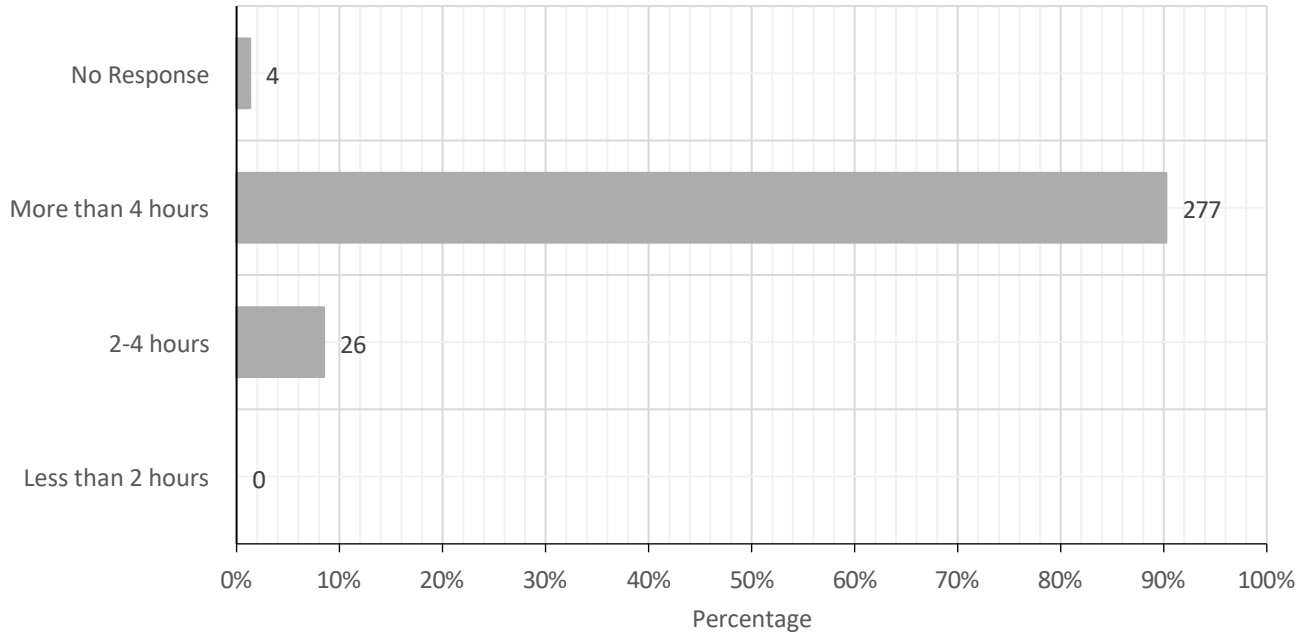


Figure 28. How long is your shift today?



Discussion and Limitations

There are some significant exposures to physical loads that could be easily remedied by improved scanning equipment, stools for cashiers and perhaps redesign of shelving. It is also possible that if there was agreement with management that a proactive ergonomic plan be implemented there could be results beyond a reduction of claims to the WSIB. It is of interest to note when proactive action took place in Quebec they found:

- Reduced the number of back injuries
- Greater likelihood of reduced absenteeism
- Improved productivity
- Reduced material loss
- Improved industrial relations.

The significant limitation to this study was management's' absence from the process. Workers were reluctant to participate and there was very limited feed back from managers about issues and possible solutions.

Future Steps

Redo of the survey with management support

Use available data and isolate problem such as standing and scanning

Conduct joint intervention to address issues in current and new facilities

Apply for a Mitacs grant to develop a long-term ergonomics programme.

Appendix II

Evolving Pipe Joining Methods and their Association to Musculoskeletal Symptoms for Residential Plumbers

(i) Background
(ii) Process
(iii) Letter of support
(iv) Survey

(i) Background

The health and safety representative of the United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of United States and Canada (UA) Local 46 had a working relationship with the staff of Infrastructure Health and Safety Association (IHSA). The Union Health and Safety representative (HSR) raised concerns about MSDs resulting from crimping associated with new plastic piping materials with the ISHSA representative.

Plastic piping systems gained popularity in Canada and the US. In Ontario, plastic piping has become the material of choice in new residential and commercial construction. Past investigations of MSD hazards in plumbing have focused on more general aspects of the tasks including manual material handling, kneeling, awkward postures during installation, and overhead work. However, limited research addressed MSD risks related to tasks involved in joining plastic pipes. Based on concerns about MSDs from the tradesmen, the IHSA representative contacted the research staff at CRE-MSD and that contact resulted in this study of plumbers.

(ii) Process

Several meetings were held including tradesmen and the research staff. It was decided to document the physical exposure of plumbers using a variety of joining methods. With the assistance of the union, graduate students we attended 25 worksites. Because we had not yet informed the employers' association of the study plans we only attended worksites when we could be accompanied by union co-investigators. The IHSA representative obtained different

crimping tools, which represented manual and hydraulic mechanisms. He was able to share the tools with working plumbers to be tested for a week at a time. The workers provided feed back about the tools.

At the same time a survey, which is attached, was designed to be disturbed to members of UA 46. Questions included demographic factors, work history, musculoskeletal discomfort in the previous 12 months and last 7 days which were adapted from the Nordic Questionnaire on Musculoskeletal Disabilities.

Multiple methods of survey distribution were employed. The research team target 600 low-rise residential plumbers. In the first round of recruitment, the Local mailed out the survey with stamped self-addressed envelopes, as well as a letter signed and endorsing the study by the Union Business Manager (the equivalent of a Local Union President) in a University of Waterloo envelope. A follow-up post-card was sent to union membership signed by union officials, and finally another reminder was mailed in a union envelope to the original list. The alternative forms of mailing were specifically chosen to encourage those recipients unlikely to respond to either a postcard or a University of Waterloo letter. At the same time the original H&S representative and other union representatives were making the rounds to different worksites and encouraging the membership to participate. The questionnaire in a fillable form was also loaded onto the CRE-MSD and Union websites. We received 186 survey responses.

At the same time, a field and lab-based biomechanical assessment of plumbing tasks was conducted. The investigation documented fatigue effects of residential plumbers during their workday and workweek. For the exploratory laboratory study, the team recruited 10 university-

aged participants. That work resulted in a paper outline physical findings for exposed individuals.

The research team met with 20 plumbing contracts during a regular meeting organized by IHSA staff. Alternative crimping tools were introduced. The employers were proved with information about the costs and ergonomic value of the hydraulic tools. Only 1 employer expressed interest in exploring the benefit of the tools.

A focus group was also held with union representatives was arranged. The plumbers were informed of e study findings. They share concern about the Generation I and II tools. Specifically, the tools were expensive and required frequent modifications. They also indicated that Generation 1 tool was heavy and not suitable to small spaces.

Before completing the final version of the paper, I interviewed a number of plumbers who had the ability to independently choose building materials and tools. They were questioned about their choice of tools and the factors that influenced their decisions. They all indicated that when possible they used more expensive piping which accommodated hydraulic tools. Ony when it was not practical did they use manual crimping tools.

This research paper included quantitative data about the incidence of MSDs, the building materials and tools that are commonly used. It goes beyond the quantitative data to explore how the organization of work and socioeconomic factors influence plumbers' health and safety.

(iii) LETTER OF SUPPORT

Infrastructure Health & Safety Association™
Work Safe for Life

Friday, December
2, 2016

Research Opportunities Program
Transfer Partner & Research Funding Unit
Strategy and Integration Branch
Prevention Office, Ministry of Labour
10 Dundas Street East, 8th floor
Toronto ON M7A 0B2

I am writing to provide support for the application of Dr. Philip Bigelow and Dr. M. Yung for funding under the Research For the Workplace Program (ROP) for the project, "Minimizing Fatigue among Plumbers and Implementing Strategies to Inform Small Businesses".

IHSA is pleased to support this research which has been advanced by our Labour-Management Network and the residential plumbing sector. The work of residential plumbers has undergone significant change in the past few years, and plumbers have had growing concerns about the possible health impact of the changing work practices. This research will allow us to study work practices proactively and hopefully reduce possible adverse health effects in the future. We believe that this study of fatigue is important not only to plumbers but also to other working populations whose tasks require forceful repetitive activities.

IHSA sees itself as a conduit between the workplace and researchers. In this case we can assist in the recruitment of participants from both labour and management. Furthermore, as well established knowledge brokers, we can help in the dissemination of the study results to the entire Construction and Electrical Utilities sectors. To communicate the findings, we will be pleased to participate in conferences, journal articles, and webinars. These communication medium has proved to be useful in the past. We will also be glad to share findings in our IHSA magazine and will encourage the research team to attend our Labour-Management Health and Safety Committee Network, and various employer association meetings.

IHSA will also act as a collaborator. Our ergonomists have assisted in the study design and will assist in the analysis of the data and drafting of reports coming out of the research. We will share

not only our technical knowledge but a practical understanding of the workplace. IHSA has worked with CRE-MSD
in the past and have always found it an important and valuable relationship, with a joint goal of transferring research findings to the working population.

Sincerely,

Enzo Garritano
President, CEO

(iv) SURVEY

Plumbers Task and Symptom Survey

CONFIDENTIAL **PARTICIPANT'S ID** _____

A. DESCRIBING YOURSELF

1. Your age: _____
2. Your gender: Male _____ Female _____
3. Your weight: _____lbs (or) _____kg
4. Your height: _____ft _____in (or) _____cm
5. How many hours in total did you work in the last 2 weeks? _____ Hours
6. Did you work more than 10 months last year? □Yes □No

B. DESCRIBE YOUR JOB

1. How long have you been a plumber? _____years
2. Are you an apprentice or journeyman? □Apprentice □Journeyman
3. How old were you when you entered the trade? _____years
4. How long have you been with your current employer? _____years
5. Do you get paid by piece work or by the hour? □Piece work □Hourly
6. How many journeymen work for your company? _____
7. Do you hold any position with the union? _____
8. When is the last time you had a health and safety course? _____years

   What was it

   _____

9. How do you get most of your health and safety information?

   Employer associations Union Suppliers trade magazines Coworkers Trade Other

10. How physically demanding would you consider your work to be?

□Much too heavy □Too heavy □About right □ Too light □ much too light

11. In the last month, how often have you felt exhausted after your shift?

□Every day □Most days □Half the time □A few days □Never

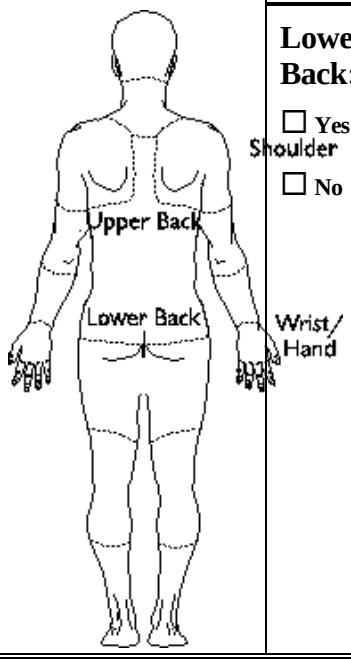
12. Are you able to take short breaks of a minute or so during work if you need to do so?

□Yes □No

13. Is your current work speed or work pace:
□ Much too fast □ Too fast □ About right □ Too slow □ Much too slow

14. Overall, how do you feel about your job?
□ Very Satisfied □ Satisfied □ Dissatisfied □ Very Dissatisfied

D. GENERAL MUSCULOSKELETAL TROUBLES						
	To be answered by everyone	To be answered only by those who have had trouble				
In this picture you can see the approximate position of the parts of the body referred to in the questionnaire. You yourself have to decide in which part you have or have had your trouble (if any).	Have you at any time during **the last 12 months had trouble** (such as ache, pain, discomfort, numbness) that you believe to be work related, with any of these areas of the body in:	During the last 12 months have you been **prevented from carrying out normal job activities** because of this trouble:	What is the **total** length of time that the trouble has **prevented** you from doing your normal job activities during the **last 12 months?**	Have you had **trouble** at any time during **the last 7 days**, that you believe to be work related?	According to the scale below, what is the **level of discomfort** in this body part within the last 30 days? 0 No Discomfort 1 2 Fairly Comfortable 3 4 5 Moderate Discomfort 6 7 8 Very Uncomfortable 9 10 Extreme Discomfort	According to the scale below, **how often** do you have pain or discomfort in this body part within the last 30 days? 0 Never 1 Rarely (few times/month) 2 Frequently (few times/week) 3 Constantly (nearly every day)
	Shoulders: ☐ **Yes in right** ☐ **No** ☐ **Yes in left** ☐ **Yes in both**	**Shoulders:** ☐ **Yes in right** ☐ **No** ☐ **Yes in left** ☐ **Yes in both**	**Shoulders:** ☐ **0-7 days** ☐**8 -30 days** ☐**More than 30 days**	**Shoulders:** ☐ **Yes in right** ☐ **No** ☐ **Yes in left** ☐ **Yes in both**	**Severity of Discomfort**	**Frequency**
	Wrists/Hands: ☐ **Yes in right** ☐ **No** ☐ **Yes in left**	**Wrists/Hands:** ☐ **Yes in right** ☐ **No** ☐ **Yes in left**	**Wrists/Hands:** ☐ **0-7 days** ☐**8 -30 days** ☐**More than 30 days**	**Wrists/Hand:** ☐ **Yes in right** ☐ **No** ☐ **Yes in left**	**Severity of Discomfort**	**Frequency**



☐ Yes in both	☐ Yes in both		☐ Yes in both		
Upper Back: ☐ Yes ☐ No	**Upper Back:** ☐ Yes ☐ No	**Upper Back:** ☐ 0-7 days ☐8-30 days ☐More than 30 days	**Upper Back:** ☐ Yes ☐ No	Severity of Discomfort	Frequency
Lower Back: ☐ Yes ☐ No	**Lower Back:** ☐ Yes ☐ No	**Lower Back:** ☐ 0-7 days ☐8-30 days ☐More than 30 days	**Lower Back:** ☐ Yes ☐ No	Severity of Discomfort	Frequency

D. DESCRIBE YOUR TASKS

1. What percent of the time that you work at:
   Ceiling level: □All (100%) □Most (75%) □Half (50%) □Some (25%) □None

   Waist level: □All (100%) □Most (75%) □Half (50%) □Some (25%) □None

   Floor level (sinks): □All (100%) □Most (75%) □Half (50%) □Some (25%) □None

2. In the last 12 months, while performing **rough-in tasks,** have you experienced a **heavy physical exertion** that required medical attention?: □Yes □No

3. Which crimping tools do you use <u>the most</u> to connect the plastic tubing system:

   □ Manual crimping tools □Powered crimping tools
   □ Manual stretchable PEX tools □Powered stretchable PEX tools

D.1. Copper Pipe Installation

1. Do you install copper pipes? □Yes □No ***(if no, skip to section D.2)***

2. What percent of the work requires you to install copper pipes?
   □All (100%) □Most (75%) □Half (50%) □Some (25%) □None

3. Rate the level of **grasping effort** required to install copper pipes on the following scale.

   0 – – – – - 0.5 -------- 1 -------- 2 – – – – - 3 -------- 4 -------- 5 -------- 6 -------- 7 -------- 8 – – – – - 9 -------- 10
   Nothing at all Light Heavy Very Heavy Almost Max.

4. Using the following scale, rate the level of discomfort when installing copper pipes for the following body parts. (indicate the number in the blank)

   0 – – – – - 1 -------- 2 -------- 3 -------- 4 -------- 5 -------- 6 -------- 7 -------- 8 -------- 9 – – – – - 10
   No discomfort Worst discomfort ever

   Shoulders: _____ Hands / Arms: _____ Upper back: _____ Lower back: _____

5. What are the advantages of using copper pipes? (Check all that apply)
   □Saves time □Increases productivity □Improves quality
   □Safer □Easy to use □Comfort
   □Other, specify: _____

6. Please provide an explanation to your response to the question above.

   _____

7. What are the disadvantages of using copper pipes? (Check all that apply)
   □High initial cost □Incompatibility with jobsite conditions □Quality concerns
   □ Safety concerns □Difficulty of maintenance □High effort
   □ Other, specify: _____

8. Please provide any additional feedback on installing copper pipes.

   _____

   _____

   _____

D.2 Manual Crimping

1. Have you used manual crimping tools? □Yes □No ***(if no, skip to section .D 3)***

2. Do you use short handle (~12") or long handled (~15") manual crimpers?
   □Short handle □Long handle □Both short and long

3. How long have you been using manual crimping tools?
   □One season □Two-Three Seasons □Four or more seasons

4. On average, how many crimps do you perform a day? (add check the box with range of average #)
   □< 50 □50 - 100 100 - □ 200 □> 200

5. What percent of the time do you perform manual crimping of ½ inch pipe as oppose to ¾ inch pipe?
   □100% use of ½ inch pipes □75% use of ½ inch pipes □ 50% use of ½ inch pipes
   □25% use of ½ inch pipes □0% use of ½ inch pipes, only ¾ inch pipes

6. What percent time do you use two hands to manually crimp ½ inch pipes?
   □All (100%) □Most (75%) □Half (50%) □Some (25%) □None

7. What percent time do you use two hands to manually crimp ¾ inch pipes?
   □All (100%) □Most (75%) □Half (50%) □Some (25%) □None

8. How often do you lubricate and maintain the crimping tool?
   □Daily □Weekly □Every other week □Once a month □Less than once a month

9. Rate the level of **grasping effort** required to operate the tool on the following scale.

   0 – – – – - 0.5 -------- 1 -------- 2 – – – – - 3 -------- 4 -------- 5 -------- 6 -------- 7 -------- 8 – – – – - 9 -------- 10
   Nothing at all Light Heavy Very Heavy Almost Max.

10. What are the advantages of using manual crimping tools? (Check all that apply)
    □Saves time □Increases productivity □Improves quality
    □Safer □Easy to use □Comfort
    □other, specify: _____

11. How did you get the crimping tool?

Rent it, Buy it Employer supplied, Supplied by plastic pipe supplier

12. Please provide an explanation to your response to the question above.

_____

_____

13. What are the disadvantages of using manual crimping tools? (Check all that apply)
□High initial cost □Incompatibility with jobsite conditions □Quality concerns
□ Safety concerns □Difficulty of maintenance □High effort
□ Other, specify: _____

14. lease provide any additional feedback regarding the use of manual crimping tools.

_____

_____

_____

D.3 Powered Crimping

1. Have you used a powered crimping tool? □Yes □No ***(if no, skip to question D.4)***

2. Have you used hydraulic or battery power crimping tools?
□Hydraulic □Battery □Both hydraulic and battery

3. How long have you been using powered crimping tools?
□One season □Two-Three Seasons □Four or more seasons

4. How often do you use a powered crimping tool?
□ Seldom □Occasionally □Most of the time

5. What percent of the time do you perform powered crimping of ½ inch pipe as oppose to ¾ inch pipe?
□100% use of ½ inch pipes □75% use of ½ inch pipes □50% use of ½ inch pipes
□25% use of ½ inch pipes □0% use of ½ inch pipes, only ¾ inch pipes

6. Rate the level of **grasping effort** required to operate the tool on the following scale.

0 – – – – - 0.5 -------- 1 -------- 2 – – – – - 3 -------- 4 -------- 5 -------- 6 -------- 7 -------- 8 – – – – - 9 -------- 10
Nothing at all Light Heavy Very Heavy Almost Max.

7. What are the advantages of using powered crimping tools? (Check all that apply)
   □Saves time □Increases productivity □Improves quality
   □Safer □Easy to use □Comfort
   □other, specify: _____

8. Please provide an explanation to your response to the question above.

   _____

   _____

9. What are the disadvantages of using powered crimping tools? (Check all that apply)
   □High initial cost □Incompatibility with jobsite conditions □Quality concerns
   □ Safety concerns □Difficulty of maintenance □High effort
   □ Other, specify: _____

10. How did you first learn about powered crimping tools?
    □Supplier □Saw it on a worksite □Informed by workers
    □Trade show □Trade association □CSAO

11. Are powered crimping tool available for use on a trial basis, such as renting, in your area?
    □Yes □No

12. How did you get the powered crimping tool?

    Rent it, Buy it Employer supplied, Supplied by plastic pipe supplier

13. Please provide any additional feedback regarding the use of powered crimping tools.

    _____

    _____

D.4 Powered Stretchable PEX Tools

1. Have you used a powered stretchable PEX tool? □ Yes □ No ***(if no, skip to the end)***

2. How long have you been using powered stretchable PEX tools?
   □One season □Two-Three Seasons □Four or more seasons

3. Have you used hydraulic or battery power crimping tools?
   □Hydraulic □Battery □Both hydraulic and battery

4. How often do you use powered stretchable PEX tool?
   □Seldom □Occasionally □Most of the time

5. What percent of the time do you powered stretchable PEX tool for ½ inch pipe as oppose to ¾ inch pipe?
   □100% use of ½ inch pipes □75% use of ½ inch pipes □50% use of ½ inch pipes
   □25% use of ½ inch pipes □0% use of ½ inch pipes, only ¾ inch pipes

6. Rate the level of **grasping effort** required to operate the tool on the following scale.

   0 – – – – - 0.5 -------- 1 -------- 2 – – – – - 3 -------- 4 -------- 5 -------- 6 -------- 7 -------- 8 – – – – - 9 -------- 10
   Nothing at all Light Heavy Very Heavy Almost Max.

7. What are the advantages of using powered stretchable PEX tools? (Check all that apply)
   □Saves time □Increases productivity □Improves quality
   □Safer □Easy to use □Comfort
   □other, specify: _____

8. Please provide an explanation to your response to the question above.

   _____

   _____

9. What are the disadvantages of using powered stretchable PEX tools? (Check all that apply)
   □High initial cost □Incompatibility with jobsite conditions □Quality concerns

   □ Safety concerns □Difficulty of maintenance □High effort

   □ Other, specify: _____

10. How did you first learn about powered stretchable PEX tools?
    □Supplier □Saw it on a worksite □Informed by workers

    □Trade show □Trade association □CSAO

11. Are powered stretchable PEX tools available for use on a trial basis, such as renting, in your area?

    □Yes □No

12. How did you get the stretchable tool?

    Rent it, Buy it Employer supplied, Supplied by plastic pipe supplier

13. Please provide any additional feedback regarding the use of powered stretchable PEX tools.

    _____

Thank you for taking the time to participate in this study and complete this questionnaire.

APPENDIX III
Health and Safety Innovators in Construction

(i) Background
(ii) Original Interview schedule
(iii) Papers and presentations
(iv) Process

(i) Background

` For more than 10 years I have been engaged in research projects concerning health and safety in the construction sector. My roles varied from PhD student to project coordinator. As a participant in that work, I was either principal author, co-author or presenter of 10 publications in peer reviewed journals and 12 presentations at professional and academic conferences. My reason for listing these specific works is to highlight the scope of my understanding of the construction sector. That work has led to this paper. Based on this broad experience I identified themes about successful innovators and welcoming settings in this sector. These themes led to this paper which summarizes occupational health successes.

(ii) Standard Innovation Interview Guidelines

Semi-structured Interview Protocol (adapted from Conklin, et al., 2011)

Thank you for agreeing to participate in this research study. Your time and effort are greatly appreciated.

General Questions about participation in the study

1. Can you tell me about your current job and role,

2. How long have you held your current position?

3. How long have you been in this line of work?

4. Can you tell me how you came to be involved in this study to disseminate tools and methods to reduce the risk of MSDs?

5. Can you tell me how you learnt about this study and the innovations that it was promoting to reduce MSDs?

Probes:

· requested to participate by CSAO/IHSA or other;

· heard about it at a presentation;

· were offered a trial period to use a tool;

· were interviewed; heard about it at a meeting; etc.

6. Did you try out any of the innovative tools or methods?

7. Have you bought any of the innovative tools or methods?

8. What were you hoping to achieve by participating in this study?

Evidence Questions

1. When looking for better ways to do your work, what type of knowledge (eg. Research evidence, best practices, etc./) is most useful?

Probe:· By being exposed to this study, what type of knowledge were you exposed to?

· Did you find the information about the tools to be trustworthy?

2. Were the tools and methods that you were shown by the Construction Safety Association (IHSA) relevant for your work?

3. Would it be enough to have a tool or process recommended by CSAO to make a decision, or would other factors be involved in your decision to adopt a new tool or method?

If there were other factors what are they?

· Costs

· Productivity

· Code changes

· Information from colleagues

4. Was it clear to you how you could use any of these tools or methods to do your work?

· Did you need to take other steps to modify these tools and methods useful for your work?

5. Did the tools and methods that you accessed through this project make sense based upon your own work experience?

6. Did you ask your workers about their perspective on the tools and methods?

· Do you consider their views and experiences when you make your decisions?

7. What was the most useful to you about participating in this study?

Probe: Was it

· The new ideas that you were exposed to, or

· what you learned through conversations, or

· the new contacts and relationships you made, or

· something else?

Facilitation Questions

1. Do you think it is possible to change the way you do your work to improve health and safety?

Probe:

· Should your co-workers change the way they do their work to improve their health and safety?

· What can management do to improve workers' health and safety?

2. Do you think that new tools or methods that can reduce the risk of MSDs, should be introduced into your workplace?

3. Were you aware of the activities of the Construction Safety Association and the University of Waterloo to promote these tools and methods to reduce the risk of MSDs?

4. What were the most important activities that you were exposed to as part of this study, that either helped to make the change happen, or that blocked the change? Are these kinds of activities typical of what happens in your company?

Context Questions

1. In your workplace, will it be difficult or easy to introduce changes in how things are done, based on the new tools and methods you accessed through the project?

2. Do you have the people, equipment, and money needed to make the changes?

3. Are the changes consistent with your company's strategic plan or values?

4. Will your co-workers and supervisors be receptive to the change?

5. What will your role be in implementing any change? Can you identify any other roles among your co-workers or others?

6. How will you know if the change has succeeded? How do you evaluate performance in your organization?

7. When an improvement or change is introduced into your workplace, are lots of different people given a chance to try out the change, or is it left in the hands of just a few people?

8. Do your superiors usually tell you what to do, or do they usually ask you what you think needs to be done?

9. Would you say that there is a great deal of open communication and conversation in your workplace?

10. Would you say that things are continuously improving in your workplace?

11. Are you and your co-workers treated as individuals in your workplace?

Readiness for Change

1. Did you feel that you had the ability to try and adopt any of the new tools or methods?

2. Do you think that the new tools and methods that you learnt about were appropriate for your organization?

3. Do you think that you had management support to try out any of the new tools or methods?

Knowledge Utilization

1. What did you learn through this process? What new skills did you develop?

2. Has participating in this process changed the way you will do your work in the future?

3. Are you aware of any changes to policies or practices that help with adopting new ideas/tools or methods?

4. Can you see a way to use the knowledge you gained in this process to improve worker health and safety in general?

THANK YOU VERY MUCH FOR YOUR TIME AND THOUGHTS.

(iii) PUBLISHED PAPERS AND PRESENTATIONS

Carlan, N., Vi, P., Yung, M., Du, B., Bigelow, P. L., & Wells, R. P. (2023). Evolving pipe joining methods and their association to musculoskeletal symptoms for residential plumbers. *Work*, (Preprint), 1-14.

Carlan, N., Szymanski, T., Van Zetten, J., Hilbrecht, M., & Bigelow, P. (2022). The Path from Survey Development to Knowledge Activism: A Case Study of the Use of a Physical Loads Survey in a Retail Workplace. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, *32*(1), 65-76.

Yazdani, Amin, Binh Ngo, Grace Schwenk, Ben Sawicki, Phil Bigelow, Jack Callaghan, Niki Carlan, Irene Lambraki, and Richard Wells. "Development and test of a short message on manual materials handling hazards and controls in small and micro businesses." *IISE Transactions on Occupational Ergonomics and Human Factors* 6, no. 1 (2018): 11-20.

Ngo, B. P., Yazdani, A., Carlan, N., & Wells, R. (2017). Lifting height as the dominant risk factor for low-back pain and loading during manual materials handling: A scoping review. *IISE Transactions on Occupational Ergonomics and Human Factors*, *5*(3-4), 158-171.

Yazdani, A., Bigelow, P., Carlan, N., Naqvi, S., Robson, L. S., Steenstra, I.,. & Wells, R. (2016). Development and evaluation of a questionnaire to document worker exposures to mechanical loading at a workplace level. *IIE Transactions on Occupational Ergonomics and Human Factors*, *4*(1), 38-53.

Carlan, N. A., Kramer, D. M., Bigelow, P., Wells, R., Garritano, E., & Vi, P. (2012). Digging into construction: social networks and their potential impact on knowledge transfer. *Work*, *42*(2), 223-232.

Kramer, D. M., Wells, R. P., Bigelow, P. L., Carlan, N. A., Cole, D. C., & Hepburn, C. G. (2010). Dancing the two-step: collaborating with intermediary organizations as research partners to help implement workplace health and safety interventions. *Work*, *36*(3), 321-332.

Kramer, D., Bigelow, P., Vi, P., Garritano, E., Carlan, N., & Wells, R. (2009). Spreading good ideas: A case study of the adoption of an innovation in the construction sector. *Applied Ergonomics*, *40*(5), 826-832.

Carlan, N. A., Kramer, D. M., Vi, P., Plawinski, M., Garritano, E., Bigelow, P. L., & Wells, R. P. IDENTIFYING INNOVATIONS TO PREVENT MSDS IN THE CONSTRUCTION SECTOR.

Presentations include:

They Adopted the Tool! Using a Framework to Evaluate a Diffusion-of-Innovations Intervention in the Construction Sector (poster presentation). Global Implementation Conference, August 2013 Washington D.C.

Working together on Innovations: Industry and Researchers. Presented at Partners In Prevention, April 2013. Toronto.

New Tools - New Issues: What do we know about crimping? Poster at Partners in Prevention Conference. April 2013 Toronto

Factors that Enhance the Adoption of New Tools: A survey to use. Poster at Partners in Prevention Conference. April 2013 Toronto.

Innovations to prevent Musculoskeletal Disorders (MSDs) in the construction sector. Presented at Partners In Prevention, April 2013 Toronto.

Researching the Construction Sector: Bridges and Barriers. Presented at Partners In Prevention, April 2013, Toronto.

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Vancouver, Symposium for CARWH Work and health research in the complex world of construction, Topics and Speakers: Evaluating KTE: applying a multi-theoretical approach; Desre Kramer; Researching and disseminating innovations in the masonry construction; Jennifer A. Hess, Researching the impact of production plumbing Dr. Philip Bigelow, Intermediaries as Facilitators of Research in Non-standard Workplaces; Peter Vi; Women's health in apprenticeship trades: metal workers and electricians; Nicola Cherry. August 2012,

A Multidisciplinary Team Using Multiple Methods Qualitatives 2011, Brantford

Marching to a different drummer: knowledge dissemination in the construction sector in Ontario Paper presented to Association of Canadian Ergonomists Annual Conference, British Columbia 2010.

Adapting a knowledge transfer framework from health care to the construction sector presented to Canadian Association for Research on Work and Health. 2010 Toronto,

Knowledge transfer in the changing world of work presented to Qualitatives 2010, Brantford

Spreading New Ideas in the Construction Sector. Paper presented to Association of Canadian Ergonomists Annual Conference, 2007: Toronto.

A pilot study investigating manual material handling of ladders from construction service vans. In *Proceedings of the Association of Canadian Ergonomists. 38th Annual Conference, Toronto, Canada*.

(iv) PROCESS

This research paper is a summary of work with independent operators, construction companies varying in size from 2 to 1,000 employees and health and safety organizations. The foundational work for this analysis was a multiyear project as set out below.

There were three phases to the original programme. In Phase I, health and safety specialists at a labour management meeting of refrigeration/air-conditioning specialists identified an innovation for their subsector — a hydraulic ladder-lift. The lift allowed a ladder to be moved onto the roof of a vehicle without requiring the operator to climb on to the truck and lift the ladder. The participants identified 33 managers as opinion leaders and they were asked to try the ladder-lift at no cost to their companies. Thirteen managers agreed to participate and they were followed to determine the effectiveness of the innovation. Workers/operators who used the tools were also interviewed briefly.

During Phase II, the team selected 20 innovations that they expected would reduce MSDs. Innovations were introduced by sharing tools, circulating fact sheets, and conducting focus groups with company health and safety committees. Interviews focused on the characteristics of companies that introduced innovations including .corporate structure (private /public ownership), unionization, the status of workers (permanent/contingent), and barriers and facilitators influencing the adoption of the innovations.

In Phase III and IV studies were focused on the use of new tools I the plumbing trade and MSDs in the retail sector.

The original interviews were semi-structured and addressed the methods of introducing innovations and the characteristics of innovations. In total, I conducted 102 formal interviews.

The interviews were conducted by phone, tape-recorded, and generated transcripts that were from 10 to 28 pages in length. In addition, multiple informal discussions were held during worksite visits. The qualitative data also included the results of focus groups with employers and workers during the preparation of the research proposals.

Following completion of Phase III, an additional examination of the interview transcripts revealed unexpected patterns. Specifically, there was significant information about the employers' histories, organizational structures, decision-making practices, and participants' personal and work backgrounds. This data seemed to warrant further exploration.

Based on the literature and the findings of this research I selected 11 innovations which had been implemented and had the potential for success. The companies ranged from small owner-operator to large construction firms with several hundred employees. The innovations also represented a variety of trades including bricklaying, paving and floor installation.

Because this research relied on secondary analysis there were no new interview schedules produced. The themes were compiled on previous analysis or the multiple presentations on the innovation process.