# WORK-RELATED EXPOSURES AND INJURIES AMONG THE AGING UNITED STATES WORKFORCE

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# ABSTRACT

**Introduction:** Work-related hazards may compromise the health and safety of workers, especially that of aging workers. An employee's health and safety behaviors in the workplace are a result of interplay among physical and psychosocial work characteristics. Injuries are likely to occur in conditions where there is a mismatch between the capabilities of the employee and the work requirements. Limited longitudinal research efforts have specifically focused on the injury experiences, and their consequences among the aging workforce.

**Methods:** This longitudinal study, conducted among a cohort of United States (U.S.) adults aged 50 years and above, enabled: i) investigation of the associations between work-related physical factors and injuries; ii) comparison of the injured and uninjured workers for any new functional limitations, and reduced working hours post injury; iii) analyses of associations between psychosocial work factors and injuries; iv) comparison of two common approaches for analyzing longitudinal data with injuries as an outcome. The cohort to conduct these analyses was obtained from the Health and Retirement Study (HRS), a biennial nationally representative panel study of U.S. adults. The HRS respondents who were working for pay in the year 2004 (n = 7,212) formed the cohort for analyses investigating the associations between physical work requirements and injuries, and the consequences of such injuries. The cohort to investigate the association between psychosocial work factors and injuries included 3,305 working adults who responded to the HRS's psychosocial and lifestyle questionnaire in the years 2006 and 2010. Each of these cohorts were followed until 2014. Crude and adjusted incident rate ratios, and hazard ratios were obtained from generalized estimating equations (GEEs) and marginal structural models (MSMs), and Cox Hazard models. Variables included as confounders were demographic, health-related variables, and other work characteristics.

**Results:** Those whose jobs required excessive physical effort, lifting heavy loads, and stooping/kneeling/crouching all/almost all the time, compared to none/almost none of the time, had over twice as high the risk of experiencing injuries. The MSMs (IRR: 2.62, 95% CI: 2.14, 3.20) provided an estimate higher than the GEEs (2.09, 1.67, 2.62). Injured, compared to uninjured adults, had a higher risk for having a functional limitation and reduced working hours post injury. Finally, important gender-based differences were identified when the modeled exposures included combinations of two psychosocial factors.

**Conclusions:** Several physical and psychosocial factors elevated the injury risks among the aging workforce. It is therefore important to holistically investigate all exposures that may affect the risks for injuries in this population.

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# ORGANIZATION

The organization of this thesis provides initial chapters including an introduction, a comprehensive literature review, and presentation of the research design and methods. These chapters are followed by three major papers (Chapters IV, V, and VI) that report the major findings from the study; because these papers are prepared for publication in peer-reviewed journals, there is some redundancy pertinent to the literature cited and the methods presented. A final chapter provides a discussion of study validity and the results of the study.

# CHAPTER I - INTRODUCTION

Injuries are the consequences of acute exposures to energy. This energy that exists in amounts that exceed the threshold of physiological tolerance can be in the form of mechanical, thermal, electrical, chemical, or radiation. In addition, an injury may also result from a vital element deficiency that might occur from drowning, strangulation, freezing, etc. (Haddon, 1989, Baker et al., 1984). Injuries had traditionally been perceived as random, unavoidable “accidents.” However, within the last few decades, through improved knowledge and understanding, both unintentional and intentional injuries are recognized as largely preventable events. As a result, decision-makers worldwide have started focusing on injuries and their health implications and injury policy has been firmly placed in the public health arena. The World Health Organization (WHO) categorizes injuries as self-inflicted or caused by road traffic events, disasters, interpersonal violence, drowning, fires, wars, poisonings, and falls (WHO, 2012). From the 2013 Global Burden of Disease Study, it was reported that 973 million people sustained injuries that warranted some type of healthcare while 4.8 million people died from them (Haagsma et al., 2016). These alarming statistics demonstrated that injuries are still an important public health problem.

As defined by the Occupational Safety and Health Administration, an injury or illness is considered to be *work-related* if an event or exposure in the work environment either caused or contributed to the resulting condition or significantly aggravated a pre-existing condition (Bureau of Labor Statistics (BLS)-Occupational Safety and Health definitions). In the year 2007, over 8.5 million non-fatal and 5,600 fatal work-related injuries, and 400,000 non-fatal and 53,000 fatal work-related illnesses occurred in the United States (U.S.). These involved estimated direct and indirect costs of about $250 billion, identifying them as an important public health concern. This is second only to medical and indirect costs for cardiovascular diseases. Of the total cost, two-thirds was attributed to work-related injuries and the rest to work-related illnesses (Leigh, 2011).

More recently, in 2015, the BLS identified 2.9 million nonfatal work-related injuries and illnesses (95.2% were injuries) that were reported by private industry employers in the U.S., accounting for a rate of 3.0 cases per 100 equivalent full-time workers. Next, a total of 752,600 injury and illness cases were reported among the approximately 18.4 million state and local government workers in the same year resulting in a rate of 5.1 cases per 100 full-time workers (BLS, Economic News Release). In the same year, the overall incidence rate of nonfatal occupational injury and illness cases requiring days away from work was 104.0 cases per 10,000 full-time workers. There were a total of 1,153,490 days-away-from-work cases in private industry, state government, and local government and the median days away from work was eight days. As far as age group-specific statistics are concerned, workers in the age group 45-54 for all ownerships had the highest number of days away-from work cases i.e., 280,100 days which resulted in a rate of 112.8 cases per 10,000 full-time workers. However, workers in the age group 55-64 years, had the highest incidence rate with 115.8 cases per 10,000 full-time workers (BLS, 2016). Additionally, the BLS has reported that fatal injury rates were lower among younger workers (2.3 per 100,000 FTE workers for those aged 25 to 34 years) and higher among older workers (9.4 per 100,000 FTE workers for those aged 65 years and older) (BLS, 2016). It is now recognized that one of the major challenges with which the injury prevention and workers' compensation communities are faced, is the aging workforce.

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# CHAPTER II - LITERATURE REVIEW

## DATA ON THE PROBLEM – AN OVERVIEW

### The aging United States workforce

Work and hazards related to work, that may result in work-related injuries, compromise the health and safety of the workers (Schulte, 2012). In the U.S. work-related injuries and illnesses, combined, have been estimated to cost $250 billion (Leigh, 2011). Several factors play an important role in affecting the overall health and safety of a worker, including age. Age, specifically, influences a worker's susceptibility or resistance to various hazards to which they are exposed in the workplace (Schulte, 2012). With the overall U.S. population aging, the proportion of the aging working population is increasing and, by the year 2020, workers aged 55 years and above will comprise 25% of the workforce (Hayutin et al., 2013). It is known that an employee's health and safety behaviors in the workplace are a result of interplay among physical, and psychosocial work environments (Sorensen et al., 2011), and that injuries are likely to occur in conditions where there is a mismatch between the capabilities of the employee and such work requirements (Silverstein, 2008). However, research pertaining to the potential associations between a spectrum of physical and psychosocial work-related factors and injury experiences of aging workers remains limited. The sections ahead focus on discussing why research efforts must be specifically targeted towards aging workers.

### Work-related injuries among the aging workforce

Although workers aged 55 years and above experience lower rates of non-fatal work-related injuries, compared to their younger counterparts, the impact of such injuries is greater, resulting in more severe outcomes, in terms of health-related and work-related consequences (Grandjean et al., 2006; Silverstein, 2008). Such injuries resulted in over 1.1 million days-away-from-work cases in the year 2015 among the U.S. private industry, state government, and local government. Additionally, workers, aged 55-64 years compared to all others, had the highest incidence rate of days-away-from-work (115.8 cases per 10,000 full-time workers) (BLS-Nonfatal Occupational Injuries and Illnesses Requiring Days Away From Work, 2016). Table 1 shows BLS data for the incidence rate of and median days away from work for nonfatal injuries from 2013-2015. The table compares the rates between those 55-64 years of age and other younger age groups. In the same year, those aged 65 years and above had a fatal injury rate four times that of workers in the age group of 25 to 34 years (BLS-Census of Fatal Occupational Injuries, 2016).

The sections ahead focus on physical and psychosocial work-related factors that may have a potential causal association with injuries among aging workers.

## OVERVIEW OF THE STUDIES TO DATE

### Physical work-requirement factors and work-related injuries

Work-related physical demands that do not match an employee's abilities constrain an employee's progress toward working safely and, hence, may pose a risk for injuries (Hollander, 2010, Nahrgang et al., 2011). Table 2 presents a detailed summary of the existing research efforts investigating the association between physical work-requirement factors and injuries. Among the U.S. adults aged 50 years and older, about 44% have a job that requires physical effort almost all or most of the time, and another 25% are employed in positions that require physical effort at least some of the time (Benz et al., 2013). There is evidence that physical work requirements like heavy physical work, lifting and forceful movements, bending and twisting, whole-body vibration, and static work postures are associated with back injuries. Further, repetition, force, and posture have been found to be associated with neck and neck/shoulder injuries (Bernard, 1997).

**Data gaps:** Previous researchers have conducted studies to investigate the association between physical work-requirement factors and certain specific occupational groups (Table 2). The majority of previous research efforts targeted towards work-related requirements and injuries have involved cross-sectional study designs, from which causal associations related to temporality cannot be assured (Mann, 2003). Literature specifically focused on the aging workforce is especially lacking.

**Work-related psychosocial factors and work-related injuries**

An imbalance between such demands and resources may increase an individual’s risk for injuries or illnesses (Landsbergis, 2003, Sauter et al., 1999). The relation between stressors and health outcomes is affected not only by the stressors but also by individual characteristics. While stress responses in young, healthy individuals may be adaptive and not impose a health risk, if it is unremitting particularly in older or unhealthy individuals, it may affect health over the long-term. Combinations of multiple stressors that may act together may be more potent than single stressors (Schneiderman et al., 2005)

Karasek’s work strain model (Karasek, 1979) (Figure 1) suggests that work-related strain results from the interaction between the perceived task-level psychological and physical demands at work and work decision latitude or control. This strain may be associated with several adverse health and safety outcomes. Another model i.e., the work-based effort-reward imbalance (Figure 2) does not consider work control-related domains like the work strain model (Siegrist, 1996, Ostry et al., 2003), but it overlaps with the latter model in terms of extrinsic task-level demands. The effort-reward imbalance model, however, considers intrinsic personality characteristics which may influence the perceived stressors and resultant hazards. Over-commitment to work, a personality trait considered in this model, may also lead to work-family conflict and play an important role in shaping an employee's safety and health outcomes (Figure 3). Further details on each of the specific work-related psychosocial factors and their potential associations with work-related injuries has been provided in Table 3.

**Data gaps:** Much of the presented evidence, even though limited, comes from cross-sectional studies, primarily focused on small, selected populations (Vermeulen and Mustard, 2000, Nakata et al., 2006, Kim et al., 2009, Cantley et al., 2015, Lee et al., 2015). Additionally, many previous studies have focused only on specific, rather than all categories of potentially stressful work-related factors. Research efforts are needed to provide a holistic understanding of how various work-related psychosocial factors and their interactions influence work-related injury experiences, especially among the aging workforce.

**Consequences of work-related injuries: Comparing the injured and uninjured workforce**

Work-related injuries and illnesses result in a variety of physical and social (personal and work life-related) consequences via complex and multi-factorial relations (Dembe, 2001). This is evident from previous research efforts which have suggested that injured workers experience symptoms severe enough to interfere with work, home/recreation activities, and sleep (Keogh, 2000). Injured workers also appeared to be more likely to leave their jobs (Brewer, 2012).

**Data gaps:** Empirical research into the social consequences of work-related injuries and illnesses appeared to be limited. Most of the available research findings have included functional and vocational status, satisfaction, and worker experiences with the workers' compensation and medical care systems (Dembe, 2001). Further, most studies have focused on either a particular type of injury, used cross-sectional study designs and descriptive analysis, and / or were limited to a particular state, geographically, thus limiting the generalizability of the findings. While there are some studies that have compared the health and disability and work status-related consequences of injuries between aging and younger workers (Pransky et al., 2005; Algarni et al., 2015), research efforts that have compared disability and work status change-related outcomes between injured and uninjured persons are under-researched.

### Other contributing factors

It has also been documented that certain demographic, health-related and, other work-related characteristics may confound the associations between physical work-related factors and injuries (Ghosh et al., 2004, Baron et al., 2013). It is also important to understand how socio-demographic characteristics like gender, race, ethnicity, age, and health-related factors may play a role in the relation between psychosocial work-related factors and injuries (Vermeulen et al., 2000, Landsbergis, 2003, Rugulies et al., 205, Schneiderman et al., 2005, Rugulies et al., 2007).

### Comparing two analytical approaches: Marginal structural models versus traditional repeated-measures regression models

Answering a question, for example, whether a particular exposure is causally-related to an outcome is often difficult to answer due to the presence of confounders and other factors that might be related both to the exposure and outcome under consideration. Randomized controlled trials, which are one of the best ways to ensure that treatment assignment is independent of other covariates, are not always feasible.

With observational studies, where treatment assignment may be dependent on factors that also influence the outcome, it is important to adjust for such factors (confounders). Conditional and Marginal approaches can be used to adjust for confounding that may exist in an observational study. A marginal approach works by creating weights which balance each substratum of covariates; predictions are, then, made on this weighted sample (Crowson et al., 2013).

In the presence of time-varying exposures, standard methods that model the probability of the outcome conditioned on past exposures and confounder history (e.g., generalized estimating equations) may provide biased effect estimates. This is especially the case when there is a time-dependent exposure that not only predicts future exposure and other contributing factors, but is also a predictor of the outcome of interest itself (Robins et al., 2000, Hernan et al., 2000, VanderWeele, 2011).

**Data gaps:** Very limited research efforts have used marginal structural models to analyze injuries. In fact, most of the existing research is limited to chronic diseases/outcomes. Injuries, however, are different as they can be recurrent and prior injuries may be risk factors for future injuries.

Major data gaps exist in research efforts pertaining to holistic analyses of both the physical and psychosocial factors that are associated with injuries, especially among the aging workforce. Additionally, many existing studies are cross-sectional; hence, causal inferences cannot be made from them. The purpose of this research is to fill in the stated gaps by conducting longitudinal analyses focused on analyzing the associations between work-related factors and injuries among workers aged 50 years and above and additionally compares two longitudinal analysis techniques.

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**Table 1: Incidence rates for nonfatal work-related injuries and illnesses requiring days away from work per 10,000 full-time workers, 2013-2015, Bureau of Labor Statistics**

| | **All age groups combined** | | **55-64 year old** | |
|---|---|---|---|---|
| **Year** | Incidence Rate per 10,000 Full-time workers | Median Days away from Work | Incidence Rate per 10,000 Full-time workers | Median Days away from Work |
| 2013 | 109.4 | 8 | 114.5 | 13 |
| 2014 | 107.1 | 9 | 116.3 | 14 |
| 2015 | 104.0 | 8 | 115.8 | 13 |

**Table 2: Summary of Literature for work-related injuries among aging workers: Work-requirement factors and injuries and consequences of such injuries**

| Author(s) | Year | Purpose of Study | Population | Methods | Findings and Conclusions, and Critique |
|---|---|---|---|---|---|
| Algarni FS, Gross DP, Senthilselvan A, et al. | 2015 | To compare younger and middle-aged working adults (25-54 years), adults nearing retirement (55-64 years) and adults past typical retirement (≥65 years), who sustained work-related musculoskeletal injuries. | Alberta workers' compensation claimants with musculoskeletal injuries | Cross-sectional study with descriptive statistics on a range of demographic, employment, injury and clinical characteristics obtained from a large, population-based database. | Older injured workers (aged 55 years and above) were more likely to experience serious injuries. Such workers may need accommodations at their jobs but employers may not be able to provide these. Older workers also appear to have disadvantages with respect to vocational rehabilitation perspective as they were less likely to be offered such services, despite having more severe injuries.<br><br>Critique: This was a cross-sectional study; therefore, causal conclusions based on temporality cannot be made. Further the work-related injury claims accepted by a workers' compensation board may not represent all older workers. |

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| Bernard BP ed. | 1997 | To examine the epidemiologic evidence of the relation between selected musculoskeletal disorders (MSDs) of the upper extremity and the low back and exposure to physical factors at work | U.S. workforce | Review of literature for physical work factors and the development of MSD's. This review also included psychosocial factors as the exposures of interest because prognosis of a particular disorder may be modified by psychosocial factors. A search strategy of bibliographic databases identified more than 2,000 studies. Finally, over 600 studies were included in the detailed review process. | This critical review of the epidemiologic literature identified a number of specific physical exposures strongly associated with specific MSDs. A substantial body of research provides strong evidence of an association between certain work-related physical factors when there are high levels of exposures (e.g., repetitive lifting of heavy objects in extreme or awkward postures) and MSDs.<br><br>Critique: There is limited detailed quantitative information about exposure-disorder relations between risk factors and MSDs. There is also little evidence as to how individual factors may be associated with physical factors and influence the outcome. |
| Brewer C, Kovner C, Greene W, et al. | 2012 | To identify factors that affect turnover of newly licensed registered nurses in U.S. hospitals | A nationally representative sample of 1,653 registered nurses in the U.S. who | This study used a longitudinal panel design and mailed surveys to a nationally representative sample of hospital registered nurses, one | Full-time employment and more frequent sprains and strains (including back injuries) resulted in more turnover. Multiple points of intervention |

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| | | | were recently licensed by examination for the first time | year apart. Descriptive statistics and binomial probit regression were used to estimate the turnover incidence and analyze the data. | exist. One specific approach that may improve turnover rates is hospital policies that reduce injuries.<br><br>Critique: Those who work in non- hospital settings may have different causes of turnover. Research to identify precursors of turnover that are not avoidable may help to refine turnover models for this work group. |
| Dembe AE | 2001 | To conduct a literature review on social consequences of occupational injuries and illnesses and develop a conceptual framework | U.S. workforce represented by the review articles | This study provided a conceptual framework for identifying and analyzing the 'hidden' social consequences of injuries and illnesses. The author reviewed studies that had been performed in this area, and proposed a research agenda to guide future efforts to understand the social consequences of occupational injuries and illnesses. | Complex and multifactorial relations were described by which occupational injuries and illnesses produce a variety of social consequences.<br><br>Critique: Empirical research into the social consequences of work-related injuries and illnesses appeared to be limited. Most of the available research discussed functional and vocational status, satisfaction, and worker experiences with the workers' compensation and medical care systems. |

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| Gardner LI, Landsittel DP, Nelson NA. | 1999 | To examine the associations of job-related lifting and material handling, with the incidence of work-related back injuries and to examine the evidence for acute versus chronic causal models for back injuries in this population | A cohort of 31,076 material handlers from 260 U.S. merchandise stores of a single company | This dynamic historical cohort was obtained from the company's 260 stores located in Vermont, Rhode Island, Massachusetts, Michigan, North Carolina, Kentucky, Delaware, New Jersey, and Pennsylvania. Analyses involved calculating rates of injuries. | Workers in jobs with the greatest physical work requirements had an injury rate of 3.64 per 100 person-years versus 1.82 in workers with lesser work requirements. Workers with the greatest physical work requirements and those with the shortest duration of employment were at the highest risk of back injuries.<br><br>Critique: This study investigated a specific occupation, the injury experiences of which may be different from other occupations. It is important to consider the varied exposures among different occupations and industries. |
| Ghosh AK, Bhattacherje A, Chau N. | 2004 | To assess the relation between demographic, and work-related characteristics and injuries among coal mine workers | 2,900 male coal mine workers working in underground mines in eastern India | Data for this case-control study were obtained between the years 1996-2000, with the study sample chosen randomly. A questionnaire was developed to achieve the study goals. Cronbach's alpha | Older age (>45 years vs <30 years, OR: 2.59; 1.38, 4.85), poor perception of working conditions and work-related stress played significant roles in affecting the workers' injury occurrences. |

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| | | | | was used to test inter-rater reliability. Adjusted odds ratios were used to provide the study estimates. Fatal and serious injuries were excluded from the analyses. | Critique: This is also a study that is limited to a particular high risk work group, the injury-related experiences of which may be different from other work groups. |
| Grandjean C K, McMullen PC, Miller KP, et al. | 2006 | To identify the variables related to traumatic injuries of older workers | U.S. workers aged 50 years and above | This study was a retrospective review of occupational injuries and associated factors in workers ≥ 50 years presenting for care between 1998 and 2003 at a mid-Atlantic regional trauma center. Descriptive statistics were used to summarize sample and variable characteristics. | The results of this case-based study showed that older workers had higher fatality rates than younger workers. As age increased, the Injury Severity Score also increased.<br><br>Critique: Data on severe traumatic injuries among workers in the U.S. that do not result in death, is sparse. Identification of characteristics associated with older workers' severe occupational injuries can help development of target-based interventions. |
| Hollander IE, Bell NS | 2010 | To analyze the potential association between working in physically demanding army | 305,708 U.S. army soldiers in the most populated (largest) 15 heavily, 15 moderately, and | Data were obtained from the Total Army Injury and Health Outcomes Database. This dataset links individual soldiers' records from DoD administrative and health data | Controlling for gender, race, and age, soldiers in heavily demanding jobs were at increased risk for any-cause injury, on-duty injuries, any-cause hospitalizations, and |

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| | | jobs and risk of serious health outcome (hospitalization or disability) | 15 lightly physically demanding occupations | sources and included soldier's personnel records, inpatient hospitalizations, and disability discharges. Hazard ratios were calculated using Cox models. | any-cause disability, but not for musculoskeletal disability. Additionally, although musculoskeletal disorders are often the result of acute injury, the demographic and occupational risk patterns differ from acute injury. Therefore, job assignments should more accurately match physical capabilities to job demands and/or jobs should be redesigned to reduce injuries.<br><br>Critique: Not all army jobs were coded and the study could only capture 64% of the enlisted army population. The injury-related experiences of those not included could be different from those in the study cohort. |
| Leigh J | 2011 | To provide estimates of the national costs of occupational injury and illness among civilians in the U.S. for 2007 | Fatal and nonfatal injury statistics from national databases | Injury, disease, employment, and inflation data were obtained from the U.S. BLS and the Centers for Disease Control and Prevention (CDC). Cost data were obtained from the National Council on | The numbers of fatal and nonfatal injuries in 2007 were more than 5,600 and 8,559,000, respectively, at costs of $6 billion and $186 billion. The numbers of fatal and nonfatal illnesses were |

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| | | | | Compensation Insurance, the Healthcare Cost and Utilization Project, and the National Academy of Social Insurance, and estimates of Attributable Fractions (AF) of diseases with occupational components, and national estimates for all health care costs provided in the literature. Total costs were calculated by multiplying the number of cases by the average cost per case. | more than 53,000 and nearly 427,000, respectively, with cost estimates of $46 billion and $12 billion. The total estimated costs were approximately $250 billion. Injuries, therefore, pose an important public health problem that has a major cost burden |
| Zwerling C, Sprince NL, Wallace RB, et al. | 1996 | To identify the potential risk factors for occupational injuries among older workers | 7,089 workers aged 50 years and above who responded to the first HRS survey | Cross-sectional analyses of factors associated with injuries were conducted and odds ratios were provided. | This cross-sectional study showed that among the aging workforce that jobs with i) excessive physical work requirements, ii) lifting heavy loads, iii) stooping/kneeling/crouching had risks for injuries, twice those who had no such requirements (respective ORs and CIs: i) 2.45; 1.89, 3.18; ii) 3.40; 2.55, 4.53; iii) 2.23; 1.76, 2.83).<br><br>Critique: There is still little known about the risk factors for occupational injuries |

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| | | | | | among older workers. The results presented in the study are based on a cross-sectional analysis and causal interpretations cannot be made. |

**Table 3: Summary of Literature for work-related injuries among aging workers: Work-requirement factors and injuries and consequences of such injuries**

| Author(s) | Year | Purpose of Study | Population | Methods | Findings and Conclusions, and Critique |
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| Cantley LF, Tessier-Sherman B, Slade MD, et al. | 2015 | To examine associations between work-related injuries and musculoskeletal disorder risk, given expert ratings of job-level psychosocial demands and job control, adjusting for job-level physical demand | Nine thousand two hundred and sixty production and maintenance workers at eight aluminum manufacturing plants | Expert ratings of job-level physical and psychological demand and control measures were obtained for two years among the study cohort. Multivariate mixed effects models were used to estimate relative risks. | Compared with workers in jobs rated as having low psychological demands, workers in jobs with high psychological demands had 49% greater risk of serious injuries and serious musculoskeletal disorders. Workers in jobs rated as having low control displayed increased risk for minor injuries and minor musculoskeletal disorders (RR=1.45; 95% CI 1.12 to 1.87) compared with those in jobs rated as having high control.<br><br>Critique: This research effort was again limited to a particular occupational group. Additionally, the authors limited their analyses to a certain types of psychosocial |

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| | | | | | stressors, pertaining to job demands, and control. |
| Clougherty JE, Souza K, Cullen MR | 2010 | To facilitate understanding of the potential causal role of the job in determining health outcomes | 15,000 aluminum manufacturing employees across eight U.S. states and review from other studies | Cohort study of aluminum manufacturing employees comparing health outcomes by job status<br><br>Review of existing research focusing on six major areas i.e., role of work status, psychosocial job stressors, workplace physical and chemical hazard exposures, work organization matters, gradient of new forms of nonstandard or "precarious" employment such as contract and shift work, and emerging evidence that women may be impacted differently | Cohort study results: Elevated hypertension risks among blue-collar employees, relative to white-collar; exposures to physical and chemical hazards were negligible among the better-educated salaried workforce.<br><br>Review: There is broad evidence linking psychosocial work characteristics to cardiovascular risk. An estimated 60% or more living U.S. adults are substantially exposed to hazardous physical, chemical or biologic hazards for some period of time during their working careers. The most salient hazards in the workplace are trauma and bodily injury. As more and more workers engage in nontraditional work hours, concern for the health consequences associated with work-shifts have intensified, with cardiovascular disease |

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| | | | | | and its antecedents being of greatest concern.<br><br>Critique: The context of the workplace has been increasingly revealed to be an important predictor of health. It is therefore important to investigate many different occupations as the workforce dynamics may change accordingly. |
| Fischer FM, Oliveira DC, Nagai R, et al. | 2005 | To evaluate physical and psychological dimensions of adolescent labor (such as job demands, job control, and social support in the work environment), and their relation to reported body pain, work injuries, sleep duration and daily working hours | Three hundred and fifty-four adolescents attending evening classes at a public school in São Paulo, Brazil | Psychosocial information was obtained using the Job Content Questionnaire. In addition, information regarding health status was obtained. Data collection took place in April and May 2001. Multiple logistic regression analysis was used to determine relations among variables. | Psychological job demands were related to body pain (OR=3.3), higher risk of work injuries (OR=3.0) and reduced sleep duration in weekdays (Monday to Thursday) ($p<0.01$).<br><br>Critique: The study indicates that, besides physical stressors, psychological factors must be considered as they may be associated with negative job conditions and health effects. Causal assumptions cannot be made from this effort as the study was cross-sectional in nature. |

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| Hämmig O, Brauchli R, Bauer GF | 2012 | To investigate the associations of effort-reward imbalance and work-life imbalance with general stress and burnout | The study was based on survey data collected in 2007 among the personnel of a large public hospital in the canton of Zurich, covering a random sample of 502 employees of all professions and positions. | Prevalence rates, correlation coefficients, standardized regression coefficients and odds ratios were calculated as measures of association. | Work-life imbalance was found to be more strongly associated with general stress and burnout than effort-reward imbalance. General stress plays a (rather minor) mediating role in the relations between effort-reward imbalance and burnout and, particularly, between work-life imbalance and burnout.<br><br>Critique: This analysis was also limited to certain psychosocial exposures. Additionally, a spectrum of occupations was not considered. Illness and injury experiences may differ by different occupations, and findings from one occupational category may not be generalizable to all others. |
| Hayutin A, Beals M, Borges E | 2013 | To examine the current demographic trends and explain what these mean for employers, workers, and policy makers | Data from U.S. national surveys | The report is focused on seven key issues that have important implications for adapting to an aging workforce including, population age shifts, labor force shifts, industry and occupation age structures, | Three key dimensions characterize the coming population shifts in the U.S.: continued growth, increased diversity, and aging of the population. Specifically, the population of mature workers, age 45-64, has grown rapidly |

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| | | To provide a big picture framework for understanding the labor force challenges and opportunities that are emerging from ongoing demographic shifts | | issues and implications related to job tenure and employment, age-related work preferences, compensation, and job types. | over the last 20 years. By 2020, older workers aged 55 years and above will account for 25% of the U.S. labor force.<br><br>Critique: The U.S. population is aging and at risk for injuries. It is important to explore various psychosocial factors, and not just physical work-requirement factors that may compromise the health and safety of this vulnerable work group. |
| Karasek Jr RA | 1979 | To develop and test a stress-management model of job strain | National stratified sample of housing units in the U.S. and random sample of the full adult Swedish population | Data from two national surveys from the U.S. and Sweden were used to test the model. | The job strain model predicts that mental strain results from the interaction of job demands and job decision latitude. The model clarifies contradictory findings based on separated effects of job demands and job decision latitude.<br><br>Critique: The consistent finding is that it is the combination of low decision latitude and heavy job demands which is associated with mental strain. This work-related strain is one of the important psychosocial factors that may compromise |

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| | | | | | the health and safety of the workers. However, there could be other factors too, and strain may be just one of them. It is important to explore all the potential psychosocial factors that employees may be exposed to. |
| Lee SJ, You D, Gillen M, et al. | 2015 | To examine the relations between psychosocial work factors and new or recurrent injury among hospital workers | A total of 492 hospital workers from two hospitals in the San Francisco Bay Area | Job strain, total support, effort-reward imbalance, over-commitment, and musculoskeletal injury at baseline were examined in logistic regression models as predictors of new or recurrent injury experienced during a two-year follow-up period. | The overall cumulative incidence of injury over follow-up was 35.6% (51.7 % for re-injury among baseline injury cases; 30.6 % for new injury among referents). Significantly increased risks with baseline job strain (OR 1.26; 95% CI 1.02-1.55) and effort-reward imbalance (OR 1.42; 95% CI 1.12-1.81) were observed for injury, only among the referents. Over-commitment was associated with increased risk of injury only among the cases (OR 1.58; 95% CI 1.05-2.39). The effects of various psychosocial work factors on new or recurrent injury risk appear to differ by previous injury experience. |

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| | | | | | Critique: This study analyzed the association between several work-related psychosocial factors and injuries while considering other confounding variables. However, the analyses were still limited to one particular occupation. |
| Nakata A, Ikeda T, Takahashi M, et al. | 2006 | To examine the association between psychoso cial job stress and occupat ional injuries among workers in small and medium-sized enterprises. | 1,049 men and 721 women from 244 enterprises that were small and medium sized | Perceived job stress was evaluated with the Japanese version of the generic job stress questionn aire, which covered 14 job stress variables. Occupational injury was assessed by self-report during the last one-year period. | Workers with high quantitative workload (odds ratio [OR] = 1.55 for men, 1.62 for women), high cognitive demands (OR = 1.70 for men, 1.53 for women), and low job satisfaction (OR = 1.33 for men, 1.93 for women) had significantly increased risks of occupational injury.<br><br>Critique: There is an independent relation between psychosocial job stres s and self-reported occupational injury in small and medium-sized enterprises. However, it is important to explore all occupations ranging from small to large to get a complete picture of the issue. |

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| Kim HC, Min JY, Min KB, et al. | 2009 | To investigate if job strain had an effect on the risk of occupational injury of workers in small- to medium-sized manufacturing companies | 1,209 workers in South Korea were included in this study | At baseline, job stress was measured using the Job Demand and Decision Latitude Questionnaire. After six months, work-related injuries were assessed. Logistic regression models were used to show the study findings. | For men, the high job-demand group (OR = 1.71, 95% CI = 1.13–2.59) and high strain group (OR = 1.79, 95% CI = 1.02–3.14) showed increased risk of occupational injury. For women, high job-demand (OR = 2.11, 95% CI = 1.18–3.78), low job control (OR = 1.80, 95% CI = 1.02–3.17), and high job strain (OR = 3.57, 95% CI = 1.62–7.86) were significantly associated with occupational injury.<br><br>Critique: The present analyses were limited to manufacturing industry, and were cross-sectional in nature. Additionally, job-related strain was the only psychosocial exposure considered. |
| Krisor SM, Rowold J | 2013 | To identify the impact of variables from the classic mental health model within the | Three different samples were used: 358 employees from a travel company; 113 from a care | All study participants received a self-report questionnaire. Effort, reward, and effort-reward imbalance, and over-commitment were | Over-commitment is related with work-family conflict. Work-family variables should be included in general models of mental health in work psychology. Management |

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| | | context of work-family conflict<br><br>To identify he relevance of work-family conflict for work promotion | facility; and 63 from a psychiatric facility | measured using the effort-reward imbalance questionnaire. A six-item questionnaire measured work-family conflict. Analyses involved using structural equation modeling. | should highlight the importance of workplace health promotion and work-life balance.<br><br><u>Critique:</u> This study reflects that it is not only important to consider work-related psychosocial factors but also the potential spill-over between work and family that may compromise the health and safety of the employees at work. The authors did look at three different occupational groups, however, the sample size was somewhat limited. |
| Rugulies R, Krause N | 2005 | To investigate if exposure to an adverse psychosocial work environment increases the risk of neck and low back injuries | A cohort of 1974 transit vehicle operators employed by the San Francisco Municipal Railway | Five different data sources were used to accomplish the study goals. The outcomes of the study were the first incidence of low back injury and the first incidence of neck injury during 7.5-years of follow-up. Psychosocial workplace factors were measured with the Job Content Questionnaire. Injury information was obtained | For low back injuries, increased hazard rates were found for job strain and iso-strain based on tertiles, with hazard ratios (HR) of 1.30 (95% CI=0.96–1.75) and 1.41 (95% CI=0.98–2.01), respectively. For neck injuries, job strain and iso-strain based on median split showed HRs of 1.27 (95% CI=0.99–1.63) and 1.33 (95% CI=1.01–1.77), respectively. |

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| | | | | from administrative datasets. | Critique: This study shows the importance of the psychosocial work environment in the etiology of musculoskeletal injuries among transit operators. However, this research effort like many previous ones was also limited to a particular work group and hence the findings cannot be generalized to other work groups. |
| Rugulies R, Krause N | 2007 | To examine if effort-reward imbalance predicts incidence of doctor-diagnosed low back and neck injuries | A cohort study of 1974 transit vehicle operators employed by the San Francisco Municipal Railway | Five different data sources were used to accomplish the study goals. The outcomes of the study were the first incidence of low back injury and the first incidence of neck injury during 7.5-years of follow-up. Psychosocial workplace factors were measured with the Job Content Questionnaire. Injury information was obtained from administrative datasets. | The highest quartile of effort-reward imbalance showed an HR of 1.32 (95% CI 0.94 to 1.86) for low back injuries and an HR of 1.66 (95% CI 1.16 to 2.38) for neck injuries after adjustment for all covariates.<br><br>Critique: This longitudinal research effort considered effort-reward imbalance as the only work-related psychosocial exposure of interest while there may be others that influenced the association. Next, the analyses were only limited to a particular occupational group i.e., transit drivers. |

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| Sauter S, Murphy L, Colligan M, et al. | 1999 | To provide necessary knowledge to understand, and reduce stress in the workplace | U.S. workforce: NIOSH publication | Review of existing research | One-fourth of employees view their jobs as the number one stressor in their lives. Problems at work are more strongly associated with health complaints than are any other life stressor.<br><br>Prevention of stress as work requires a comprehensive approach that combines stress management with needed organizational change such as making sure that the workload is in line with workers' capabilities and resources, and clearly defines workers' roles and responsibilities. |
| Sauter SL, Brightwell WS, Colligan MJ, et al. | 2002 | To understand and prevent hazards arising from the organization of work | U.S. (U.S.) workforce: NIOSH publication | Review of existing research | There is an urgent need for research efforts to better understand worker exposure to organizational risk factors for illness and injury, and how these exposures may be changing.<br><br><u>Critique:</u> There is a greater need for comprehensive research efforts targeting |

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| | | | | | organizational practices and policies that may protect worker safety and health. |
| Schneiderman N, Ironson G, Siegel SD | 2005 | To help understand the complex relationship between psychosocial stressors and health outcomes | Review of literature | Review of existing research focused on some of the psychological, behavioral, and biological effects of specific stressors, the mediating psycho-physiological pathways, and the variables known to mediate these relations. | Stress is a central concept for understanding both life and evolution. Acute stress responses in young, healthy individuals may be adaptive and typically do not impose a health burden. In contrast, if stressors are too strong and too persistent in individuals who are biologically vulnerable because of age, genetic, or constitutional factors, stressors may lead to disease.<br><br><u>Critique:</u> Much is still not known about the relation between stress and health. To holistically understand how work-related psychosocial factors affect the health and safety of the employees, it is important to consider various individual and combinations of such factors. |
| Siegrist J | 1996 | To develop another model | A cohort of 416 male blue-collar | Two studies were conducted: 1) 6.5 year | High-cost/low-gain conditions at work must be considered a |

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| | | addressing stressors in the workplace | workers, and 179 male, middle managers | prospective study of a cohort of 416 male blue-collar workers; 2) cross-sectional analysis of associations between indicators of effort–reward imbalance at work and major coronary risk factors such as hypertension, elevated fibrinogen, elevated atherogenic lipids, and smoking in a sample of male, middle managers. Review of existing literature was included as well. | risk constellation for cardiovascular health. Indirect support came from related studies that were performed without explicit reference to the model.<br><br>Critique: Besides work-related strain which is one of the most commonly explored psychosocial factors that may affect the health of the population, there may be other factors affecting health and safety. An example of one such factor is the effort-reward imbalance. However, each of these models may show different associations among age groups. Most of the existing literature, including this effort have considered illnesses as the outcome, while injuries remain under-researched. |
| Turner N, Hershcovis MS, Reich TC, et al. | 2014 | To investigate the relations between work-family interference (i.e., work-family conflict and family- | Two samples were used including a sample of 645 UK healthcare workers, and 128 | Two items each were used to capture work-family conflict, and family-work conflict. Four items from the General Health Questionnaire measured | Work-family conflict may represent a hazard because it generates psychological distress in those experiencing such inter-role conflict, and psychological distress, in turn, |

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| | | work conflict) and workplace injuries as mediated by psychological distress. | manufacturing and service employees. | psychological distress. To assess injuries, participants were asked to indicate how frequently over the last four weeks they had sustained a range of nine categories of work-related injuries. Analysis involved using structural equation modeling with list-wise deletion. | may result in higher workplace injuries. Family-work conflict, did not exert the same effects as work-family conflict on workplace injuries.<br><br>Critique: The study findings increase recognition of the safety benefits to both organizations and employees in helping employees to balance work and family demands. Other psychosocial exposures that may affect this association also need to be considered. |
| Vermeulen M, Mustard C. | 2005 | To determine if there is a gender variation in the relations among job strain, social support at work, and psychological distress | A cross-sectional sample of 7,484 employed Canadians | The sample was selected from respondents to the health questionnaire component of the 1994/1995 National Population Health Survey, Canada. General information was gathered on all household members, and a more detailed health interview was conducted with a randomly selected household member who was at least 12 years of | Compared with low-strain work, high-strain and active work were associated with a significantly higher level of distress in both men and women. Differences in psychological distress in relation to psychosocial work exposures were greater for men than for women.<br><br>Critique: The study indicates that psychosocial work exposures may be a more |

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| | | | | age. The psychological distress scale was based on a subset of six questions in the Composite International Diagnostic Interview. Job strain, and social support were measured using an abbreviated form of the Job Content Questionnaire. | significant determinant of psychological well-being in male, compared with female workers. However, the analyses were cross-sectional and causal assumptions cannot be made; these associations need to be explored via longitudinal research efforts. |
| Yang T, Shen YM, Zhu M, et al. | 2015 | To investigate the effects of workplace support on job stress and presentism in an aging workforce | A cohort of 1649 workers aged 50 ears and above | The 2010 wave of the Health and Retirement Survey was used to obtain the study sample. The study variables were obtained from the participant lifestyle questionnaire. Structural equation modelling was used to evaluate the data. | Co-worker support had a significant direct negative effect on job stress ($\beta = -0.10$; $p < 0.001$) and presentism ($\beta = -0.11$; $p < 0.001$). Supervisor support had a significant direct negative effect on job stress ($\beta = -0.40$; $p < 0.001$) but not presentism.<br><br>Critique: This research effort highlighted the importance to consider work-related support as an important psychosocial exposure. The effort also specifically focused on the aging work group which may have different experiences than the younger counterparts. However, work-related support |

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| | | | | | was the only exposure that the authors considered, while there could be several others as identified by other research efforts e.g., work-related strain, work-family conflict, etc. |

**Figure 1: Karasek's Demand-Control Model**

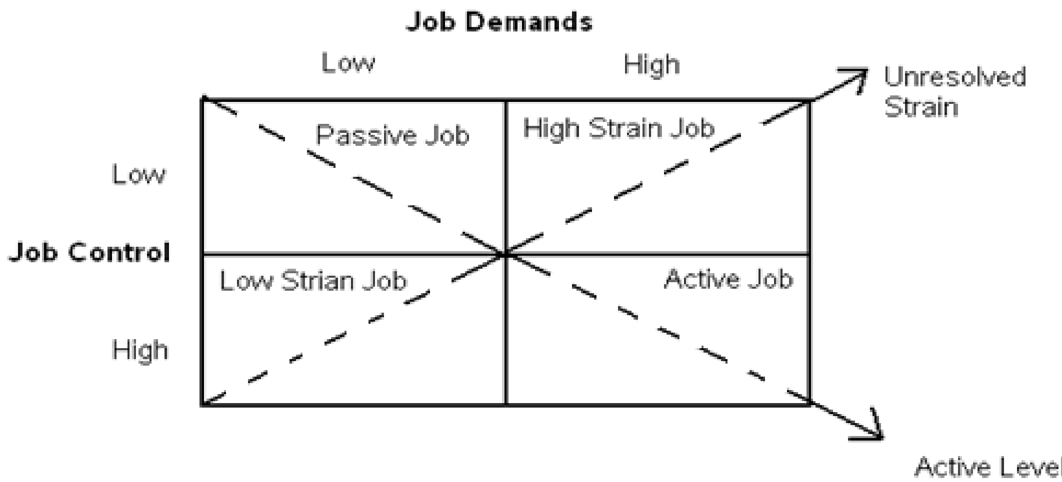


**Figure 2: Seigerist's Effort-Reward Imbalance Model**

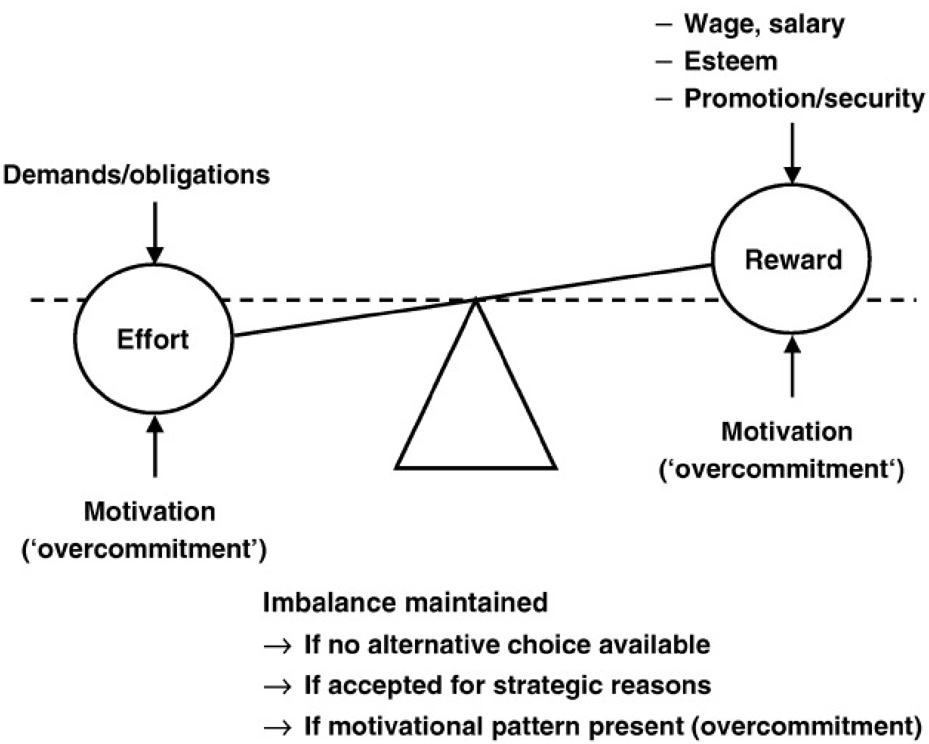
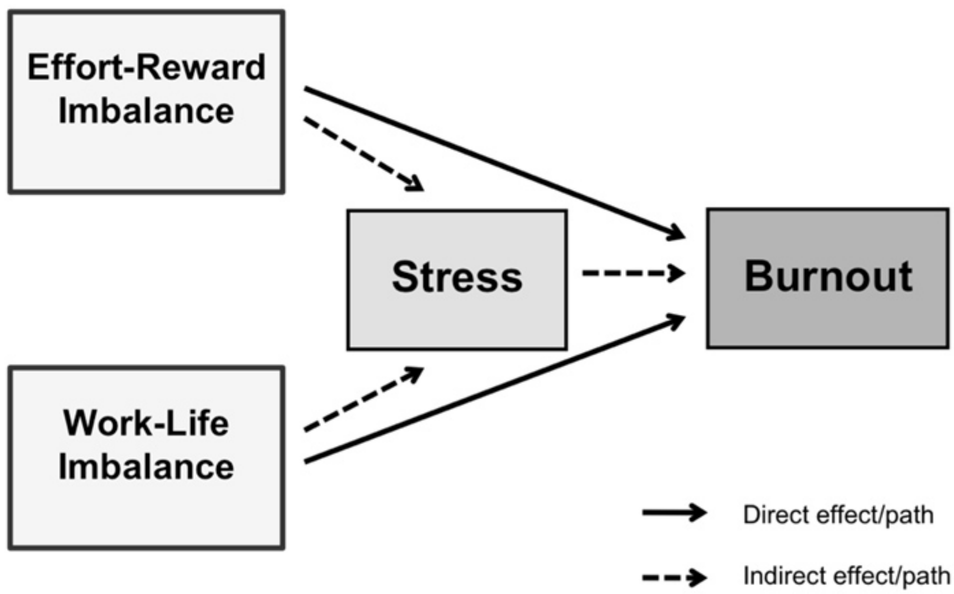


**Figure 3: Seigerist's Effort-Reward Imbalance and Work-Life Imbalance Model**



# CHAPTER III - RESEARCH DESIGN AND METHODS

## SPECIFIC AIMS

The goal of this study was to identify both work-related physical and psychosocial factors that contribute to the occurrence of work-related injuries among the aging U.S. workforce. This study also aimed to compare injured and uninjured adults relevant to their health and work-related outcomes, and compare traditional methods for analyzing repeated-measures injury data with a lesser used method. This study was approved by the Institutional Review Board (IRB) at the University of Minnesota (Appendix A).

The study goals were achieved using the following aims:

**Aim 1: Analyze the association between physical work-requirement factors (excessive physical effort, lifting heavy loads, and stooping/kneeling/crouching) and the occurrence of work-related injuries among a cohort of aging U.S. workers, adjusting for essential personal and work-related characteristics.**

*The hypothesis was that the risk for injuries will be greater among those whose workplaces have higher, compared to lower, physical requirements.*

**Aim 2: Compare the injured and uninjured population, identified in Aim 1 with regards to any new functional limitations (difficulties with large muscle movements, gross and fine motor movements, and activities of daily living), and reduced working hours from the previous the wave.**

*The hypothesis was that injured, compared to uninjured, aging workers will have a greater risk for having functional limitations and reduced working hours than in the previous survey wave.*

**Aim 3: Analyze the association between work-related psychosocial factors (work-related demands, control, rewards, support, and work-family conflict) and the occurrence of work-related injuries among a cohort of aging U.S. workers.**

*This hypothesis was that workers who perceive their workplaces to have greater psychosocial demands and lesser resources to meet such demands will be at a higher risk for injuries, compared to those who perceive their workplaces to be more balanced in terms of such demands and resources. Additionally, the risk estimates are likely to be different by gender.*

**Aim 4: Methodologically and analytically compare the generalized estimating equations and marginal structural models for analyzing Aim 1 i.e., the association between work-requirement factors and injuries.**

*This hypothesis was that risk estimates obtained from marginal structural models will be different from those obtained from generalized estimating equations.*

The current study, addresses a National Occupational Research Agenda (NORA) aim to stimulate improved work practices and innovative research in multiple ways, as described below. This study also impacts several -- if not all 10 of the NIOSH NORA National Sector Agendas. The focus on aging workers has been a major NIOSH priority for several years because of the potential impact on occupational health and safety. This effort also enabled a distinctive opportunity to examine personal and work-related outcomes among injured and uninjured adults, in a manner that is not typically possible, and provides important information that can serve as a basis for development of relevant intervention efforts.

## TARGET POPULATION AND STUDY COHORT SELECTION

The target population was aging U.S. workers, aged 50 years and above. With the overall U.S. population aging, the proportion of the aging working population in the workforce is increasing as well. It is projected that, by the year 2020, workers 55 years of age and over will account for 25% of the U.S. labor force, a 12% rise from the year 2000 (Hayutin et al., 2013).

The study population consisted of U.S. workers aged 50 years and above who responded to the Health and Retirement Study (HRS) survey in the year 2004. HRS, which is a publicly available, and nationally-representative, multistage area probability sample of U.S. households with an eligible household financial unit as the unit of observation, is funded by the National Institute on Aging. The HRS includes a supplemental oversampling of Blacks, Hispanics, and the residents of Florida, which allows for independent analysis of key subgroups. This longitudinal panel study, which has been active since 1992, surveys a representative sample of over 20,000 U.S. aging adults over the age of 50 years in waves that occur every two years. A large proportion of the sample population is either retired or approaching retirement at the baseline interview time. The sample is replenished every six years with persons within the age group of 51-56 years at baseline to maintain a steady-state design. The HRS enables researchers to investigate both current issues and changes over time due to its longitudinal nature using several core, enhanced, and off-year survey modules that are administered both in English and Spanish. While only community-dwelling aging adults are sampled, respondents are followed into nursing homes or other institutional settings if they relocate. Sampling weights account for selection, and non-response for each survey wave (Sonnega et al., 2014, HRS, 2014).

## DATA COLLECTION

To take advantage of the longitudinal nature of the data, six interview waves (wave 7 (year 2004) through wave 12 (year 2014)) of the HRS, were used for this study. The decision to begin the study observation period in 2004 was made because: i) until 1998, two major HRS cohorts had not been combined; and ii) year 2004 was a sample replenishment year which provided more power for the analyses.

There were a total of 20,129 primary HRS respondents in the year 2004 (wave 7), from which this study included a cohort of 7,212 aging adults who, in the year 2004, were *working for pay* (either self-employed or working for others) and were *aged 50 years and above* (Figure 1). This cohort of 7,212 adults was then followed prospectively until the year 2014, the most recent HRS wave for which data have been made available. At each study wave after the baseline, persons who were no longer working for pay were excluded from the main analyses. However, separate analyses were conducted to determine if a work-related injury may have led an employee to leave the workforce, the *entire* original cohort of 7,212 persons was included when injured and uninjured adults were compared for any new functional limitations, and reduced working hours.

Also, important, is that HRS, through its psychosocial and lifestyle questionnaire (PSL), commenced data collection on work-related psychosocial factors in 2006, after pilot testing it in 2004. Because this information is only available for a rotating 50% of the study sample at each survey wave (Figure 2), the cohort used to analyze the association between work-related psychosocial factors and injuries was obtained from the years 2006, and 2008 to include information on the entire original sample. This process provided a cohort of 3,305 aging adults. Follow-up psychosocial factors-related information was every four years for each study participant. For example, follow up information those who participated in the PSL survey in the year 2006 was available in 2010.

Data files, relevant to all the study variables, with the exceptions of work-related injuries and work-related psychosocial factors, were obtained from the RAND data file which is a user-friendly file derived from available HRS waves. These files contain cleaned and processed variables with consistent and intuitive naming conventions, and model-based imputations. They are available in wide format with all observations for each person presented in single rows for all the study waves. Next, data pertaining to the work-related injuries, and work-related psychosocial factors were obtained from HRS core files; these files are provided in long format with repeated observations for each study participant represented in separate rows. The RAND data file was merged with the HRS Core files, using the household and person identification number, to create the needed data file for all exposures and outcomes of interest for this study.

A conceptual figure (Figure 3) was then designed, based on the study aims. This figure identifies the personal exposures including demographic, health and lifestyle, income and assets, along with work-related exposures including psychosocial exposures that might be associated with work-related injury events. The figure also depicts the consequences of the injury events in terms of any functional limitations incurred and reduced working hours compared to the previous wave.

## Measurements and Definitions

### ***Dependent variable: Work-related Injury***

The HRS defines work-related injuries as "any injuries at work that required special medical attention or treatment or interfered with your work activities." Those who responded 'yes' were further asked about the number or counts of such injury events at work.

### ***Independent variables***

Personal and health-related factors

*Demographic factors:* Information was obtained for: age as of the survey wave; gender; race; ethnicity; education; marital/partner status; being born in the U.S. or not; and household income and assets.

*Health-related factors:* Information pertaining to alcohol consumption (number of drinks consumed per week); smoking behavior; presence of chronic physical and mental health conditions (high blood pressure, diabetes, heart problems, lung disease, stroke, arthritis, and psychiatric problems); and presence of depression-related symptoms in the past two weeks prior to the interview (acute depression) were obtained.

Work-related factors

*Work-related characteristics:* Information was obtained on work-related characteristics, including: work category (U.S. Census Occupation and Industry Codes-based masked categories**)**; total hours worked during each wave in primary and second jobs, if any; work status assessed as full-time, part-time, and partly-retired; having a second job; tenure in the current workplace; and any previous history of work-related injuries.

*Work-requirement factors:* Physical work-requirements factors of interest included work requirements for excessive physical effort, lifting heavy loads, and stooping kneeling crouching. All three stated factors were measured on a Likert scale, ranging from all/almost all of the time to none/almost none of the time. The associations between these three physical work requirements and injuries (Silverstein, 2008, Hollander, 2010, Nahrgang et al., 2011), were identified.

*Psychosocial factors:* Data regarding the psychosocial work exposures were obtained from the work-related stressors section of the HRS's PSL questionnaire (PSL questionnaire 2006-2010). This contained information regarding perceptions about: physical work demands; salary adequacy; promotion aspects; work security; workload; freedom; skill development; control; need to work fast; conflicting work demands; and work-personal life conflict. These were measured on a four-level Likert scale (Table 1) and used both individually and in combination with other factors. The psychosocial factors listed in Table 1 were used to evaluate the associations between: work-related strain (Karasek, 1979) i.e., *work demands / work control*; effort-reward imbalance (Siegrist et al., 1996, Ostry et al., 2003) i.e., *work demands / rewards obtained*; work-related support (Jhonson and Hall, 1988, Fischer et al., 2005, Vafaei and Kristman, 2013); work-family conflict (Turner et al., 2014); along with their interactions (Johnson and Hall, 1988, Fischer et al., 2005), and work-related injuries.

Health and work-related consequences work-related injuries

*Functional limitations:* These were assessed as having any difficulty with *five summary measures*, including: activities of daily living (bathing, eating, dressing, walking across a room, and getting in or out of bed); large muscle activity (sitting for two hours, getting up from a chair, stooping or kneeling or crouching, and pushing or pulling a large object); gross motor movements (walking one block, walking across the room, climbing one flight of stairs, and bathing); fine motor movements (picking up a dime, eating, and dressing); and mobility index (walking several blocks, walking one block, walking across the room, climbing several flights of stairs and climbing one flight of stairs).

*Reduced working hours:* Reduced working hours were identified as a change to working fewer hours compared with the previous interview wave. This also included those who partially or completely retired, plus those who worked part-time in the following interview wave. This research effort enabled analysis of the association between injury status and the stated outcomes (Dembe, 2001, Keogh, 2000).

**CONCEPTUAL/CAUSAL MODELS**

Directed acyclic graphs (DAGs), a type of graphical causal models (Greenland et al., 1999) were developed *a priori* to estimate the potential causal effects (Hill, 1965) of the exposures of interest on the outcome. The two example DAGs in Figures 4 and 5 represent the hypothesized associations between the work-related factors including work-requirement factors, and psychosocial factors and injuries, and other personal, health-related, and work-related characteristics that may affect these associations (Ghosh et al., 2004, Schneiderman et al., 2005, Rugulies and Krause, 2007, Sorensen et al., 2011). Note that the variables that are directly related with both the exposures and outcome, and are not in the causal pathway, are the confounding variables that were included for adjustment (Table 2). Figure 6 is a DAG for a marginal structural model analyzing the association between work-requirement factors and injuries.

DAGs have an advantage over traditional techniques for confounder selection because, in contrast to other methods, they enable identification of variables that may introduce conditional associations and bias if included in the statistical models (Shrier and Platt, 2008). DAGs have now been recognized as tools that are based on the formal rules used to derive mathematical proofs (Elwert, 2013). This approach has been used in several previous injury-related studies (Gerberich et al., 2011, Gerberich et al., 2014).

## DATA ANALYSIS

### Aim 1: Analyze the association between physical work-requirement factors (excessive physical effort, lifting heavy loads, stooping/kneeling/crouching) and the occurrence of work-related injuries among a cohort of aging U.S. workers, adjusting for essential personal and work-related characteristics.

Descriptive statistics were first calculated for the total injured and uninjured population from the study cohort of 7,212 adults, aged 50 years and above. Then the proportions of injured and uninjured adults across each of the study variables including personal, health-related factors, and work-related factors were estimated. Next, for conducting longitudinal analyses, work-related injuries were then modeled both as the number of injury events (counts) and occurrence of injury (yes/no); respectively, incidence rate ratios (IRRs) and hazard ratios (HRs) were estimated. For estimating the IRRs, generalized estimating equations (GEEs) (Ballinger, 2004), with a negative binomial distribution of the errors, and accounting for within-person and within-household correlations, were used. HRs were obtained using Cox hazard models (Cox, 1972), with the counting process technique (Andersen & Gill, 1982), and accounting for within-person correlations. Multivariable models were prepared using the DAG provided in Figure 4. These are also presented in Table 2. The variables adjusted for included: age; gender; race; ethnicity; chronic physical and mental health conditions; acute depression; alcohol consumption; work category; work tenure; and previous history of wok-related injuries (hours worked was the offset or exposure time).

**Aim 2: Compare the injured and uninjured population, identified in Aim 1 with regard to any new functional limitations (difficulties with large muscle movements, gross and fine motor movements, and activities of daily living), and reduced working hours from previous wave.**

The injured and uninjured cohort was compared in terms of any functional limitations incurred as well as reduced working hours. Functional limitations and work status changes were modeled as binary variables in terms of presence of any new difficulty with the five functional limitations, and reduced working hours. Risk ratios (RRs), in lieu of odds ratios (ORs), obtained from a log-binomial model were estimated to model this association. This is because ORs are difficult to interpret and are non-collapsible. As an alternative, RRs are collapsible (i.e., without any confounders, a weighted average of stratum-specific ratios will be equal to the ratio obtained from a two-by- two table of pooled counts from stratum-specific tables), and easy to interpret (Cummings, 2009; Richardson et al., 2017).

**Aim 3: Analyze the association between work-related psychosocial factors (work-related demands, control, rewards, support, and work-family conflict) and the occurrence of work-related injuries among a cohort of aging U.S. workers.**

Descriptive statistics were first calculated indicating the total injured and uninjured population from the study cohort of 3,305 adults aged 50 years and above as identified from the years 2006 and 2008 of the HRS survey. Work-related injuries were modeled as the number of injury events (counts); the exposure time used was total hours worked since the last interview wave. Incidence rate ratios (IRRs) were estimated using the GEEs with a negative-binomial error distribution and accounting for within-person and within-household correlations (Ballinger, 2004). The models were then stratified by gender, as suggested by previous researchers (Vermeulen and Mustard, 2000). As identified in the DAG, in Figure 5, the variables adjusted for, included: age; race; ethnicity; marital/partner status; presence of chronic physical and mental health conditions; presence of acute depression; number of alcoholic drinks consumed per week; work status; work category; work tenure; and previous history of injuries (Table 2).

**Aim 4: Methodologically and analytically compare the generalized estimating equations and marginal structural models for analyzing Aim 1 i.e., the association between work-requirement factors and injuries.**

First the probability of having the exposure i.e., physical work requirements, was modelled dependent on a set of fixed and time-varying exposures obtained by preparing a DAG. For each of the study participants, at each time point or survey wave, both inverse probability person- and wave-specific exposure ($W^{x}_{ij}$) and censoring weight ($W^{c}_{ij}$) were estimated. This IPW, as explained earlier, was proportional to the inverse or reciprocal to the probability of each person receiving the exposure and censoring history that they received at each wave. These weights, respectively, account for the measured confounders and measured selection bias that may be created by the participants' exposures (Robins et al., 1999, Cole et al., 2008).

It is important to note that the obtained weight may lead to extreme weights such that the estimates i.e., $\beta_1$ will have large variance and wider confidence intervals. Hence, it has been suggested to use stabilized exposure ($SW^{x}_{ij}$) and censoring weights ($SW^{c}_{ij}$) (Robins et al., 2000, Cole et al., 2008, Li et al., 2010). The stabilized weights can be obtained by adding a numerator term to the weight equation. This numerator is primarily the probability of a participant receiving his or her own exposure, irrespective of other exposures (Hernan et al., 2000, Cole et al., 2008). Detailed procedures for obtaining these weights is provided by previous researchers (Robins et al., 2000, Cole et al., 2008). A weighted repeated measures regression model i.e., GEE was then fit using the obtained standardized weights. All analyses were conducted using SAS statistical software (SAS institute, 2015).

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**Table 1: Psychosocial work-related factors and the respective questions from the PSL questionnaire**

| **Work-related psychosocial factors** | **Respective questions** |
|---|---|
| *Work demands (created by summarizing three psychological and one physical demand) | • I am under constant time pressure due to a heavy workload.<br>• Considering the things I have to do at work, I have to work very fast.<br>• In my work, I am free from conflicting demands that others make.<br>• My work is physically demanding. |
| Work control | • I have very little freedom to decide how I do my work.<br>• I have the opportunity to develop new skills.<br>• At work, I feel I have control over what happens in most situations. |
| Support at the work | • I receive adequate support in difficult situations. |
| *Efforts involved in the work (physical and psychological work demands) | • I am under constant time pressure due to a heavy workload.<br>• Considering the things I have to do at work, I have to work very fast.<br>• In my work, I am free from conflicting demands that others make.<br>• My job is physically demanding. |
| Rewards obtained from the work | • I receive the recognition I deserve for my work.<br>• My salary is adequate.<br>• My job promotion prospects are poor.<br>• My job security is poor. |
| **Work-family conflict | • Work makes personal life difficult.<br>• Other people determine most of what I can and cannot do.<br>• What happens in my life is often beyond my control. |

*Both work demands and efforts measure “task-level” demands
**Intrinsic characteristic; measured as rarely, sometimes, often, and most of the time (all others measured as strongly disagree, disagree, agree, and strongly agree)

**Table 2: Multivariable models for the study aims**

| Aims | Exposures of Interest | Outcomes | Adjusted Variables |
|---|---|---|---|
| Aim 1 and Aim 4 | Work-requirement factors | Work-related injuries | Age, gender, race, ethnicity, chronic physical and mental health conditions, acute depression, alcohol consumption, work category, work tenure, and previous history of wok-related injuries (hours worked was the offset or exposure time) |
| Aim 2 | Work-related injuries | Functional limitations | Age, gender, race, education, work category, and hours worked |
| | | Reduced working hours | Age, gender, race, education, work category, hours worked, and having a second job |
| Aim 3 | Work-related psychosocial factors | Work-related injuries | Age, race, ethnicity, marital status, presence of chronic physical and mental health conditions, presence of acute depression, number of alcoholic drinks consumed per week, work status, work category, work tenure, and previous history of injuries (hours worked was the offset or exposure time) |

**Figure 1: Cohort selection: Work-requirement factors and injuries**

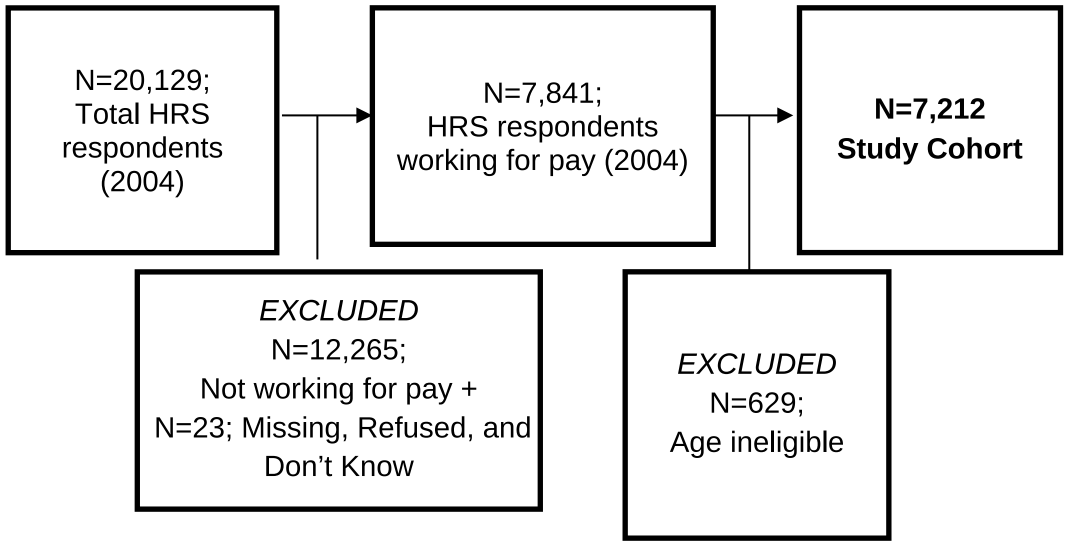


**Figure 2: Timeline for the collection of psychosocial data in the PSL questionnaire**

| | Prior | 2004 | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **Core Sample** | +* | + | + | +◊ | +◊ | +◊ | +◊ | +◊ |
| **LB Sample** | | | **A** | **B** | **A** | **B** | **A** | **B** |

\+ = Indicators of depression
* = Various small sample modules
◊ = Single life satisfaction item
A = First random 50% subsample
B = Second random 50% subsample

**Figure 3: Conceptual figure depicting the exposures and outcomes for the entire project, 2004-2014**

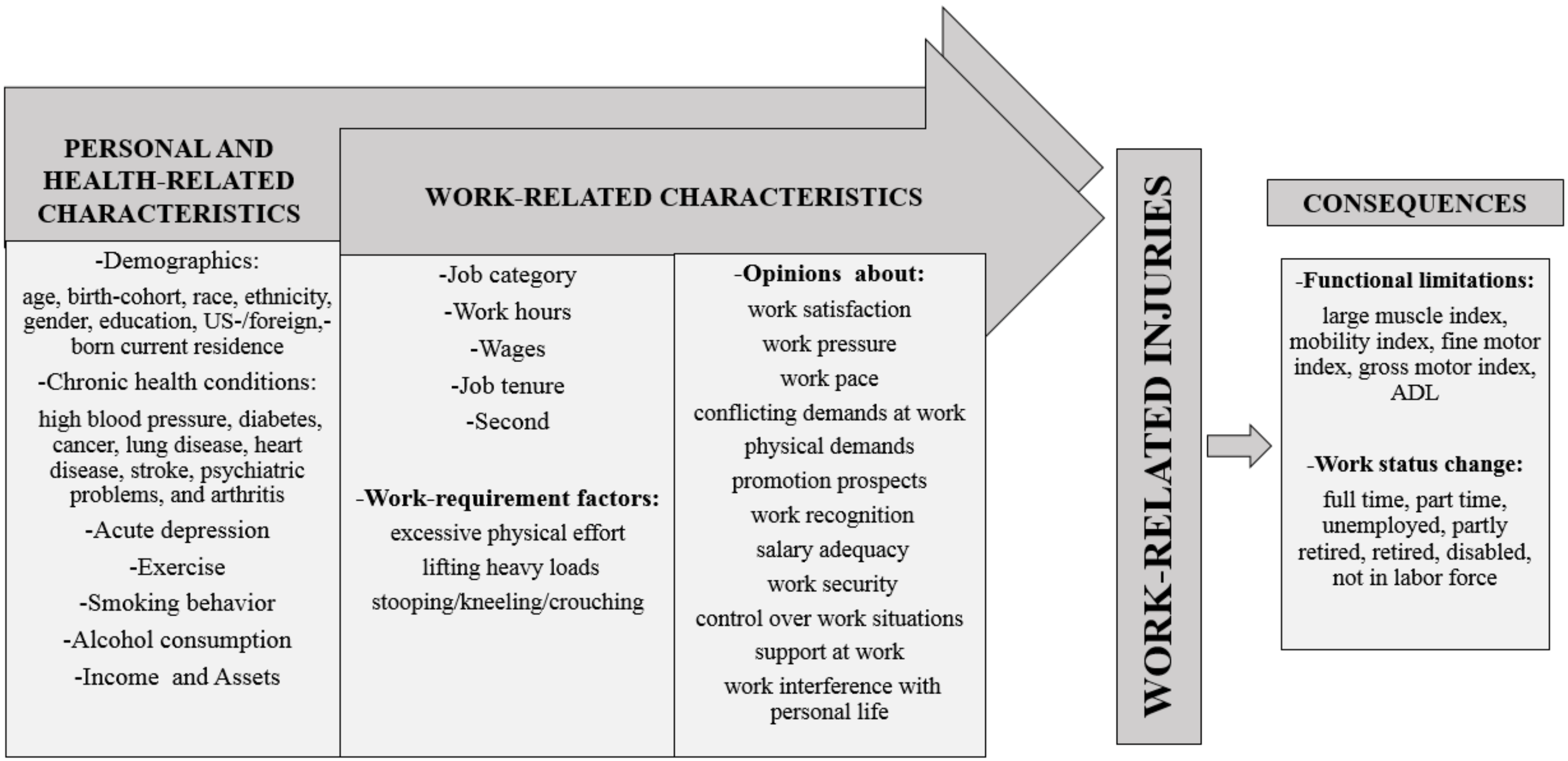


**Figure 4: Directed acyclic graph (DAG) for work-requirement factors as the exposure of interest and work-related injuries as the outcome**

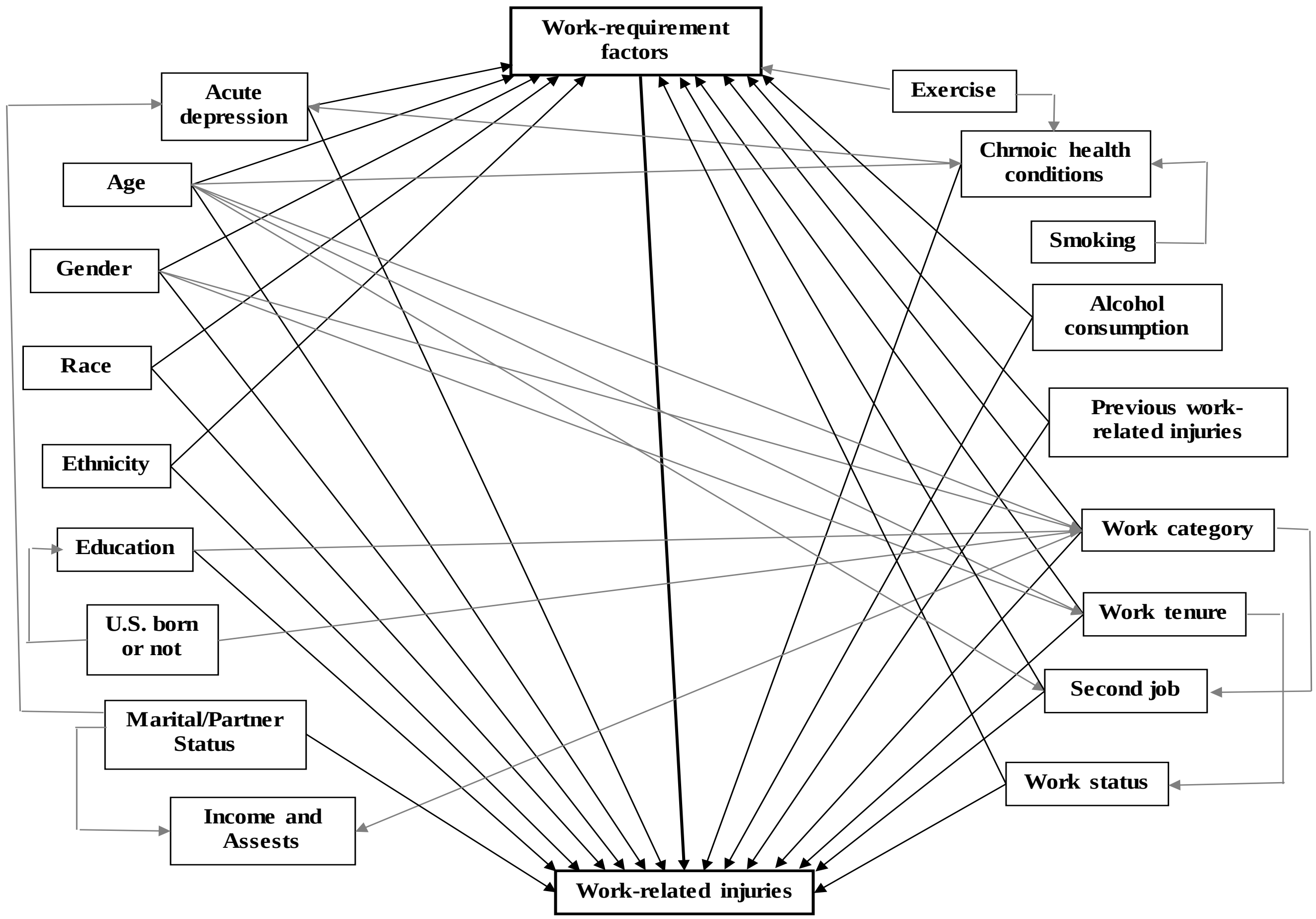


**Figure 5: Directed acyclic graph (DAG) for work-related psychosocial factors as the exposure of interest and work-related injuries as the outcome**

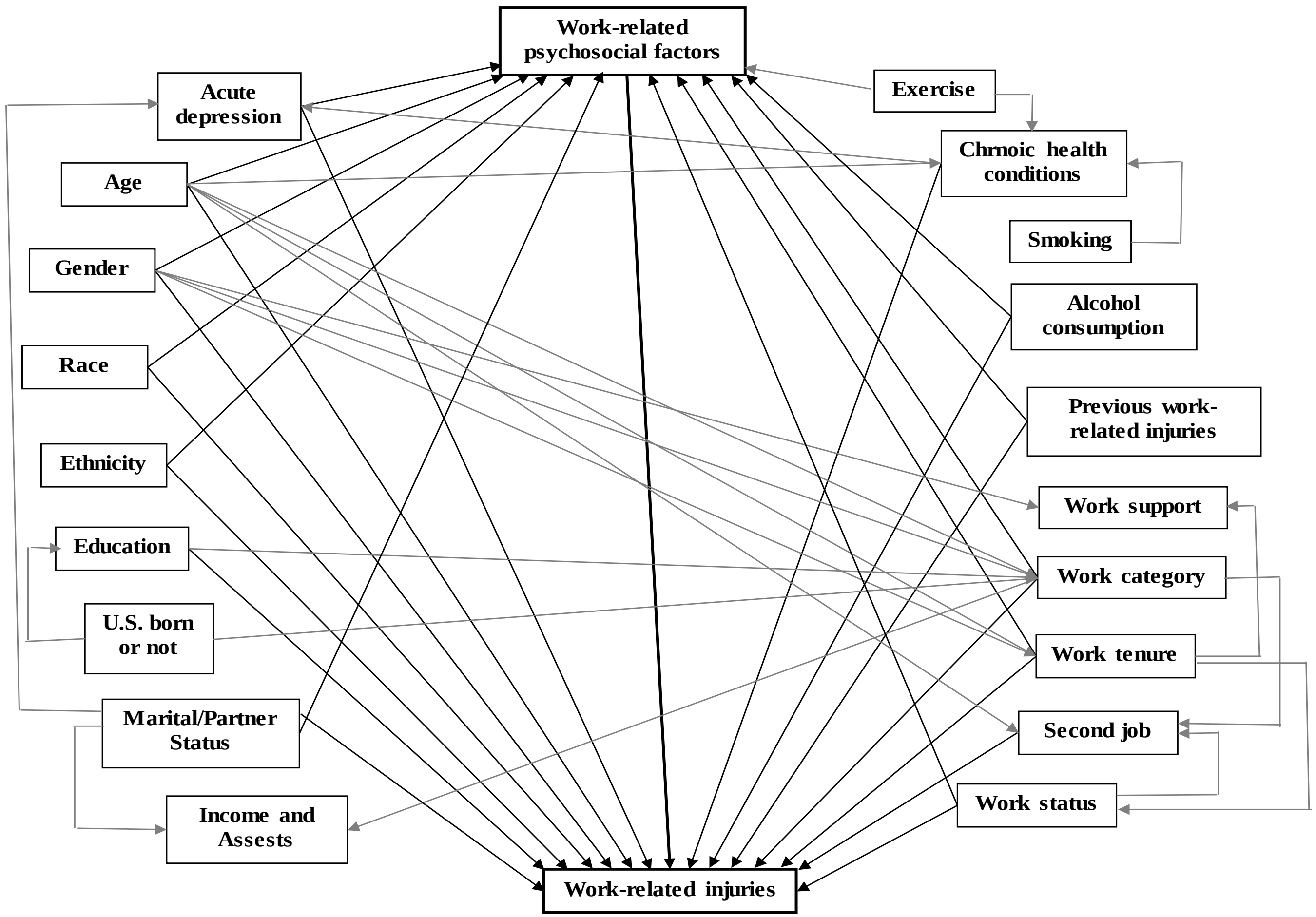
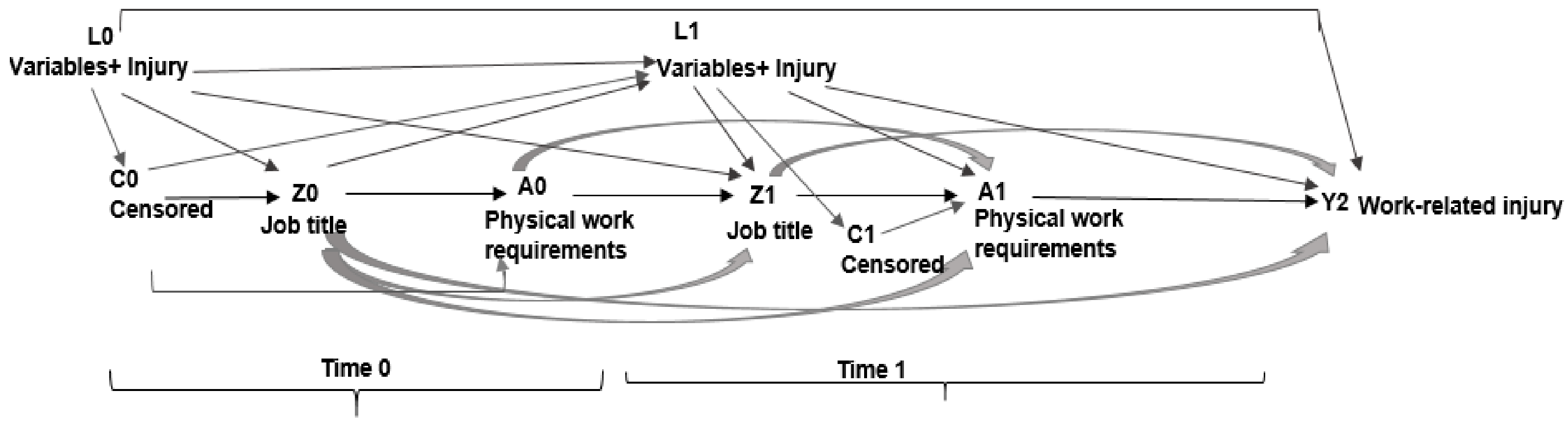


**Figure 6: Directed acyclic graph (DAG) for work-requirement factors as the exposure of interest and work-related injuries as the outcome; marginal structural model approach with two time-points as an example**



## CHAPTER IV - MANUSCRIPT 1

# A LONGITUDINAL STUDY OF WORK-RELATED INJURIES: COMPARISONS OF HEALTH AND WORK-RELATED CONSEQUENCES BETWEEN INJURED AND UNINJURED AGING UNITED STATES ADULTS


## ABSTRACT

### INTRODUCTION

Age may affect one's susceptibility to the myriad physical hazards that may pose risks for work-related injuries. Aging workers are not only at a risk for work-related injuries, but at an even higher risk for more severe health and work-related consequences. However, limited longitudinal research efforts have focused on such injuries among the aging workforce.

### PURPOSE

This study aimed to investigate the association between physical work-related factors and injuries among United States (U.S.) workers, and then compare the injured and uninjured workers with regard to consequences including, functional limitations, and reduced working hours post injury.

### METHODS

A cohort of 7,212 U.S. workers aged 50 years and above from the U.S. Health and Retirement Study were retrospectively followed from 2004 to 2014. Data on exposures were lagged by one survey wave prior to the outcome of work-related injuries and consequences, respectively. Crude and adjusted incident rate ratios, and hazard ratios were estimated using generalized estimating equations and Cox models.

### RESULTS

Risk of experiencing a work-related injury event was over two times greater among those whose job had work requirements for physical effort, lifting heavy loads, and stooping/kneeling/crouching, compared to those who did not. Over time, injured compared to uninjured workers had higher risks of functional limitations and working reduced hours.

**CONCLUSIONS**

The aging workforce is at a high risk of experiencing injuries. Further, injured adults are not only more likely to incur a disability prohibiting daily life-related activities, over time, but, also, were more likely to work reduced hours. It will be important to consider accommodations to minimize functional limitations that may impair resulting productivity.

## INTRODUCTION

Work and hazards related to work may result in work-related injuries and compromise the health and safety of workers (Schulte, 2012). In the United States (U.S.) work-related injuries and illnesses, combined, have been estimated to cost $250 billion (Leigh, 2011). Several factors play an important role in affecting the overall health and safety of a worker, including age. Age, specifically, influences a worker's susceptibility or resistance to various hazards to which they are exposed in the workplace (Schulte, 2012). With the overall U.S. population aging, the proportion of the aging working population is increasing and, by the year 2020, workers aged 55 years and above will comprise 25% of the workforce (Hayutin et al., 2013). Therefore, there is a need to address the potential risks for injuries among aging workers.

While workers aged 55 years and above experience more severe consequences as a result of injuries than their younger counterparts, the rates of non-fatal work-related injuries are lower among the older, compared to the younger group (Grandjean et al., 2006; Silverstein, 2008). As reported by the Bureau of Labor Statistics, work-related injuries resulted in over 1.1 million days-away-from-work cases in the year 2015 among the U.S. private industry and state and local governments. Importantly, workers aged 55-64 years, compared to all other age groups, had the highest incidence rate of days-away-from-work (115.8 cases per 10,000 full-time workers) (Bureau of Labor Statistics-Nonfatal Occupational Injuries and Illnesses Requiring Days Away From Work, 2016). In the same year, those aged 65 years and above had a fatal injury rate four-times that of workers in the age group of 25 to 34 years (Bureau of Labor Statistics-Census of Fatal Occupational Injuries, 2016).

An employee's health and safety behaviors in the workplace are a result of interplay among various work requirements, including physical work requirements (Sorensen et al., 2011). Injuries are likely to occur in conditions where there is a mismatch between the capabilities of the employee and these work requirements (Silverstein, 2008) because requirements that do not match an employee's abilities constrain an employee's progress toward working safely (Hollander, 2010; Nahrgang et al., 2011). There is evidence that heavy physical work, lifting and forceful movements, bending and twisting, whole-body vibration, and static work postures are associated with back injuries. Further, repetition, force, and posture have been found to be associated with neck and neck/shoulder injuries (Bernard, 1997). Among the U.S. adults aged 50 years and older, about 44% have a job that requires physical effort almost all or most of the time, and another 25% are employed in a position that requires physical effort at least some of the time (Benz et al., 2013). Therefore, a large proportion of the aging U.S. workforce may be at a risk for injuries related to such physical work requirements.

Still, limited longitudinal research efforts have focused on physical work requirements and health and safety outcomes, including injuries, among the aging workforce. Since the majority of the existing research efforts have involved cross-sectional study designs, causal associations related to temporality cannot be made (Mann, 2003). Additionally, previous studies that investigated the association between physical work-requirement factors and injuries have been limited to certain specific occupational groups. For example, a study conducted among 31,076 material handlers, from 260 retail merchandise stores in the U.S., reported that workers in occupations with the greatest physical work requirements had an injury rate of 3.64 per 100 person-years versus 1.82 among workers with lesser requirements (Gardner et al., 1999).

Work-related injuries and illnesses may further lead to adverse personal life and work-related outcomes (Keogh, 2000; Dembe, 2001; Kim et al., 2012). However, there also remains a deficiency of quantitative literature assessing the consequences of such work-related injuries (Okechukwu et al., 2016). Existing research efforts have focused largely on workers' compensation-related payments and return-to-work as the consequences of an injury. However, other less explored personal life-, health-, and work-related consequences of such injuries also need to be investigated (Keogh, 2000; Dembe, 2001). Many of the existing studies have compared health- and work-related consequences of injuries between aging and younger workers (Pransky et al., 2005; Algarni et al., 2015) but research efforts are still needed to compare such outcomes between injured and uninjured aging workers.

The aims of this study were, i) to analyze the potential associations between physical work-requirement factors and injuries, and ii) to explore the health-, and work-related consequences of such injuries among a cohort of United States (U.S.) workers aged 50 years and above while accounting for other socio-demographic, health-, and work-related characteristics that might influence these associations (Ghosh et al., 2004;, Baron et al., 2013; Kim et al., 2012).

**METHODS**:

The data for this study were obtained from the Health and Retirement Study (HRS), a nationally-representative panel study of aging U.S. adults. The HRS which is a multistage area probability sample involves a representative sample of the U.S. population aged over 50 years and their spouses, has been surveying over 20,000 aging U.S. adults, since 1992, in biennial waves. Sampling weights have been provided to account for wave specific differential probability of selection and non-response (Sonnega et al., 2014).

**Study design:** For the purpose of this study, HRS waves from the years 2004-2014 were used. Year 2004 was chosen as the starting point because until 1998, two major HRS cohorts had not been combined and after 1998, the first sample replenishment year was 2004 (Sonnega et al., 2014). Year 2014 was chosen as the study end point because this was the most recent year for which the data were available. Approval to conduct this study was obtained from the Institutional Review Board, University of Minnesota.

This research incorporates temporal causal assumptions (Hill, 1965) to examine the associations between the exposures and outcomes. Accordingly, to examine the association between work-requirement factors and injuries, injury data were obtained from waves subsequent to those from which the exposures were obtained. Thus, work-requirement factors were obtained from the years 2004-2012, and injury outcome data were obtained from 2006-2014. Similarly, data on any functional limitations and reduced working hours were obtained from waves subsequent to those from which injuries were obtained.

**Study sample:** A total of 7,212 adults, who participated in the HRS survey in the year 2004, aged 50 years and above and working for pay in 2004, formed the cohort for this study. *For the first research question* investigating the association between physical work requirements and work-related injuries in the entire cohort, those who were not working for pay, at each survey wave, were excluded from the analyses. Also excluded were those who dropped out of the HRS sample (3.4%), and those who died (12%) over the study duration. *For the second research question* that investigated the association between work-related injuries and health-, and work-related outcomes, the entire original cohort of 7,212 workers was retained, only dropping those who either died or dropped from the HRS study sample; those who stopped working for pay in the subsequent survey waves were retained. This was done to examine if being injured at any point in time during the study period would lead respondents to stop working for pay -- an important injury-related consequence.

**Study variables:** All the study variables included in the analyses were self-reported. The primary exposures of interest for the first study aim were physical work-requirement factors, including work requirements for excessive physical effort, lifting heavy loads, and stooping kneeling crouching – all measured on a Likert scale, ranging from all/almost all of the time to none/almost none of the time. Missing information was imputed by carrying information from the last wave forward.

The outcome of interest for the first study aim was work-related injuries. These were ascertained as "any injuries at work that required special medical attention or treatment or interfered with your work activities." Those who experienced a work-related injury were further asked about the number of such events. The current analyses uses injuries both as a binary outcome (yes/no), and as the number of such events (counts).

For the second study aim, injury status (injured versus uninjured) was the exposure of interest. The outcomes of interest were, i) any new functional limitations, ii) and reduced working hours. Functional limitations were assessed as having difficulties with five summary measures including, activities of daily living (bathing, eating, dressing, walking across a room, and getting in or out of bed); large muscle activity (sitting for two hours, getting up from a chair, stooping or kneeling or crouching, and pushing or pulling a large object); gross motor movements (walking one block, walking across the room, climbing one flight of stairs, and bathing); fine motor movements (picking up a dime, eating, and dressing); and mobility index (walking several blocks, walking one block, walking across the room, climbing several flights of stairs and climbing one flight of stairs). While HRS collected the counts of functional limitations, for this analysis, due to low cell counts these were categorized as a binary variable i.e., having any new functional limitation or not.

Reduced working hours was identified as a change to working fewer hours than in the previous interview wave. This also included those who partially or completely retired, as well as those who worked part-time in the following interview wave. As an example, those who changed work status from originally working full-time to part-time, or retiring in the subsequent wave, or from working part-time to retiring, were recognized as having reduced working hours.

Other potential confounding variables considered, for the analyses, included: demographic and health-related characteristics i.e., respondents' age as of the survey wave, gender, race, ethnicity, education, and marital/partner status, and health-related information regarding presence of chronic physical and mental health conditions, and acute depression; and lifestyle factors of number of alcoholic drinks consumed per week, and smoking patterns; total household assets and income. Also included were other work-related characteristics, including: work category grouped as white collar, blue collar, and service; total hours worked during each wave; work status assessed as full-time, part-time, and partly-retired; having a second job; and tenure in the current workplace. Further information on the measurement of each of these variables is presented in the later sections.

**Statistical analyses:** Multivariable models were developed using Directed Acyclic Graphs (DAGs) that enable graphical displays of the a priori hypothesized causal links between the exposures of interest and the outcome. The DAGs helped to identify an essential set of confounding variables to adjust for in order to estimate the potential causal association between the exposure of interest and the outcome (Greenland et al., 1999, Shrier & Platt, 2008). DAGs have previously been used for injury-related research, as well (Gerberich et al., 2001, Gerberich et al., 2014). Figure 1 represents a DAG example with work-requirement factors as the exposure of interest, and work-related injuries as the outcome, along with the set of essential confounding variables that must be considered in the analyses.

Work-related injuries were modeled both as the number of injury events (counts) and occurrence of injury (yes/no); respectively, incidence rate ratios (IRRs) and hazard ratios (HRs) were estimated. For estimating the IRRs, generalized estimating equations (GEEs) (Ballinger, 2004), with a negative binomial distribution of the errors and accounting for within-person and within-household correlations were used. HRs were obtained using Cox hazard models (Cox, 1972) with the counting process technique (Andersen & Gill, 1982), and accounting for within-person correlations. Changes, from the previous survey wave, in functional limitations and reduced working hours, were modeled as binary variables in terms of presence of any new functional limitation and reduced working hours. Risk ratios (RRs), instead of odds ratios (ORs) obtained from a log-binomial model, were used to model this association. This is because ORs are difficult to interpret and are non-collapsible. As an alternative, RRs are collapsible (i.e., without any confounders, a weighted average of stratum-specific ratios will be equal to the ratio obtained from a two-by- two table of pooled counts from stratum-specific tables), and easy to interpret (Cummings, 2009; Richardson et al., 2017). While sampling weights were obtained from the HRS, these were not used in the final analyses as these did not alter the study results. Note that, sensitivity analyses were conducted and the exposures of those who were censored were compared to those who were retained in the HRS survey. Additional sensitivity analyses compared the primary respondents with proxy respondents.

All analyses were conducted, using SAS statistical software (SAS, 2012).

**RESULTS**

At baseline, in 2004, about 5% (n=397 of 7,212 total) of the aging adults in this cohort, experienced a work-related injury. Most injured persons (63%) were in the age-group of 50-60 years, were White (77%) and Non-Hispanic (89%) (Table 1). Two-thirds of the injured persons had at least one or more chronic health condition, and 58% had acute depression at the time of the survey. Table 1 also shows that the most common work categories, in which injured persons were engaged, included machine operators, transportation operators, and professional and technical services; 75% held full-time employment.

Table 2 presents the results from the crude and adjusted GEE and Cox models, modeling the associations between physical work-requirement factors i.e., work requirements for excessive physical effort, lifting heavy loads, and stooping/kneeling/crouching, and the outcome of injuries. Compared with those whose workplaces did not include the three work requirements, those who had these requirements had a significantly higher risk of experiencing injuries (Table 2). Results of both the GEE and Cox models show that as the work requirements increased from “some of the time” to “all or almost all of the time,” the risk of injuries increased, as well.

Table 3 shows results from the GEE and Cox models, comparing injured and uninjured aging adults in the study in terms of any new functional limitations incurred, and reduced working hours. In general, adjusted models showed that injured, compared with uninjured, aging workers were more likely to experience new functional limitations, and to work reduced hours. For example, injured, compared with uninjured persons, were almost twice as likely to have a difficulty with activities of daily living. Note that due to model convergence issues, a parsimonious set of confounding variables were included in this part of the analysis (Table 3).

**DISCUSSION**

Results of this longitudinal cohort study analyses indicated that the risk of work-related injuries among the aging workers increased as the work requirements for excessive physical effort, lifting heavy loads, and stooping/kneeling/crouching increased. Specifically, the risk of injuries among those whose work had these physical work requirements “all or almost all the time,” was two-times that of those whose work did not have such requirements.

Similarly, from an earlier analysis of a cohort of 51-61 year old non-farmers in the HRS dataset whose work required heavy lifting, compared to those whose work did not, a risk of having a work-related injury was over two times greater (Zwerling et al., 1996, Zwerling et al., 1998). A cross-sectional study conducted, using data from the U.S. National Longitudinal Survey of Youth (NLSY), also found that those whose workplaces encompassed the stated physical work requirements were also about twice as likely to experience injuries at their workplaces (Dembe et al., 2004); this compares to a three-fold high risk observed in the current study.

A study conducted among six industrial sectors that were part of the Israeli Cardiovascular Occupational Risk Factors Determination in Israel, reported that the incidence of injuries increased with increasing levels of work-related physical stress involved (Melamed et al., 1999). Another study (Hollander & Bell, 2010), that specifically focused on the U.S. Army, documented that soldiers in heavy versus light demanding work were at a higher risk for any cause of injuries and disabilities (HR: 1.45, 95% CI: 1.34, 1.57).

As noted earlier, work-related injuries and illnesses can be associated with several health and work-related consequences, including functional impairments, disabilities, job loss, absenteeism etc. (Dembe, 2001, Keogh et al., 2000). However, the majority of previous research relied on Workers' Compensation data to investigate such outcomes. Therefore, injured and uninjured populations could not be compared in terms of any functional limitations, or work hour changes. For example, a previous study, focused on Workers' Compensation claims and investigated the consequences of upper extremity cumulative trauma disorders (Keogh et al., 2000); it was found that one to four years following claims filing, more than half of the claimants reported having symptoms that interfered with work (50%+) and recreational (60%+) activities. Further, only 64% reported being able to perform normal activities of daily living. Results also showed that the likelihood of normal function decreased with increasing age (OR: 0.94, CI: 0.91, 0.97). In addition, approximately 40% reported job loss one to four years post-claims filing.

However, the current research compared such consequences between aging injured and uninjured employees, and found that injured employees had a higher risk of experiencing functional limitations, and reduced working hours than the previous survey wave. Similar results were documented from another study that used data from the Work, Family and Health Network, and investigated the association between occupational injuries and job loss (Okechukwu et al., 2016). It was reported the risk of having an involuntary job loss, as a consequence of the injury, was twice as high among the injured, compared to the uninjured, workers (OR: 2.19; CI: 1.27, 3.77). Similar results were also obtained from a study that sampled newly registered hospital nurses in the U.S. and found that those experiencing work-related sprains and strains, including back injuries, were more likely to report subsequent job loss (Brewer et al., 2012). Contrary to these findings, a study that focused solely on male workers, using the U.S. NLSY, found no association between injuries and job loss among unionized workers (Woock, 2009).

This study has several strengths owing to its focus on the aging U.S. workforce, and use of longitudinal analysis techniques. However the findings from this study must be interpreted in view of some of the limitations. First, the data are based on self-reports and also involve a minimum of two-year recall periods. Therefore, there may be a potential for differential misclassification. This is because the estimates may be biased away from the null among those who experienced a work-related injury-related event as they may remember their exposures better than those who did not experience such injuries. It is also possible that those who were censored over the study period may be different from those who were retained in terms of their exposures. However, sensitivity analyses revealed that injured/uninjured and censored/non-censored were similar in terms of their exposures. It is also possible that there could be some bias in the estimates associated with proxy interviews. While the results of this study would be considered generalizable to the U.S., it cannot be compared to other country data. The results would also not be expected to be generalizable to younger working populations, or other work groups due to potentially different exposures.

## CONCLUSIONS

This unique longitudinal research effort serves as a basis to provide insights into work-related injury experiences and their consequences among aging U.S. workers, whose proportion in the workforce is increasing. The risk of work-related injuries is especially high among aging U.S. workers employed in physically demanding jobs. Employers must consider providing accommodations, relevant to work requirements, for workers to prevent functional limitations that may impair resulting productivity.

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**Table 1: Baseline demographic, other personal, and work-related characteristics among the uninjured and injured study cohort (N=7,212)**

| Exposures | Uninjured n (%) | Injured n (%) |
|---|---|---|
| **Age categories** | | |
| 50-60 year old | 3,892 (56.9) | 226 (63.3) |
| 60-70 year old | 2,255 (33.0) | 107 (30.0) |
| 70 years and above | 612 (9.0) | 21 (5.9) |
| **Gender** | | |
| Men | 3,375 (49.3) | 168 (47.1) |
| Women | 3,465 (50.7) | 189 (52.9) |
| **Race** | | |
| White/Caucasian | 5,490 (80.3) | 275 (77.0) |
| Black/African American | 945 (13.8) | 54 (15.1) |
| Other | 403 (5.9) | 28 (7.8) |
| **Ethnicity** | | |
| Hispanic | 594 (8.7) | 38 (10.6) |
| Non-Hispanic | 6,245 (91.3) | 319 (89.4) |
| **Birthplace** | | |
| US born | 6,097 (89.1) | 322 (90.2) |
| Born elsewhere | 722 (10.6) | 34 (9.5) |
| **Education** | | |
| Left high-school/GED | 1,166 (17.0) | 77 (21.6) |
| High-school graduate | 1,954 (28.6) | 115 (32.2) |
| Some college | 1,698 (24.8) | 95 (26.6) |
| College and above | 2,020 (29.5) | 70 (19.6) |
| **Marital/partner status** | | |
| Married/partnered | 5,165 (75.5) | 245 (68.6) |
| Separated/divorced/ widowed | 1,439 (21.0) | 98 (27.4) |
| Never married | 232 (3.4) | 14 (3.9) |
| **Total household assets ($)** | | |
| <=63,500 | 3,731 (54.6) | 239 (67.0) |
| >63,500 | 3,109 (45.5) | 118 (33.1) |
| **Alcohol consumption (drinks/week)** | | |
| None | 4,031 (58.9) | 226 (63.3) |
| 1-5 | 2,715 (39.7) | 122 (34.2) |
| 6 or more | 79 (1.2) | 6 (1.7) |
| **Chronic physical health conditions** | | |
| 0 | 2,216 (32.4) | 90 (25.2) |
| 1 | 2,305 (33.7) | 124 (34.7) |
| 2 or more | 2,319 (34.0) | 143 (40.1) |
| **Acute depression** | | |
| No | 3,437 (50.2) | 134 (37.5) |
| Yes | 3,117 (45.6) | 207 (58.0) |

| | | |
|---|---|---|
| **Work category** | | |
| Managerial | 1,016 (14.8) | 38 (10.6) |
| Professional/technical | 1,314 (19.2) | 52 (14.6) |
| Sales | 718 (10.5) | 27 (7.6) |
| Clerical/administrative | 1,105 (16.1) | 40 (11.2) |
| Health care | 174 (2.5) | 27 (7.6) |
| Protection service | 121 (1.8) | 11 (3.1) |
| Household/building cleaning service & Food preparation service | 271 (4.0) | 16 (4.5) |
| Personal service | 438 (6.4) | 26 (7.3) |
| Mechanical/Repair | 202 (2.9) | 12 (3.4) |
| Farming/forestry/fishing | 200 (2.9) | 18 (5.0) |
| Construction/Extraction | 222 (3.2) | 20 (5.6) |
| Precision production | 184 (2.7) | 9 (2.5) |
| Operators: machine, transportation | 815 (11.9) | 57 (16.0) |
| **Work status** | | |
| Full-time | 4,391 (64.2) | 270 (75.6) |
| Part-time | 966 (14.1) | 45 (12.6) |
| Partly retired | 1,483 (21.7) | 42 (11.8) |
| **Work tenure** | | |
| Five years or less | 2,966 (43.4) | 128 (35.8) |
| More than five years | 3,486 (56.2) | 229 (64.1) |
| **Work-requirement factors** | | |
| **Excessive physical effort** | | |
| All/almost all the time | 1,136 (16.6) | 98 (27.4) |
| Most of the time | 822 (12.0) | 64 (17.9) |
| Some of the time | 1,799 (26.3) | 95 (26.6) |
| None/almost none of the time | 2,255 (33.0) | 64 (17.9) |
| **Lifting heavy loads** | | |
| All/almost all the time | 495 (7.2) | 54 (15.1) |
| Most of the time | 349 (5.1) | 27 (7.6) |
| Some of the time | 1,418 (20.7) | 107 (30.0) |
| None/almost none of the time | 3,750 (54.8) | 133 (37.2) |
| **Stooping/kneeling/crouching** | | |
| All/almost all the time | 916 (13.4) | 94 (26.3) |
| Most of the time | 609 (9.0) | 47 (13.2) |
| Some of the time | 1,972 (28.8) | 101 (28.3) |
| None/almost none of the time | 2,516 (36.8) | 79 (22.1) |
| **Total** | 6,840 (94.8) | 357 (4.9) |
| Missing values are not shown | | |

**Table 2: Analysis of the associations between physical work-requirement factors and work-related injuries (N=7,212)**

| Exposures | Outcome: Number of injury events | | Outcome: Injured or not | |
|---|---|---|---|---|
| | Crude IRRs | Adjusted IRRs* | Crude HRs | Adjusted HRs** |
| **WORK-REQUIREMENT FACTORS** | | | | |
| **Excessive physical effort** | | | | |
| All/almost all the time | 3.96 (3.15, 4.97) | 2.19 (1.57, 3.05) | 3.42 (2.80, 4.18) | 2.32 (1.77, 3.03) |
| Most of the time | 2.91 (2.25, 3.74) | 1.71 (1.19, 2.46) | 2.48 (1.99, 3.08) | 1.84 (1.37, 2.47) |
| Some of the time | 1.83 (1.47, 2.28) | 1.46 (1.11, 1.91) | 1.77 (1.45, 2.15) | 1.59 (1.24, 2.02) |
| None/almost none of the time | 1 | 1 | 1 | 1 |
| **Lifting heavy loads** | | | | |
| All/almost all the time | 3.88 (3.15, 4.45) | 2.27 (1.60, 3.24) | 3.35 (2.75, 4.09) | 2.52 (1.88, 3.39) |
| Most of the time | 2.12 (1.62, 2.77) | 1.69 (1.14, 2.49) | 2.24 (1.74, 2.89) | 1.81 (1.27, 2.58) |
| Some of the time | 2.26 (1.88, 2.70) | 1.74 (1.37, 2.21) | 2.12 (1.81, 2.47) | 1.89 (1.54, 2.31) |
| None/almost none of the time | 1 | 1 | 1 | 1 |
| **Stooping/kneeling/crouching** | | | | |
| All/almost all the time | 3.88 (3.16, 4.78) | 2.20 (1.61, 3.01) | 3.30 (2.72, 3.99) | 2.41 (1.83, 3.15) |
| Most of the time | 2.77 (2.10, 3.65) | 1.87 (1.33, 2.61) | 2.51 (2.01, 3.12) | 2.01 (1.58, 2.79) |
| Some of the time | 1.80 (1.49, 2.19) | 1.46 (1.13, 1.89) | 1.90 (1.59, 2.28) | 1.67 (1.33, 2.09) |
| None/almost none of the time | 1 | 1 | 1 | 1 |

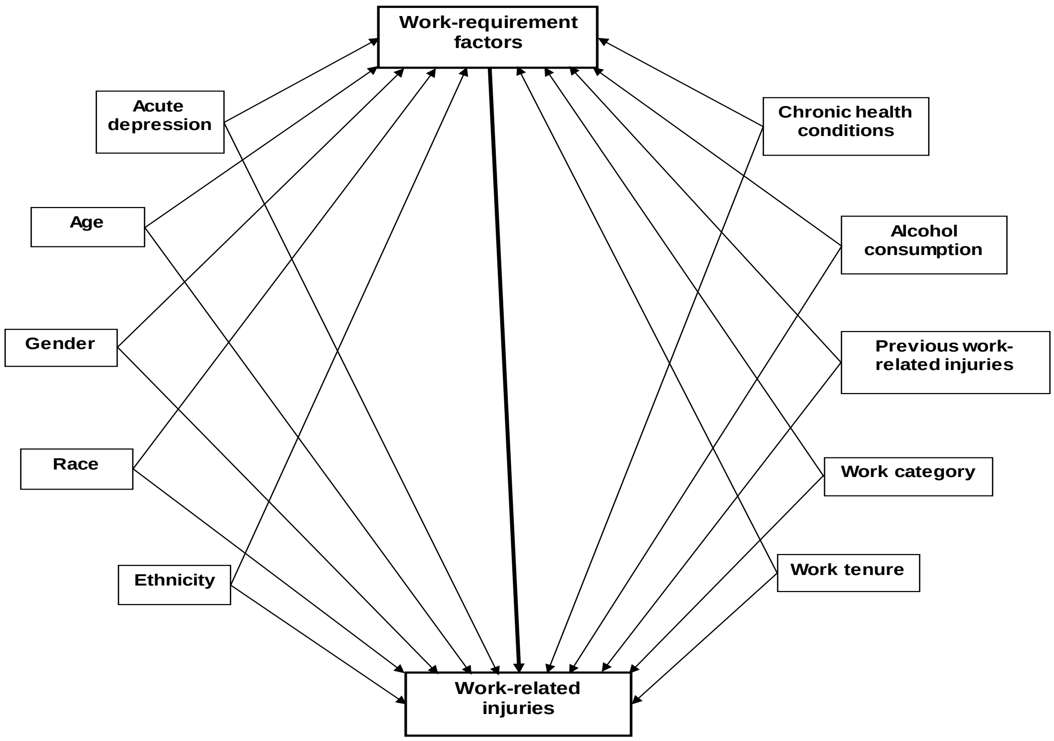
*GEE models: adjusted for age; gender; race; ethnicity; chronic physical and mental health conditions; acute depression; alcohol consumption; work category; work tenure; and previous history of wok-related injuries (hours worked was the offset or exposure time)
** Cox models: age  was used as the time to follow-up variable; other variables adjusted for were same as the GEE models

**Table 3: Comparing functional limitations and working hours among the injured and uninjured persons (N=7,212)**

| Exposures | Functional limitations and working hours comparisons among those injured as compared to uninjured | |
|---|---|---|
| | **Crude RRs** | **Adjusted RRs** |
| *** Functional limitations - Presence of any difficulty with** | | |
| **Activities of daily living** | | |
| Injured vs Uninjured | 1.75 (1.42, 2.15) | 1.92 (1.56, 2.36) |
| **Large muscle index** | | |
| Injured vs Uninjured | 1.20 (1.06, 1.36) | 1.18 (1.04, 1.35) |
| **Gross motor skills** | | |
| Injured vs Uninjured | 1.57 (1.33, 1.86) | 1.69 (1.43, 1.99) |
| **Fine motor skills** | | |
| Injured vs Uninjured | 1.86 (1.52, 2.27) | 2.09 (1.70, 2.55) |
| **Mobility index** | | |
| Injured vs Uninjured | 1.31 (1.15, 1.48) | 1.37 (1.20, 1.56) |
| ****Working reduced hours** | | |
| Injured vs Uninjured | 0.97 (0.87, 1.07) | 1.18 (1.08, 1.28) |

*Adjusted for age, gender, race, education, work category, and hours worked
** Additionally adjusted for having a second job

**Figure 1: Directed acyclic graph representing work-requirement factors as the exposure and injuries as the outcome, along with confounding variables**



## CHAPTER V - MANUSCRIPT 2

# A LONGITUDINAL STUDY OF WORK-RELATED PSYCHOSOCIAL FACTORS AND INJURIES: IMPLICATIONS FOR THE AGING UNITED STATES WORKFORCE


## ABSTRACT

### INTRODUCTION

Work life involves several demands that may exceed an employee's capabilities and lead to injuries, especially among aging workers. This study aimed to identify psychosocial work factors that may individually or, in combination with other factors, shape injury experiences among aging United States (U.S.) workers.

### METHODS

Longitudinal cohort data from the U.S. Health and Retirement Study (HRS) of 3,305 working adults aged 50 years and above, were used to estimate the relations between work-related psychosocial factors and injury incidences from 2006-2014. Information on the socio-demographic and work-related characteristics of concern was obtained from HRS survey waves preceding those from which injuries were obtained. Incidence rate ratios of injuries were estimated using generalized estimating equations. Estimates were adjusted for personal, demographic, and work-related characteristics; these potential confounders were identified a priori with directed acyclic graphs.

### RESULTS

Employees who perceived their work to be high in psychological and physical demands/efforts, low in support, and rewards, compared to those in workplaces with low demands, high support, and high rewards, had a risk nearly two times greater for experiencing injuries. Males compared with females, had a greater

risk for injuries when interactions among several psychosocial work-related factors were modeled.

## CONCLUSIONS

Although the injury-related experiences appeared comparable when the relation between individual psychosocial factors were explored, important gender-based differences were identified when interactions between the psychosocial factors were modeled.

## INTRODUCTION

Recent evolutionary changes in the organization of work activities that have outpaced knowledge about their impact may affect the health of the workforce by several pathways that increase the risk of stress-related illnesses and injuries (Landsbergis, 2003). Specifically, today's work life involves several types of psychological demands and forms of controls, and resources for meeting such demands (Clougherty et al., 2010). An imbalance between such demands and resources may lead to increased stress. This stress may, in turn, increase an individual's risk for injuries or illnesses (Sauter et al., 1999, Landsbergis, 2003), which have been associated with an annual total economic burden of $250 billion in the United States (U.S.) (Leigh, 2011). Not only is there a dearth of studies using standardized generic questionnaires to measure such stressors, but much remains uncovered regarding characteristics of the stressors and their effects on health and safety at work (Landsbergis, 2003).

The relations between stressors and health outcomes are affected not only by the stressors but also by individual characteristics. While stress responses in young, healthy individuals may be adaptive and not impose a health risk, if it is unremitting over the long-term, particularly in older or unhealthy individuals, it may affect health (Schneiderman et al., 2005). Aging workers are also at a higher risk of experiencing more severe injury outcomes. The Bureau of Labor Statistics (BLS) reported that, in 2015, the overall incidence rate of days away from work was 104 cases per 10,000 full-time equivalent (FTE) workers. Those aged 55-64 years had one of the highest incidence rates among all occupations (116 cases per 10,000 FTE) (BLS, 2017). Additionally, those aged 65 years, and above, experienced a fatal injury rate that was four-times greater than for those between 25-34 years (BLS, 2017). Integral to this issue, is that the proportion of aging employees in the U.S. workforce is increasing and, by the year 2020, will comprise of 25% of the workforce.

Research further indicates that combinations of multiple stressors that may act together may be more potent than single stressors (Schneiderman et al., 2005). However, even individual stressors may also be associated with poor health and safety outcomes. For example, poor work-related social support from co-workers and supervisors has been found to have an independent association with work-related injuries (Vafaei and Kristman, 2013). On the other hand, Karasek's work strain model is an example of a model that suggests that work-related strain results from the interaction between the perceived task-level psychological and physical demands at work and work decision latitude or control. This strain may be associated with several adverse health and safety outcomes ( Karasek, 1979).There is some evidence from selected occupations and small-medium sized enterprises that have documented relations between combinations of demands and control, and work-related injuries (Nakata et al., 2006, Lee et al., 2015). There is also evidence from selected occupational groups that individual components of the strain model i.e., work demands and control may have an independent association with work-related injuries (Rugulies and Krause, 2005, Cantley et al., 2015). This work-related strain, further in combination with low work support, is considered to be a more harmful stressor than strain alone and entails a greater risk of work-related injuries (Johnson and Hall, 1988, Fischer et al., 2005).

Another model is the work-based effort-reward imbalance model; while it does not consider work control-related domains like the work strain model (Siegrist, 1996, Ostry et al., 2003), it overlaps with the latter model in terms of extrinsic task-level demands. The effort-reward imbalance model, however, considers intrinsic personality characteristics which may influence the perceived stressors and resultant hazards (Siegrist, 1996). This model has been also shown to be independently associated with certain types of injuries (Rugulies and Krause, 2008). Over-commitment to work, a personality trait considered in this model, may also lead to work-family conflict and play an important role in shaping the workforce's safety and health outcomes. However, occupational health psychology frameworks have rarely studied these aspects together (Krisor and Rowold, 2013, Turner et al., 2014). Interestingly, it has been suggested that work-family conflict (work-related demands interfering with family responsibilities), but not family-work conflict (family life impeding work activities), is related to work-related injuries (Vermeulen and Mustard, 2000).

Much of the presented evidence, even though limited, comes from cross-sectional studies, primarily focused on small, selected populations (Vermeulen and Mustard, 2000, Nakata et al., 2006, Cantley et al., 2015, Kim et al., 2009). Additionally, many previous studies have focused only on specific, rather than all categories of potentially stressful work-related factors. Research efforts are needed to provide a holistic understanding of how various work-related psychosocial factors and their interactions influence injury experiences at work. Further, it is important to understand how socio-demographic characteristics like gender, race, ethnicity, age, and health-related factors play a role in this complex mechanism (Johnson and Hall, 1998, Vermeulen and Mustard, 2000, Rugulies and Krause, 2005, Rugulies and Krause, 2009). Studies have also suggested that gender is an effect modifier in the relation between psychosocial work stressors and injuries (Vermeulen and Mustard, 2000). Research on aging workers is especially needed because not only are they at risk for injuries but, also, they may experience more severe consequences because of the injuries (Landsbergis, 2003, BLS, 2017).

The present study enabled investigation of the associations between a spectrum of psychological work-related factors and injury occurrences among a working cohort of aging U.S. adults. In addition to investigation of the standard psychosocial factors (Seigrist, 1996, Ostry et al., 2003, Vafaei and Krsitman, 2013, Turner et al., 2014), other factors, and their interactions, that might shape injury experiences of the aging workforce, were also included.

**METHODS:**

Approval to conduct this study was obtained from the Institutional Review Board, University of Minnesota, under the exempt review. The cohort for this repeated-measures study was obtained from the Health and Retirement Study (HRS), a biennial nationally representative longitudinal panel study of U.S. adults aged 50 years and above that has been active since 1992. HRS has maintained a response rate of over 85% for all survey waves. Data pertaining to the study variables were obtained from various HRS survey modules (Sonnega et al., 2014). While the core HRS survey facilitates data collection every two years, the HRS module that provides longitudinal information regarding work-related psychosocial factors is available only *every four years*. Pilot-tested on a random 10% of the study sample in 2004, the HRS's self-administered psychosocial and lifestyle (PSL) questionnaire has enabled collection of biennial information regarding participants' evaluations of their life circumstances, subjective well-being, and lifestyle, including evaluations of work-related factors since 2006.

The latter part of the survey, including work-related psychosocial factors, was administered only to those working for pay. A random (rotating) sample of

50% of the core panel participants receives the PSL questionnaire every biennial survey wave. The alternating 50% receives it during the next survey wave. Thus, the longitudinal data are available only at four-year intervals (Sonnega et al., 2014, PSL). Two separate sub-cohorts, with one obtained from the year 2006 HRS survey wave, and the other from the 2008 wave, formed the cohort for this study.

**Study design:** The cohort for this study includes U.S. individuals, aged 50 years and above, who were working for pay during 2006-2014 and responded to the work-related exposures section of the PSL questionnaire. The data on demographic characteristics, personal, and work-related characteristics, including work-related psychosocial factors were obtained from 2006-2012. The data on outcomes i.e. work-related injuries were obtained from the waves after these i.e., from 2008-2014. In order to make causal assumptions considering exposure and outcome temporality (Hill, 2015), data on the outcome, i.e., work-related injuries were obtained from waves subsequent to each PSL survey wave. Thus, data on injuries were obtained from the respective 2008-2014 survey waves.

**Setting and study sample:** As explained earlier, due to a rotating sample of PSL surveys, two separate sub-cohorts formed the sample for this study. The two study sub-cohorts, collected in 2006 and 2008, were combined to form the overall study sample of 3,305 working U.S. adults.

**Study variables:** The outcome for this study, work-related injuries was obtained from the core HRS questionnaire. Work-related injuries were defined as "any injuries at work that required special medical attention or treatment or interfered with your work activities." Those who reported having a work-related injury were further asked about the number or counts of such events. The primary exposures of interest i.e., work-related psychosocial factors, measured on a four-level Likert scale, were obtained from the work-related psychosocial exposures section of the PSL questionnaire (Table 1). Information was obtained regarding perceptions about physical work demands, salary adequacy, promotion aspects, work security, workload, freedom, skill development, control, need to work fast, conflicting work demands, and work-personal life conflict. The stated variable exposures were used to evaluate the relations between work-related strain (Karasek, 1996), effort-reward imbalance (Seigrist, 1996), work-related support (Johnson and Hall, 1988), work-family conflict (Turner et al., 2014), along with the interactions among the stated factors (Fischer et al., 2005), and the outcome of injuries.

Other variables considered that could be potential confounders, included: socio-demographic characteristics i.e., respondents' age as of the survey wave, gender, race, ethnicity, education, marital/partner status, being born in the U.S. or not; health-related information regarding presence of chronic physical and mental health conditions, and presence of depression-related symptoms since two weeks prior to the interview (acute depression); lifestyle factors of number of alcoholic drinks consumed per week, and smoking behavior; and total household assets and income. Also included, were other work-related characteristics including: work category grouped as white collar, blue collar, and service; total hours worked during each wave in primary and second employment, if any; work status assessed as full-time, part-time, and partly-retired; having a second job; wages; tenure in the current work; and any previous history of work-related injuries (Rugulies and Krause, 2005, Rugulies and Krause, 2008). All of these, as indicated earlier, were obtained from the core HRS questionnaire that is administered biennially.

**Statistical methods:** Similar to previous studies (Rugulies and Krause, 2005, Rugulies and Krause, 2009, Kim et al., 2009, Vafaei and Krsitman, 2013), psychosocial work factors including work demands, work control, efforts put into the work, rewards obtained from the work, and work-family conflict were created by summarizing the respective individual factors (Table 1). The remaining work condition (i.e., support at work) was used as recorded in the survey. For the factors created, by summarizing several individual factors, a researcher (Kim et al., 2009) suggested using the median to signify high and low exposures. For example, a summary score was first calculated for each individual's survey wave for specific work demands. Then, the overall median score for work demands was estimated, and an individual, whose score was above the median, was considered to have high work demands and vice versa. Next, work-related strain, and effort-reward imbalance scales were created by dividing the total psychological work demands by work control (Work-related strain = Work demands / Work control), and total work-related efforts by the rewards obtained (Effort-reward imbalance = Work-related efforts or demands / Rewards obtained), respectively. Values on the scale that were greater than one were considered high and those at or below one were considered low (Rugulies and Krause 2008).

Directed acyclic graphs (DAGs) were developed *a priori* to graphically represent the hypothesized associations between the psychosocial exposures of interest and the outcome, and to select potential confounders for adjustment for each of the individual multivariable models (Greenland et al., 1999). DAGs have an advantage over traditional techniques for confounder selection because, in contrast to other methods, they enable identification of variables that may introduce conditional associations and bias if included in the statistical models

(Shrier and Platt, 2008). DAGs are recognized as tools that are based on the formal rules used to derive mathematical proofs (Elwert, 2013). Figure 1 depicts a DAG developed in accordance with *a priori* hypothesized causal assumptions, using work-related psychosocial factors as the exposure of interest and work-related injuries as the outcome. In this figure, the *essential set of confounders,* as represented by grey background-highlighted boxes include the following: age; race; ethnicity, marital/partner status; chronic physical and mental health conditions; acute depression; alcohol consumption; work category; work status; and work tenure. Other variables considered, and also presented earlier included: education status; marital/partner status; having been born in the U.S. or not; total household assets and income; smoking status; having a second work position; and work status. These latter variables were either not related to the exposure of interest and the outcome, or were associated with them through another variable that had already been identified as a confounder in the DAG, shown in Figure 1.

Work-related injuries were modeled as the number of injury events (counts); the exposure time used was total hours worked since the last interview wave. Incidence rate ratios (IRRs) were estimated using the generalized estimating equations (GEE) with a negative-binomial error distribution and accounting for within-person and within-household correlations (Ballinger, 2004). The models were then stratified by gender, as suggested by previous researchers (Vermeulen and Mustard, 2000). In study waves where there was missing exposure information, the last available observation was carried forward to impute the missing value. All analyses were conducted using SAS statistical software (SAS, 2015).

**RESULTS:**

From the overall study cohort of 3,305 persons, 158 persons (4.6%) experienced at least one work-related injury between 2006 and 2014 (Table 2). At baseline, most injured males and females were in the 50-<60 year age group. The majority of those injured were White/Caucasian, non-Hispanic, and were U.S. born. While over half of the injured males were employed in blue-collar occupations, less than 10% of the injured females had such employment. In general, perceptions about various psychosocial factors were similar between both genders.

The data were then analyzed using unadjusted and multivariable regression models (GEE), stratified by gender as discussed before. Tables 3 and 4, respectively, present the gender stratified crude and adjusted rate ratios as obtained from GEE models for each of the individual psychosocial factors, and their interactions.

Table 3 shows that males and females who perceived their workplaces to have high versus low demands, had a greater risk for experiencing a work-related injury event. Although high versus low work-related strain, demonstrated similar elevated risks for both genders, this was significant only for women. As also shown in Table 3, low support, low rewards, and high effort-reward imbalance, compared with high support, high rewards, and low effort-reward imbalance respectively, were all associated with risks for injuries twice as high in both genders.

Table 4 presents estimates for the associations between interactions among various psychosocial factors and work-related injuries. As is illustrated in the table, an interaction of both work demands and control with work support showed that high demands, in combination with low support, compared with low demands and high support contributed to the highest risks for injuries in both genders. The effect was more pronounced among males. Females employed in high strain and low support workplaces, compared with those in low strain and high support workplaces, had a risk of injury two times greater. Further, high work-related efforts, combined with high work-family conflict, compared with a combination of low efforts and low conflict, were associated with a higher risk for injuries only among males. For both genders, the risk for injuries was almost twice as high among those who experienced high versus low effort-reward imbalance, and high versus low in work-family conflict. Further, low effort-reward imbalance and high work control, compared with high effort-reward imbalance and high control were associated with higher risk for injuries for both genders.

**DISCUSSION:**

Through this study, multivariable gender-stratified models showed that males and females who perceived their workplaces to have high, compared with low, work demands had risks nearly two times greater for work-related injury occurrences. Low, versus high, work control among males, in the current study, was also associated with a higher but not important risk for experiencing a work-related injury event. In a previous study (Kim et al., 2009), this risk among both genders was about two-times greater if they reported high psychological work demands. Similarly, a study (Johnson and Hall, 1988) conducted among adolescent workers in Brazil reported that, high work demands compared to low psychological demands, were associated with a greater risk of experiencing injuries. It was also observed that the higher the scale score, the higher the prevalence of work-related injuries [odds ratio=3.0 (p=0.02)]. Results from the study also suggested that lower work control could have serious consequences as adolescent workers with lower control tended to do more daily work on average. Another study (Lee et al., 2015), conducted in a cohort of aluminum production and maintenance workers across all ages, found that those with high, compared with low, work demands had a 49% higher risk of experiencing a serious injury. Further, workers engaged in low, versus high, control work were found to have a significantly higher risk for injuries.

From the current study, analysis conducted with work support as the exposure of interest and injuries as the outcome, revealed that those who perceived low versus high support at their workplaces had over twice the risk for experiencing injuries. A previous cross-sectional Canadian study (Fischer et al., 2005) reported that both males and females, 15-74 years of age, who had high versus low social support at their workplaces, were significantly less likely to report a repetitive strain injury. Another review (Bongers et al., 2002) showed that the magnitude of risks (odds ratios, or risk ratios) for experiencing musculoskeletal problems, among those who experienced low versus high support, ranged from 1.2-2.1.

The current research further examined combinations of work-related psychosocial factors, with social support at the workplace. The results indicated that males engaged in high demand and low support work, compared with those in low demand and high support work, had a risk of injury occurrence over four times greater. Of further interest, males working in occupations with low control and high support, compared with high control and high support, had an increased risk for injuries. Also, in females, high strain (high work demands and low control) in combination with low support, compared with low strain and high support, was associated with a risk of injury that was nearly two times greater. From a previous longitudinal study (Rugulies and Krause, 2005), conducted among transit operators, it was reported that the hazard rate (HR) for experiencing an injury was not significant, but increased [HR: 1.41 (95% CI=0.98–2.01)] among those who perceived their workplaces involved high strain and low support, compared to those with high strain and high support.

Another finding in the current study was that high, compared with low effort-reward imbalance was associated with a risk for injuries that was twice as great in both genders. In another study (Rugulies and Krause, 2009), high compared to low effort-reward imbalance, was found to be associated with a higher risk for neck injuries among transit drivers [HR: 1.66 (CI=1.16-2.38)]. Further, the current research found that males with high imbalance at work and low work control, compared to those with low imbalance and high work control, had a risk nearly three times greater for experiencing injuries. A previous study (Ostry et al., 203) that involved male sawmill workers found that high versus low imbalance was associated with a risk three times higher for reporting poor health status. The study also found that this imbalance along with low control with reference to no imbalance and high control was also associated with a greater risk for reporting poor health status.

In the current study, combinations of high work-related efforts with work-family conflict, compared to low efforts and conflict were associated with a risk for injuries nearly three times greater among males. Specifically, effort-reward imbalance was more strongly associated with injuries than work-family conflict. In contrast, a previous study (Hammig et al., 2012) found that work-family interference was more strongly associated with stress and burnout, compared to effort-reward imbalance.

This comprehensive repeated measures longitudinal study in the cohort of aging U.S. workers, enabled estimations of incidence rate ratios while adjusting for within-person and within-household correlations. The study design also allowed for the identification of potential causal associations, with consideration of temporality. However, the results of this study must be interpreted with recognition of potential limitations. Firstly, the results may not be valid for younger workers and working populations in general, as they may have had exposures different from those of the cohort for this study. The results may also not be generalizable to other countries. In addition, the data used for these analyses are based on self-report and, thus, may be biased away from the null, especially among those who experienced injury events. This is because those injured may remember their exposures better or may have exaggerated perceived psychosocial factors. As a result, differential misclassification resulting from reporting bias of the exposures may have occurred by injury status. Table 1 also indicates that a higher proportion of injured versus uninjured workers perceived their workplaces to be high in psychological and physical demands. Hence, it is possible that the observed risk is overestimated.

**CONCLUSIONS:**

This study suggests that aging workers face several psychosocial stressors in, their workplaces, which increases their risk of experiencing injuries. Importantly, there are significant gender differences among aging employees with respect to their perception of work-related psychosocial factors and experience with injuries. Even though the associations between individual psychosocial factors and injuries were comparable between genders, important gender-based differences were identified when the modeled exposures included respective combinations of two psychosocial factors. It is, therefore, important to understand and obtain a full picture of an employee's psychosocial work environment and understand how various factors may act together and affect injury occurrences in their workplaces. Future researchers must explore specific mechanisms of how such psychosocial factors in the workplace may interact to shape the injury experiences of the employees.

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**Table 1: Psychosocial work-related factors and the respective questions from the PSL questionnaire**

| Work-related psychosocial factors | Respective questions |
|---|---|
| *Work demands (created by summarizing three psychological and one physical demand) | I am under constant time pressure due to a heavy workload.<br>Considering the things I have to do at work, I have to work very fast.<br>In my work, I am free from conflicting demands that others make.<br>My work is physically demanding. |
| Work control | I have very little freedom to decide how I do my work.<br>I have the opportunity to develop new skills.<br>At work, I feel I have control over what happens in most situations. |
| Support at the work | I receive adequate support in difficult situations. |
| *Efforts involved in the work (physical and psychological work demands) | I am under constant time pressure due to a heavy workload.<br>Considering the things I have to do at work, I have to work very fast.<br>In my work, I am free from conflicting demands that others make.<br>My job is physically demanding. |
| Rewards obtained from the work | I receive the recognition I deserve for my work.<br>My salary is adequate.<br>My job promotion prospects are poor.<br>My job security is poor. |
| **Work-family conflict | Work makes personal life difficult.<br>Other people determine most of what I can and cannot do.<br>What happens in my life is often beyond my control. |

*Both work demands and efforts measure “task-level” demands
**Intrinsic characteristic; measured as rarely, sometimes, often, and most of the time (all others measured as strongly disagree, disagree, agree, and strongly agree)

**Table 2: Baseline demographic and other personal characteristics of the study cohort of United States aging workers, by injury status (N=3,305)**

| **Variables** | **Injured (n=158)** | | **Uninjured (n=3,147)** | |
|---|---|---|---|---|
| | Males n=74 | Females n=84 | Males n=1,434 | Females n=1,713 |
| | Number (%) | | | |
| Demographic and other personal factors: | | | | |
| *Age-groups* | | | | |
| 50-<60 year old | 42 (56.8) | 55 (65.5) | 655 (45.7) | 898 (52.4) |
| 60-<65 year old | 21 (28.4) | 20 (23.8) | 532 (37.1) | 588 (34.3) |
| 65 years and above | 8 (10.8) | 5 (6.0) | 231 (16.1) | 176 (10.3) |
| *Race* | | | | |
| White/Caucasian | 62 (83.8) | 67 (79.8) | 1,235 (86.1) | 1,390 (81.1) |
| Black | 10 (13.5) | 12 (14.3) | 123 (8.6) | 221 (12.9) |
| Others | 2 (2.7) | 5 (6.0) | 76 (5.3) | 102 (5.9) |
| *Ethnicity* | | | | |
| Hispanic | 7 (9.46) | 10 (11.9) | 120 (8.4) | 119 (7.0) |
| Non-Hispanic | 67 (90.5) | 74 (88.1) | 1,314 (91.6) | 1,594 (93.1) |
| *Place of birth* | | | | |
| U.S. born | 67 (90.5) | 76 (90.5) | 1,304 (90.9) | 1,564 (91.3) |
| Born elsewhere | 7 (9.5) | 8 (9.5) | 125 (8.7) | 146 (8.5) |
| *Education* | | | | |
| GED/Left high-school | 15 (20.3) | 10 (11.9) | 190 (13.2) | 217 (12.7) |
| High-school graduate | 26 (35.1) | 26 (30.9) | 341 (23.8) | 510 (29.8) |
| Some college | 19 (25.7) | 26 (31.0) | 344 (24.0) | 508 (30.0) |
| College or above | 14 (18.9) | 22 (26.2) | 559 (39.0) | 478 (27.9) |
| *Marital Status* | | | | |
| Married/partnered | 58 (78.4) | 54 (64.3) | 1,240 (86.5) | 1,189 (69.4) |
| Separated/divorced/widowed/never married | 15 (20.3) | 30 (35.7) | 185 (12.9) | 508 (29.7) |
| *Net household income and assets ($)* | | | | |
| <= 210,000 | 41 (55.4) | 51 (60.7) | 601 (41.9) | 839 (49.0) |
| >210,000 | 33 (44.6) | 33 (39.3) | 833 (58.1) | 874 (51.0) |
| *Average number of alcoholic drinks consumed per week* | | | | |
| 0 | 37 (50.0) | 58 (69.1) | 687 (47.9) | 1,079 (63.0) |

| | | | | |
|---|---|---|---|---|
| 1-5 | 15 (20.3) | 20 (23.8) | 373 (26.0) | 387 (22.6) |
| 6 or more | 20 (27.0) | 6 (7.1) | 361 (25.2) | 229 (13.4) |
| *Number of chronic health problems* | | | | |
| 0 | 13 (17.6) | 16 (19.1) | 381 (26.6) | 442 (25.8) |
| 1 | 38 (51.4) | 23 (37.4) | 478 (33.3) | 541 (31.6) |
| 2 or more | 22 (29.7) | 43 (53.6) | 566 (39.5) | 714 (41.7) |
| *Acute depression* | | | | |
| Yes | 38 (51.3) | 53 (63.1) | 548 (38.2) | 781 (45.6) |
| No | 34 (45.9) | 31 (36.9) | 852 (59.4) | 910 (53.1) |
| *Previous work-related injury history* | | | | |
| Previously injured | 19 (25.7) | 12 (14.3) | 1,266 (88.3) | 1,503 (87.7) |
| Previously uninjured | 55 (74.3) | 69 (82.1) | 147 (10.3) | 172 (10.0) |
| Work-related characteristics: | | | | |
| *Work category* | | | | |
| White-collar | 16 (21.6) | 46 (54.8) | 809 (56.4) | 1,123 (65.6) |
| Service | 14 (18.9) | 29 (34.5) | 215 (15.0) | 465 (27.1) |
| Blue-collar | 39 (52.7) | 7 (8.3) | 383 (26.7) | 100 (5.8) |
| *Work status* | | | | |
| Full-time | 59 (79.7) | 61 (72.6) | 1,042 (72.7) | 1,066 (62.2) |
| Part-time or partly-retired | 14 (18.9) | 23 (27.4) | 383 (26.7) | 631 (36.8) |
| *Tenure in the current work* | | | | |
| Five years or less | 29 (39.2) | 29 (34.5) | 495 (34.5) | 662 (38.6) |
| More than five years | 43 (58.1) | 51 (60.7) | 920 (64.2) | 1,024 (59.8) |
| Work-related psychosocial factors: | | | | |
| *Work demands or Efforts involved in the work* | | | | |
| High | 46 (62.2) | 47 (56.0) | 619 (43.2) | 688 (40.2) |
| Low | 28 (37.8) | 34 (40.5) | 792 (55.2) | 1979 (57.2) |
| *Work control* | | | | |
| Low | 46 (62.2) | 47 (56.0) | 781 (54.5) | 989 (57.7) |
| High | 26 (35.1) | 35 (41.7) | 636 (44.4) | 684 (40.0) |
| *Work-related strain (Work demands/Control)* | | | | |
| High | 13 (17.6) | 18 (21.4) | 168 (11.7) | 228 (13.3) |
| Low | 59 (79.7) | 62 (73.8) | 1,237 (86.3) | 1,420 (83.0) |
| *Support at the work* | | | | |
| Low | 16 (21.6) | 18 (21.4) | 240 (16.7) | 276 (16.1) |

| | | | | |
|---|---|---|---|---|
| High | 56 (75.7) | 65 (77.4) | 1,177 (82.1) | 1,416 (82.7) |
| *Rewards obtained from the work* | | | | |
| Low | 41 (55.4) | 50 (59.5) | 692 (48.3) | 875 (51.1) |
| High | 31 (41.9) | 26 (31.0) | 688 (48.0) | 764 (44.6) |
| *Effort-Reward Imbalance (Efforts involved in the work / Rewards obtained from the work)* | | | | |
| High | 25 (33.8) | 30 (35.7) | 286 (19.9) | 348 (20.3) |
| Low | 47 (63.5) | 45 (53.6) | 1,083 (75.5) | 1,262 (73.4) |
| *Work-family conflict* | | | | |
| High | 44 (59.5) | 45 (53.6) | 638 (44.5) | 753 (44.0) |
| Low | 28 (37.8) | 36 (42.9) | 787 (54.9) | 943 (55.1) |
| Note: Missing values are not shown | | | | |

**Table 3: Associations between each of the work-related psychosocial factors and injuries in the study cohort of aging United States workers (N=3,305): Crude and adjusted analyses**

| **Work-related psychosocial factors** | **Counts (number) of work-related injury events** | | | |
|---|---|---|---|---|
| | Crude IRR (95% CI) | | *Adjusted IRR (95% CI) | |
| | Males | Females | Males | Females |
| *Work demands or Efforts involved* | | | | |
| High vs Low | 2.66 (1.64, 4.34) | 1.69 (1.15, 2.50) | 2.63 (1.50, 4.64) | 1.68 (1.07, 2.62) |
| *Work control* | | | | |
| Low vs High | 1.58 (0.95, 2.62) | 1.18 (0.79, 1.76) | 1.48 (0.88, 2.50) | 0.94 (0.61, 1.47) |
| *Work-related strain (Work demands / Work control)* | | | | |
| High vs Low | 2.52 (1.00, 6.37) | 2.06 (1.34, 3.18) | 1.65 (0.68, 4.00) | 1.73 (1.06, 2.81) |
| *Support at the work* | | | | |
| Low vs High | 2.34 (1.06, 5.18) | 1.18 (0.73, 1.90) | 2.48 (1.34, 4.57) | 2.47 (1.53, 3.98) |
| *Rewards* | | | | |
| Low vs High | 1.30 (0.73, 2.33) | 1.73 (1.12, 2.67) | 1.73 (1.12, 2.67) | 1.78 (1.13, 2.80) |
| *Effort-Reward Imbalance (Efforts / Rewards)* | | | | |
| High vs Low | 2.87 (1.49, 5.50) | 2.02 (1.32, 3.07) | 1.91 (1.01, 3.62) | 1.78 (1.13, 2.80) |
| *Work-family conflict* | | | | |
| High vs Low | 1.84 (0.95, 3.58) | 1.28 (0.85, 1.93) | 1.22 (0.70, 2.13) | 1.04 (0.67, 1.60) |

*Adjusted for Age, Race, Ethnicity, Marital status, Presence of chronic physical and mental health conditions, Presence of acute depression, Number of alcoholic drinks consumed per week, Work status, Work category, Work tenure, and Previous history of injuries

**Table 4: Associations between different combinations of individual work-related psychosocial factors and injuries in the study cohort of aging United States workers (N=3,305): Crude and adjusted analyses**

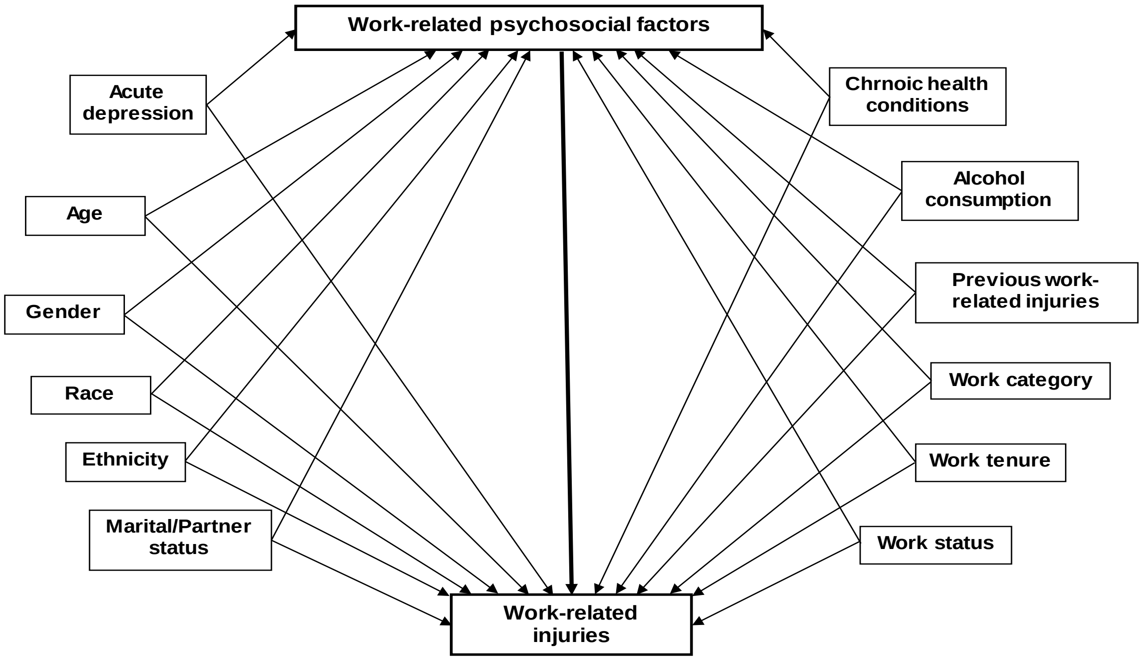
| **Work-related psychosocial factors** | **Counts (number) of work-related injury events** | | | |
|---|---|---|---|---|
| | Crude IRR (95% CI) | | *Adjusted IRR (95% CI) | |
| | Males | Females | Males | Females |
| *Work-related demands or Efforts* X *Support at the work* | | | | |
| Low demands X High support | 1 | 1 | 1 | 1 |
| Low demands X Low support | 1.37 (0.42, 4.50) | 0.68 (0.25, 1.85) | 1.19 (0.26, 5.37) | 0.37 (0.09, 1.52) |
| High demands X High support | 2.31 (1.37, 3.90) | 1.51 (0.98, 2.33) | 2.20 (1.15, 4.19) | 1.44 (0.88, 2.35) |
| High demands X Low support | 5.19 (2.09, 12.88) | 1.95 (1.11, 3.43) | 4.34 (1.81, 10.41) | 1.82 (0.99, 3.23) |
| *Work control* X *Support at the work* | | | | |
| High control X High support | 1 | 1 | 1 | 1 |
| High control X Low support | 2.52 (1.10, 5.74) | 1.35 (0.73, 2.51) | 2.55 (1.05, 6.20) | 1.12 (0.58, 2.15) |
| Low control X High support | 2.05 (1.08, 3.91) | 0.73 (0.30, 1.75) | 2.40 (1.16, 4.95) | 0.64 (0.24, 1.71) |
| Low control X Low support | 1.51 (0.54, 4.23) | 1.35 (0.70, 2.60) | 1.26 (0.40, 4.04) | 1.06 (0.51, 2.22) |
| *Work-related strain* X *Support at the work* | | | | |
| Low strain X High support | 1 | 1 | 1 | 1 |
| Low strain X Low support | 1.69 (0.78, 3.70) | 0.57 (0.22, 1.46) | 1.57 (0.61, 4.04) | 0.48 (0.17, 1.35) |
| High strain X High support | 1.67 (0.86, 3.24) | 1.57 (0.84, 2.92) | 1.19 (0.51, 2.75) | 1.19 (0.60, 2.35) |
| High strain X Low support | 3.90 (1.12, 13.66) | 2.30 (1.35, 3.92) | 2.20 (0.66, 7.36) | 1.97 (1.08, 3.59) |
| *Efforts involved in the work* X *Work-family conflict* | | | | |
| Low efforts X Low conflict | 1 | 1 | 1 | 1 |
| Low efforts X High conflict | 1.07 (0.53, 2.15) | 0.90 (0.47, 1.74) | 1.03 (0.47, 2.25) | 0.65 (0.33, 1.28) |
| High efforts X Low conflict | 2.15 (0.79, 5.90) | 1.34 (0.76, 2.37) | 2.13 (0.81, 5.58) | 1.22 (0.64, 2.32) |
| High efforts X High conflict | 2.92 (1.66, 5.13) | 1.77 (1.09, 2.88) | 3.17 (1.61, 6.21) | 1.52 (0.84, 2.74) |

| | | | | |
|---|---|---|---|---|
| *Rewards obtained* X *Work-family conflict* | | | | |
| High rewards X Low conflict | 1 | 1 | 1 | 1 |
| High rewards X High conflict | 1.90 (0.87, 4.13) | 1.43 (0.70, 2.92) | 1.96 (0.83, 4.60) | 1.02 (0.46, 2.23) |
| Low rewards X Low conflict | 1.64 (0.66, 4.08) | 1.82 (0.99, 3.35) | 1.30 (0.50, 3.38) | 1.65 (0.85, 3.20) |
| Low rewards X High conflict | 1.66 (0.95, 2.92) | 2.30 (1.29, 4.09) | 1.39 (0.74, 2.61) | 1.82 (0.99, 3.33) |
| *Effort-Reward Imbalance* X *High work-family conflict* | | | | |
| Low imbalance X Low conflict | 1 | 1 | 1 | 1 |
| Low imbalance X High conflict | 2.02 (1.11, 3.67) | 1.03 (0.61, 1.74) | 2.20 (1.13, 4.29) | 0.87 (0.49, 1.55) |
| High imbalance X Low conflict | 7.67 (2.34, 25.20) | 1.52 (0.70, 3.31) | 4.61 (1.46, 14.57) | 1.17 (0.48, 2.82) |
| High imbalance X High conflict | 2.94 (1.63, 5.30) | 2.32 (1.39, 3.86) | 2.66 (1.36, 5.20) | 1.85 (1.04, 3.30) |
| *Effort-Reward Imbalance* X *Low work control* | | | | |
| Low imbalance X High control | 1 | 1 | 1 | 1 |
| Low imbalance X Low control | 1.70 (0.84, 3.45) | 1.28 (0.62, 2.64) | 1.40 (0.51, 3.87) | 0.89 (0.32, 2.51) |
| High imbalance X High control | 3.27 (1.57, 6.79) | 2.27 (1.43, 3.62) | 2.50 (1.28, 4.87) | 1.88 (1.15, 3.10) |
| High imbalance X Low control | 2.09 (0.82, 5.33) | 1.15 (0.45, 2.95) | 2.70 (1.23, 5.90) | 0.97 (0.42, 2.20) |

*Adjusted for Age, Race, Ethnicity, Marital status, Presence of chronic physical and mental health conditions, Presence of acute depression, Number of alcoholic drinks consumed per week, Work status, Work category, Work tenure, and Previous history of injuries

X: Combination of individual psychosocial factors

**Figure 1: A directed acyclic graph (DAG) with work-related strain as the primary exposure of interest and work-related injury as the outcome, along with confounding variables**



# CHAPTER VI - MANUSCRIPT 3

## A MARGINAL STRUCTURAL MODEL APPROACH TO ANALYZE WORK-RELATED INJURIES: AN EXAMPLE USING DATA FROM THE HEALTH AND RETIREMENT STUDY


### ABSTRACT

#### INTRODUCTION

Statistical approaches that condition on the confounders may be inappropriate if the data are time-varying. Marginal structural models (MSMs) can provide valid estimates of the effect of time-varying exposures on the outcome.

#### PURPOSE

This research effort demonstrates the use of MSMs to analyze work-related injuries. Injuries as an outcome are unique since previous injuries could themselves be predictors for future injuries, exposures, and other covariates as well.

#### METHODS

7,212 working United States (U.S.) adults, aged 50 years and above who responded to the year 2004 of the Health and Retirement Study, form the study cohort that was followed until 2014. The analyses compared effect estimates measuring the associations between physical work requirements and work-related injuries using the MSMs and generalized estimating equations (GEEs). Stabilized person- and wave-specific inverse probabilities of exposures and censoring weights, incorporating previous injuries, provided the parameters for the MSMs. A product of weights was not estimated; therefore, the analysis was not restricted to complete cases.

## RESULTS

The effect estimates were consistent between the MSMs and GEEs with regard to strength and directionality. However, the effect estimate was 50% greater when the same data were analyzed using MSMs.

## CONCLUSIONS

Traditional regression models may induce bias if the data are time-varying; thus, MSMs may be more appropriate. Although estimates obtained from the MSMs are also subject to some assumptions, these are less restrictive than traditional models. This research proposes a methodology that can be used by future researchers dealing with recurrent outcomes.

## INTRODUCTION

Often researchers are interested in knowing the potential causal association between an exposure and the outcome of interest. However, except for randomized controlled trials, this may be difficult since the association may be affected by confounding variables. Conditional and marginal approaches can, however, be used to adjust for confounding that may exist in observational studies. A marginal approach works by creating weights that balance each substratum of covariates; estimates are then made on the weighted sample (Crowson et al., 2013). Through a weighting technique and projection, causal inferences can then be drawn from data where both the exposure and the censoring may depend on the past exposure history, other covariates, and the outcome itself (Bryan et al., 2004). In such cases, standard analysis techniques that condition on past exposure and confounder history, may produce biased estimates. This is because such techniques fail to take into account the time-varying nature of the data (Robins et al., 2000, Hernan et al., 2000, VanderWeele, 2011).

Alternatively, a class of models i.e., the marginal structural models (MSMs) can provide valid estimates of the effect of time-varying exposures on the outcome of interest (Robins, 1999, Robins et al., 2000, Hernan et al., 2002, VanderWeele, 2011). These models are called “marginal,” because rather than modeling the joint distribution, they model the marginal distribution of a counterfactual outcome (Robins et al., 2000). In this process, the observations are re-weighted such that potential confounders existing prior to the treatment or exposure effect are balanced (Crowson et al., 2013). Next, in the realm of econometric and social science literature, such causal models are referred to as “structural” models (Robins, 1999). The inverse probability-of-treatment or exposure or treatment weight (IPW) estimators are used to provide parameters for the MSMs. In the presence of time-varying covariates, the IPW estimators are known to be more efficient than the naïve estimators (Bryan et al., 2004).

The process of generation of IPW creates copies of each observation, therefore, forming a "pseudo-population" in which the exposure and other covariates are independent of each other (Robins et al., 2000, Hernan et al., 2000, Cole and Hernan, 2008, Li et al., 2010, Thoemmes and Ong, 2016). The term "pseudo-population" is used to signify the fact that the weighted group is not identical to the observed population; rather, it is a group that could have been sampled from a population where there was no confounding (Thoemmes and Ong, 2016). This process of using IPW can adjust both for confounding and selection bias, resulting from time-varying exposures. However, the former is contingent on four assumptions i.e., consistency, exchangeability, positivity, and no misspecification of the model used to estimate the weights (Robins, 1999).

While MSMs have been used in traditional epidemiological research for modeling chronic health outcomes for several years (Hernan et al., 2000, Nandi et al., 2011), their use in injury epidemiology research has been limited. Only one previous study (Okechukwu et al., 2016) could be identified that examined the association between work-related injuries and job loss. The current study appears to be among the first that demonstrates the use of MSMs for analyzing work-related injuries as the outcome. Work-related injuries are an important public health problem that are estimated to cost at least $250 billion, annually, in the United States (U.S.) (Leigh, 2011). Specifically, U.S. workers, aged 55 years and above, estimated to account for 25% of the workforce by 2020 (Hayutin et al., 2013), not only experience a high risk for injuries but are at an increasing risk for experiencing more severe outcomes as a result of such injuries, compared with younger workers (Grandjean et al., 2006; Silverstein, 2008, BLS, 2016).

Injuries, as an outcome, present a unique case since previous injuries could also be risk factors for future injuries, exposures, and other covariates as well. This characteristic makes analyzing injuries using MSMs different from other chronic health-related issues where the outcome occurs only once and is not recurrent. The purpose of this methodological paper is to detail the process for using MSMs to analyze work-related injuries, using a cohort of aging workers obtained from the Health and Retirement Study (HRS), and to compare the results to those of more traditional regression models.

## METHODS

Approval to conduct this study was obtained from the Institutional Review Board, University of Minnesota, under the exempt review process.

### Sample and study design

The baseline study population cohort consisted of aging U.S. workers, aged 50 years and above, who responded by self-report to the HRS survey in the year 2004. The HRS is a publicly available, and nationally-representative, multistage area probability sample of U.S. households (Sonnega et al., 2014, HRS, 2014). There were a total of 20,129 primary HRS respondents in the year 2004 (wave 7), from which this study included a cohort of 7,212 aging adults who, in the year 2004, were working for pay (Figure 1). This cohort of 7,212 adults was then followed prospectively until the year 2014, the most recent HRS wave for which data have been made available. At each study wave, following the baseline, persons who were no longer working for pay were excluded from the main analyses.

**Study variables**

Outcome: Work-related Injury: HRS defines work-related injuries as "any injuries at work that required special medical attention or treatment or interfered with your work activities." Those who reported having a work-related injury were further asked about the number or counts of such events.

Exposures: Demographic factors: Information was obtained about the respondents' age, gender, race, ethnicity, education, marital/partner status, being born in the U.S. or not, and household income and assets. Health-related factors: Information pertaining to alcohol consumption (number of drinks consumed per week), smoking behavior, presence of chronic physical and mental health conditions (high blood pressure, diabetes, heart problems, lung disease, stroke, arthritis, and psychiatric problems), and presence of depression-related symptoms in the two weeks prior to the interview (acute depression) were obtained.

Work-related characteristics: During each interview wave, these included: work category (U.S. Census-based masked categories); total hours worked in primary and second jobs, if any; work status assessed as full-time, part-time, and partly-retired; having a second job; tenure in the current workplace; and any previous history of work-related injuries. Physical work requirement, ascertained as, "does your current job require high physical effort?" was the primary exposure of interest. This was measured on a Likert scale, ranging from all/almost all of the time to none/almost none of the time. The associations between physical work requirements and injuries (Silverstein, 2008, Hollander, 2010, Nahrgang et al., 2011) were then estimated using MSMs and a traditional regression model i.e., generalized estimating equations (GEEs) (Ballinger, 2004). The physical work requirement variable was re-categorized as a binary variable. Those who reported that their workplaces entailed physical effort requirements all/almost all, most, and some of the time were identified as being employed in workplaces with high physical work requirement. Conversely, workplaces identified as having low physical requirements were those that identified such requirements as none/almost none of the time.

**Analysis**

MSMs were fit to estimate the effect of physical work requirements on work-related injuries. To accomplish this, person- and wave-specific exposure and censoring weights were first estimated. (Robins et al., 2000, Hernan et al., 2000). A directed acyclic graph (DAG) (Greenland et al., 1999) was developed *a priori* to facilitate the process (Figure 1). DAGs have previously been used in the case of time-varying covariates (VanderWeele, 2011).

In the figure, the exposure of interest i.e., physical work requirement (outcome for the person and wave-specific weight models) is denoted by the letter “A” and the integers 0, and 1 are examples of two survey time points. Accordingly, A0 represents physical work requirements at time point 0 and A1 at time point 1. Job category (Z0, Z1) is shown separately for demonstration purposes to guide the reader, while all other variables, including injuries, are indicated by variables L0, L1. Note in the DAG that the outcome i.e., work-related injuries is a time-varying variable itself and is represented along with variables in cluster L (L0, L1, Lt). Separate censoring weights were also obtained and the variables C0, and C1 denote wave-specific censoring variables. As shown, all the variables presented in the DAG demonstrate temporality i.e., those that come earlier, in time, are presented earlier in the DAG.

As guided by the DAG, at each survey wave or time point, physical work requirement, and censoring were regressed on fixed baseline, and time-varying covariate history using logistic regression models and predicted probabilities were estimated (VanderWeele, 2011). Then for each study participant, at each survey wave, both an inverse probability person- and wave-specific exposure ($W^x_{ij}$) and censoring weight ($W^c_{ij}$), accounting for those who dropped out or died, were estimated. These IPWs, explained earlier, were proportional to the inverse or reciprocal to the probability of each person receiving the exposure and censoring history that they received at each wave. Respectively, these weights accounted for the measured confounders and measured selection bias that may be created by the participants' exposures (Robins et al., 1999, Cole et al., 2008), and the study outcome of interest i.e., work-related injuries.

Weighting, however, can lead to increased variance as the sample size in the weighted data is greater than the original. This increases the possibility of type 1 error i.e., the probability of rejecting the null when it is true which can be addressed by using stabilized weights. Stabilized exposures ($SW^x_{ij}$) and censoring weights ($SW^c_{ij}$), achieved by inclusion of a numerator while creating weights can help to maintain the original sample size in the weighted data and reduce the variance (Cole et al., 2008, Xu et al., 2010, Crowson et al., 2013, Bai et al., 2015). This numerator is mostly the probability of a participant receiving his or her own exposure irrespective of other exposures (Hernan et al., 2000, Cole et al., 2008). Detailed procedures for obtaining weights, including stabilized weights, have been described previously (Robins et al., 2000, Cole et al., 2008, Li et al., 2010).

The final step for this modelling approach was, then, to run a weighted repeated measures regression model i.e., weighted GEEs (Ballinger, 2004), using the stabilized weights. Previous researchers (Hernan et al., 2002, Fewell et al., 2004, Cole et al., 2008, Nandi et al., 2011) had estimated the final weight ($SW_{ij}$) by obtaining a product of the individual wave specific weights i.e., $SW_{ij} = SW^{x}_{ij} \times SW^{c}_{ij}$. However, these previous studies involved modeling of a chronic outcome to estimate the effect that the cumulative exposure history may have had on these outcomes. Injuries, however, can be recurrent and previous injuries may not only affect future injury experiences but may also affect other exposures. Therefore, the person- and wave-standardized weight were used; a product of the weights was not obtained. Additionally, unlike chronic health-related outcomes that occur only once, if a final product of weights was used in this case, the estimates could only be calculated for the last wave. This is because injury information for all other waves would already be incorporated in the product of weights. It is important to emphasize that the repeated measures MSMs approach also generates final estimates using GEEs that are *weighted* GEEs. Separate regression models generate the person and wave-specific weights for both the exposure of interest and the censoring.

Table 1 is a dummy table representing final wave-specific weights for one person. As noted, in the table, the person with ID 1 will not have a weight in the year 2012 as the exposure information was missing. If the final weight used was a product of the wave-specific weights for this person, the person shown in the dummy table would have a missing weight. In other words, the final analyses would only be a complete case analysis (VanderWeele, 2011). Note that, other variables, represented in the DAG in Figure 1, are not shown in the table but were included in the generation of the weights. Using the individual person- and wave-specific weights, shown in the dummy table 1, allowed using all the available information from a given subject; thus, the analyses were not restricted to complete cases only. Finally, the results from traditional GEEs were compared to those from MSMs, and conclusions were drawn. In both the models, injury counts (number of injury-related events) were the outcome of interest and a negative binomial error distribution was used. Incident rate ratios (IRRs) and corresponding 95% confidence intervals (CI) were accordingly estimated.

**RESULTS**

At baseline i.e., in the year 2004, from the total sample of 7,212 aging adults in the study, 5% (n = 397) sustained at least one work-related injury; 53% of those injured were women, 77% were White/Caucasian, and 89% were Non-Hispanic. The characteristics of the study cohort are presented elsewhere (Manuscript 1).

The mean unstabilized weight was 2.07 (median = 1.15, standard deviation = 3.73, range = 189.59), while the mean stabilized weight was 1.00 (median = 0.99, standard deviation = 0.21, range = 13.13). The amount of confounding due to the time-varying covariates can be assessed by visualizing the difference in the unweighted and weighted estimates (Hernan et al., 2002). As shown in Table 2, the stabilized weight distribution included extreme weights; therefore, progressive weight truncation was considered.

The weights were progressively truncated by resetting the values that were greater (lower) than p (100-p) percentile to the value of p (100-p) percentile. However, the decision to use truncated or original weights was made, based on the bias-variance tradeoff (Cole et al., 2008). Progressively truncated weights were therefore evaluated with regard to the bias that may be created by truncation and the precision that can be increased by the same (Table 3). The mean weight, the order of magnitude reduction in the 1/minimum and maximum weights, and the degree to which the change in the truncation affected the point estimate, were also evaluated to select the final weight to be used in the model (Cole et al., 2008). It was eventually decided to use the original weights, without truncation.

The adjusted MSM (Table 3) showed that the risk of experiencing a work-related injury, among those whose jobs had high physical work requirements, compared with low physical work requirements was almost three-times greater (Incidence rate ratios (IRR): 2.62, CI: 2.14, 3.20). In comparison, the estimates obtained from the GEEs were similar in direction and strength (crude IRR: 2.69, CI: 2.21, 3.28, and adjusted IRR: 2.09, CI: 1.67, 2.62). Note that the traditional (unweighted) GEEs were adjusted for the same variables as the MSMs and both accounted for within-person and within-household correlations.

## DISCUSSION

This research effort applied MSMs for repeated-measures data to estimate the potential causal association between physical work requirements and work-related injuries. It is important to note that, while this research effort characterized the exposure of interest i.e., physical work requirement as a binary or dichotomous variable, MSMs can also be used for ordinal, or continuous exposures as well (Fewell et al., 2004).

MSMs were used because standard statistical techniques like the GEEs may be inappropriate in the presence of time-varying covariates that are affected by previous exposure levels and other covariates (Hernan et al., 2002). The observed estimates from both the GEEs and MSMs were similar in terms of strength and direction. However, comparison between the traditional GEEs that condition on a set of covariates, without taking time-varying nature of the data into account, and the MSMs -- showed that the risk of injuries appeared approximately 50% higher when the latter were used. Previous studies (Hernan et al., 2002, Suarez et al., 2011) have shown that the effect estimates could be considerably different between MSMs and alternative traditional techniques, and could also be in the opposite direction. It is possible that such a difference was not observed between the two models because aging, compared to younger, workers, may be less likely to change jobs and may be engaged in jobs with the same physical work requirements over the study period. However, future researchers who may use this methodology for different occupational settings and populations may observe results similar to those shown in the literature.

The current study used a “repeated measures” MSMs approach, suggested in a previous study (VanderWeele, 2011), wherein the associations between an exposure at two time points and the outcome in subsequent time points were assessed. However, the current research effort ultimately enabled estimating the overall risk for injuries over the entire study period since the individual person- and wave-specific weights were used in their original state.

The interpretation of the study findings should be done in light of the assumptions including, that information on the self-reported physical effort requirements is accurate, and that the measured covariates are sufficient to adjust for confounding and selection bias due to censoring. Unfortunately, these assumptions cannot be tested (Hernan et al., 2002). The assumption that the baseline and time-varying covariates are sufficient to control for confounding at each survey wave is important to make causal inference from the estimates (VanderWeele, 2011). However, extensive consideration included a wide range of covariates that could have affected the association between physical work requirement and injuries (Figure 1). The positivity assumption was not violated in this research effort since the study cohort involved only working adults. The probability of receiving the exposure i.e., physical work requirements was non-zero for all levels of time-varying covariates. The last assumption was that the exposure and censoring models were correctly specified. However, it is important to note that similar assumptions are required by traditional statistical models, as well, and when time-varying data are present, MSMs are less restrictive than the traditional models. Even in point-exposure studies, the stated assumptions are required to make causal interpretations (Hernan et al., 2000).

The major advantage of using MSMs is that they allow drawing causal inferences in situations where conventional randomization and censoring assumptions are violated. In other words, the MSMs are useful when previous exposures, and other variables affect future exposures and censoring (Bryan et al., 2004). Therefore, in the present study, controlling for the time-varying covariates, using the traditional GEEs, could not be causally interpreted as the overall effect of physical work-requirement factors on injury events.

Other alternative techniques like time-varying Cox models, and Propensity Score models may also condition on time-varying covariates that may be intermediates between the exposures of interest and the outcome. Additionally, in situations where time-varying covariates may be affected by unmeasured confounders, the former techniques may also induce collider-stratification bias. On the other hand, IPW estimators control for time-varying confounding without risk of collider-stratification bias and, also, account for bias due to informative censoring (Ali et al., 2016). MSMs however, are less useful when the exposure varies, dynamically, and where other models like the structural nested models may be more appropriate. Yet, MSMs are easier to implement and are computationally more straightforward because they are similar to traditional regression models (Robins, 1999).

## CONCLUSIONS

MSMs are an intuitively useful tool for analyzing complex epidemiological data, especially time-varying data that are not dynamically varying. A major advantage of using these models is their resemblance with standard regression models (Fewell et al., 2004). This research effort proposes a slightly different methodology for generating final IPWs for the MSMs to analyze injuries which, unlike chronic health outcomes, may be recurrent and affect future exposures and other covariates. It is suggested that this approach may also be useful for future researchers who must address other recurrent outcomes.

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**Table 1: Dummy table representing the wave specific weights for one person**

| ID | year | Physical effort | Injury events | Final stabilized weight ($SW_{ij}$) |
|---|---|---|---|---|
| 1 | 2004 | 0 | 0 | 0.99 |
| 1 | 2006 | 0 | 1 | 0.92 |
| 1 | 2008 | 0 | 0 | 0.93 |
| 1 | 2010 | 0 | 0 | 0.93 |
| 1 | 2012 | . | . | . |
| 1 | 2014 | 1 | 0 | 1.08 |

**Table 2: Percentiles (quantiles) for unstabilized and stabilized weight**

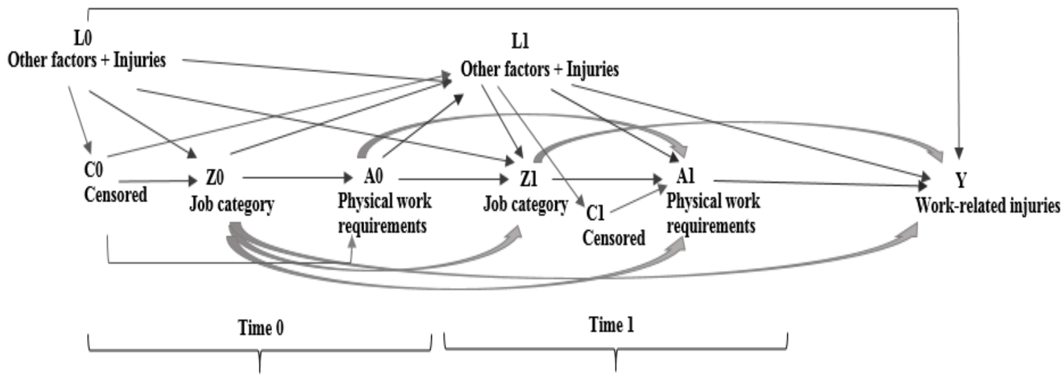
| Level | Unstabilized weight | Stabilized weight |
|---|---|---|
| 100% Max | 190.59 | 13.27 |
| 99% | 17.95 | 1.72 |
| 95% | 7.69 | 1.19 |
| 90% | 3.41 | 1.11 |
| 75% Q3 | 1.27 | 1.04 |
| 50% Median | 1.15 | 0.99 |
| 25% Q1 | 1.08 | 0.95 |
| 10% | 1.05 | 0.90 |
| 5% | 1.03 | 0.76 |
| 1% | 1.02 | 0.46 |
| 0% Min | 1.00 | 0.14 |

**Table 3: Bias-variance tradeoff: truncation percentiles, relative mean estimated weights, and incident rate ratios along with 95% confidence intervals**

| Truncation Percentiles | Estimated Weights | | *Risk of experiencing a work-related injury event among those in jobs with high physical work requirement compared to low |
|---|---|---|---|
| | Mean (standard deviation) | Minimum/ Maximum | IRR (95% CI) |
| 0, 100 | 1.00 (0.21) | 0.20/13.27 | 2.62 (2.14, 3.20) |
| 1, 99 | 1.00 (0.15) | 0.46/1.72 | 2.62 (2.15, 3.20) |
| 5, 95 | 0.99 (0.09) | 0.76/1.19 | 2.57 (2.10, 3.14) |
| 10, 90 | 0.99 (0.06) | 0.90/1.11 | 2.52 (2.05, 3.10) |

*Adjustment for fixed baseline (age, gender, race, education) and time-varying covariates (work category, previous physical effort requirements, chronic physical health conditions, acute depression, and previous injury experiences) is done by weighting

**Figure 1: Directed acyclic graph (DAG) representing the association between exposure of interest, the outcome, and other variables with two time points as an example**



# CHAPTER VII – DISCUSSION

## OVERVIEW

Work and hazards related to work, that may result in work-related injuries, compromise the health and safety of the workers (Schulte, 2012). It is known that a workforce's health and safety behaviors in the work environment are a result of interplay among physical, and psychosocial work environments (Sorensen et al., 2011). Injuries are likely to occur in conditions where there is a mismatch between the capabilities of the employee and the work requirements (Silverstein, 2008). Therefore, this longitudinal study conducted among a cohort of United States (U.S.) adults, aged 50 years and above enabled: i) investigation of the associations between work-related physical factors and injuries; ii) comparison of the injured and uninjured workers for any new functional limitations, and reduced working hours post injury; iii) analyses of associations between psychosocial work factors and injuries; and iv) comparison of two common approaches for analyzing longitudinal data with injuries as an outcome.

This study also aimed to compare traditional methods for analyzing repeated-measures injury data with a lesser used method i.e., marginal structural models. In the presence of time-varying exposures, standard methods that model the probability of the outcome, conditioned on past exposure and confounder history (e.g., generalized estimating equations), may provide biased effect estimates. This is especially the case when there is a time-dependent exposure that not only predicts future exposure but, also, is a predictor of the outcome of interest and the past history of exposure that also predicts future covariate levels (Robins et al., 2000, Hernan et al., 2000, VanderWeele, 2011).

The study population consisted of aging U.S. workers, aged 50 years and above who responded to the HRS survey in the year 2004, and reported working for pay in that year (N=7,212). This cohort of aging adults was followed retrospectively until the year 2014, the most recent HRS wave for which data have been made available. At each study wave following the baseline, persons who were no longer working for pay were excluded from the main analyses. However, information from the entire original cohort of 7,212 persons was included when injured and uninjured adults were compared, in a separate analysis, for any new functional limitations and reduced working hours. This is because a work-related injury may have resulted in an employee dropping out of the workforce. The sections below provide an overview of findings for each of the study aims respectively, and also compare these to the existing literature to derive conclusions.

## PHSICAL WORK-REQUIREMENT FACTORS AND WORK-RELATED INJURIES, AND HEALTH AND WORK-RELATED CONSEQUENCES: COMPARISONS AMONG INJURED AND UNINJURED POPULATION

In 2004, at baseline, about 5% (n=397 of 7,212 total) of adult persons in this cohort experienced work-related injuries. Compared with those whose workplaces did not include the three work requirements (excessive physical effort, lifting heavy loads, and stooping/kneeling/crouching), those who had these requirements had significantly higher risks of experiencing injuries; further, as the work requirements increased from “some of the time” to “all or almost all of the time,” the risk of injuries increased, as well. Similarly, from an earlier analysis of a cohort of 51-61 year-old non-farmers in the HRS dataset whose work required heavy lifting, compared to those whose work did not, the risk of having a work-related injury was over two times greater (Zwerling et al., 1996, Zwerling et al., 1998). A study conducted among six industrial sectors that were part of the Israeli Cardiovascular Occupational Risk Factors Determination in Israel, also reported that the incidence of injuries increased with increasing levels of work-related ergonomic stress involved (Melamed et al., 1999).

Work-related injuries and illnesses can be associated with several functional and work-related consequences, including functional impairments, disabilities, job loss, absenteeism etc. (Dembe, 2001, Keogh et al., 2000). A previous study, focused on Workers' Compensation claims and investigated the consequences of upper extremity cumulative trauma disorders (Keogh et al., 2000); it was found that one to four years following claims filing, more than half of the claimants reported having symptoms that interfered with work (50%+) and recreational (60%+) activities. Results also showed that the likelihood of normal function decreased with increasing age (OR: 0.94, CI:  0.91, 0.97). In addition, approximately 40% reported job loss one to four years post-claims filing. The current research compared such consequences between aging injured and uninjured employees and found that injured employees had a higher risk of experiencing functional limitations and reduced working hours. Similar results were also documented from another study that used data from the Work, Family and Health Network and investigated the association between occupational injuries and job loss (Okechukwu et al., 2016). It was reported the risk of having involuntary job loss, as a consequence of the injuries, was twice as high among the injured, compared to the uninjured workers (OR: 2.19; CI: 1.27, 3.77).

## WORK-RELATED PSYCHOSOCIAL FACTORS AND INJURIES

From the overall study cohort of 3,305 persons, 158 persons (4.6%) experienced at least one work-related injury between 2006 and 2014. Employees who perceived their work to be high in psychological and physical demands/efforts, low in support, and rewards, compared to those in workplaces with low demands, high support, and high rewards, had a risk nearly two times greater for experiencing injuries. Males compared with females, had a greater risk for injuries when interactions among several psychosocial work-related factors were modeled.

In a previous study (Kim et al., 2009), this risk among both genders was about two-times greater if they had high psychological work demands. Another study (Lee et al., 2015), conducted in a cohort of aluminum production and maintenance workers across all ages found that, compared with those with low work demands, those with high demands, had a 49% higher risk of experiencing a serious injury. Further, workers engaged in low control work also had a significantly higher risk for injuries. From the current study, analysis conducted with work support as the exposure of interest and injuries as the outcome, revealed that those who perceived low versus high support in their workplaces had over twice the risk for experiencing injuries. A previous review (Bongers et al., 2002), showed that the magnitude of risks (odds ratios, or risk ratios) for experiencing musculoskeletal problems among those who experienced low support, ranged from 1.2-2.1.

The current research further examined combinations of work-related psychosocial factors, with social support in the workplace. The results indicated that males engaged in high demand and low support work, compared with those in low demand and high support work, had a risk of injury occurrence over four times greater. From a previous longitudinal study (Cantley et al., 2015), conducted among transit operators, it was reported that the hazard rate (HR) for experiencing an injury was not important, but was increased [HR: 1.41 (95% CI=0.98–2.01)] among those whose work effort was high, versus low, when a combination of high strain and low support in the workplace were modeled.

Next, the current research found that males with high imbalance at work and low work control, compared to those with low imbalance and high work control, had a risk nearly three times greater for experiencing injuries. A previous study (Ostry et al., 2003), involving male sawmill workers also found that high imbalance, in combination with low control compared with low imbalance and high control, resulted in two- and four-fold high risks, respectively, for having chronic health conditions and poor health status.

**Study strengths and limitations**

This comprehensive repeated measures longitudinal study, in the cohort of aging U.S. workers, enabled estimations of incidence rate ratios and hazard ratios while adjusting for within-person and within-household correlations. The study design also allowed for the identification of potential causal associations, with consideration of temporality. However, the results of this study must be interpreted with recognition of potential limitations. Firstly, the results may not be valid for younger workers and working populations, in general, as they may have had exposures different from those of the cohort for this study. The results may also not be generalizable to other countries. In addition, the data used for these analyses are based on self-report and, thus, may be biased away from the null, especially among those who experienced injury events. This is because those injured may recall their exposures better or may exaggerate perceived psychosocial factors. As a result, differential misclassification resulting from reporting bias of the exposures may have occurred by injury status. The results also indicated that a higher proportion of injured versus uninjured workers perceived their workplaces to be high in psychological and physical demands. Hence, it is possible that the observed risk is overestimated.

### Conclusions

This longitudinal research effort serves as a basis to provide insights into the work-related injury experiences and their consequences among aging U.S. workers, whose proportion in the workforce is increasing. The study results suggest that aging workers face several physical and psychosocial stressors in their workplaces which increases their risks of experiencing injuries. The aging U.S. workforce remains at risk of experiencing work-related injuries. Additionally, injured versus uninjured adults are at greater risk for experiencing poor personal health and work-related consequences. There are significant gender differences among aging employees with respect to their perception of work-related psychosocial factors and experiences with injuries. Even though the associations between individual psychosocial factors and injuries were comparable between genders, important gender-based differences were identified when the modeled exposures included respective combinations of two psychosocial factors. Therefore, it is important to understand and obtain a comprehensive picture of psychosocial work characteristics and understand how various factors may act together and affect work-related injury occurrences among the aging workforce. Future researchers must explore specific mechanisms as to how such psychosocial factors in the workplaces may interact to result in adverse injury experiences among the employees.

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# APPENDICES

## Appendix A

Internal Review Board Approval

1606E89582 - PI Baidwan - IRB

**Subject:**IRB Review Not Required

**Date:** Tue, 28 Jun 2016 16:13:12 -0500 (CDT)
**From:** irb@umn.edu
**To:** gerbe001@umn.edu
**CC:** dobrovca@umn.edu

TO : gerbe001@umn.edu, baidw002@umn.edu,

**PI:** Navneet Kaur Baidwan

**IRB HSC:** 1606E89582

**Title:**
Analysis of the Association between Personal, and Work-Related Exposures and the Occurrence of Occupational Injuries in an Aging American Working Population

From: Institutional Review Board (IRB) The IRB determined your planned activities described in this application do not meet the regulatory definition of research with human subjects and do not fall under the IRB's purview for one or both of the following reasons:

1) The proposed activities are a) not a systematic investigation and/or b) not designed to develop or contribute to generalizable knowledge [45CFR46.102(d)].

Quality assurance activities and evaluation projects designed for self-improvement or program evaluation, not meant to contribute to "generalizable" knowledge, do not meet the threshold of research with human subjects.

Although IRB review may not be required for case studies, you still may have HIPAA obligations. Please contact the Privacy Office at 612-624-7447 for their requirements.

and/or

2) You will not obtain private identifiable information from living individuals [45 CFR 46.102(f)].

Interviews of individuals where questions focus on things not people (eg. questions about policies) do not require IRB review.

You will be analyzing aggregate data that cannot be linked to a living individual.

The above referenced IRB Human Subjects Code (HSC) will be inactivated in the database and you will have no further obligations for this project. Please do not hesitate to contact the IRB office at 612-626-5654 if you have any questions. Thank you for allowing the IRB to make the determination about whether or not review is required.

HRPP Staff

## Appendix B

## Directed acyclic graphs

**Figure 1: Directed acyclic graph (DAG) for work-requirement factors (excessive physical effort, lifting heavy loads, stooping/kneeling/crouching) as the exposure of interest and work-related injuries as the outcome**

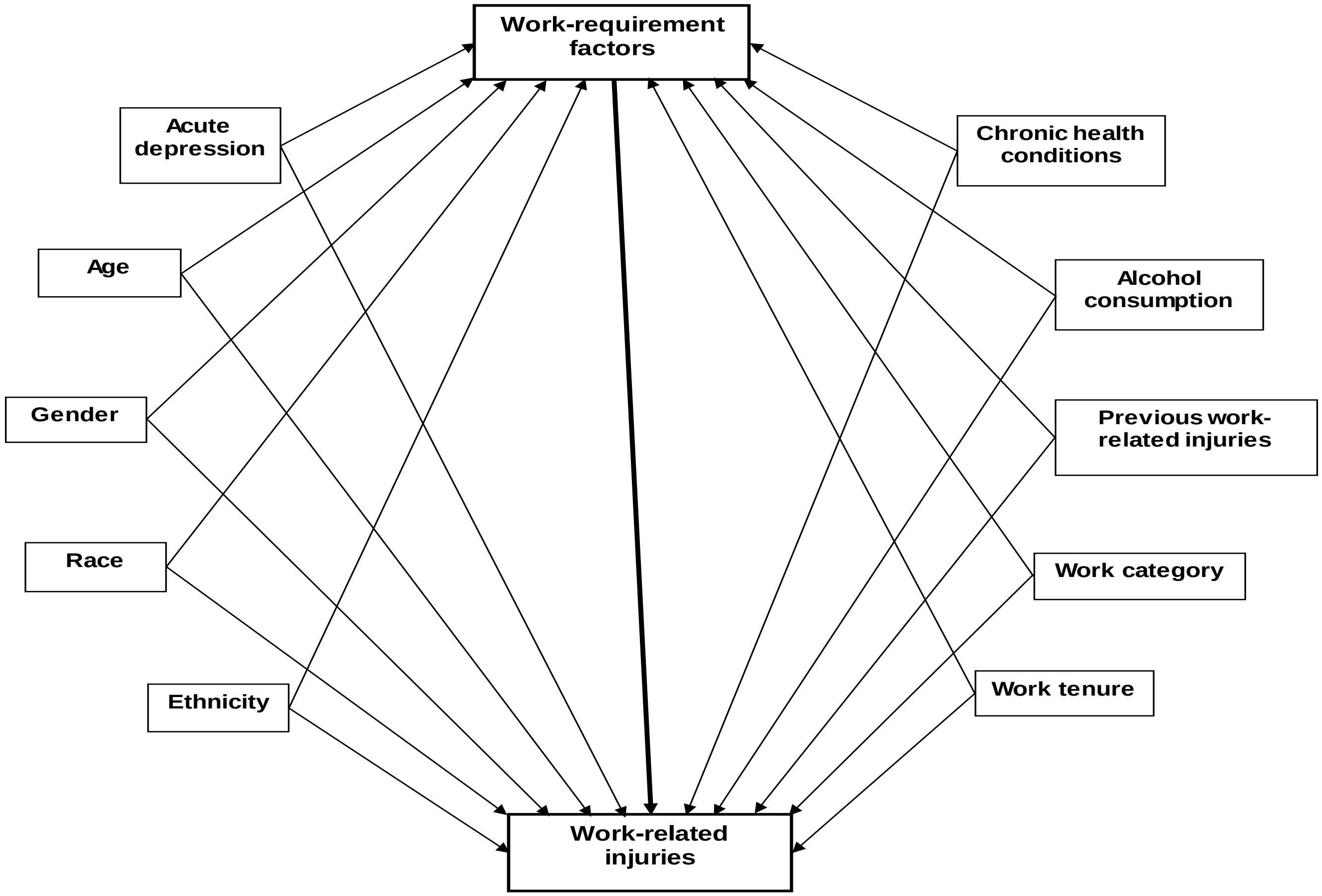

**Figure 2: Directed acyclic graph (DAG) for work-related injuries as the exposure of interest, and functional limitations as the outcome**

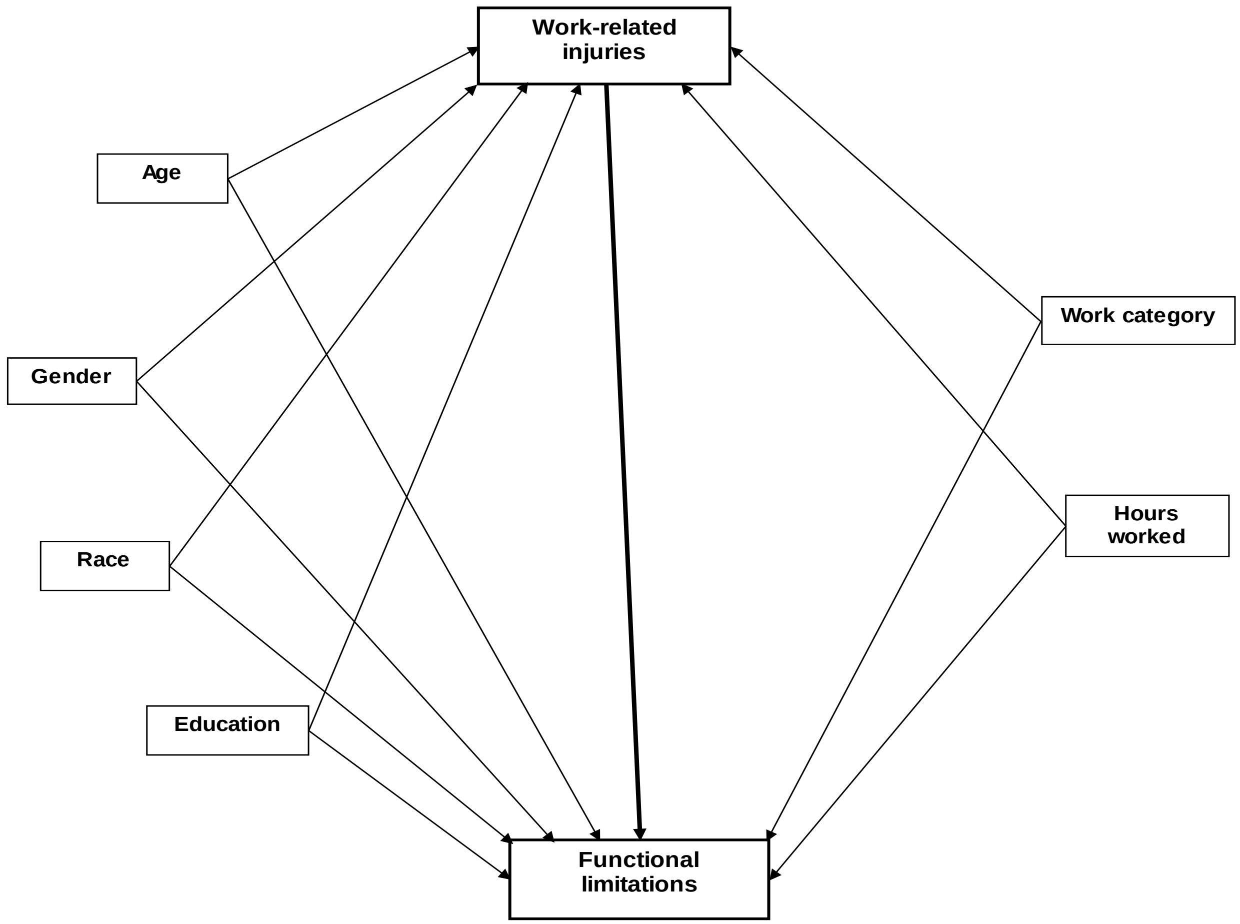

**Figure 3: Directed acyclic graph (DAG) for work-related injuries as the exposure of interest, and work status change as the outcome**

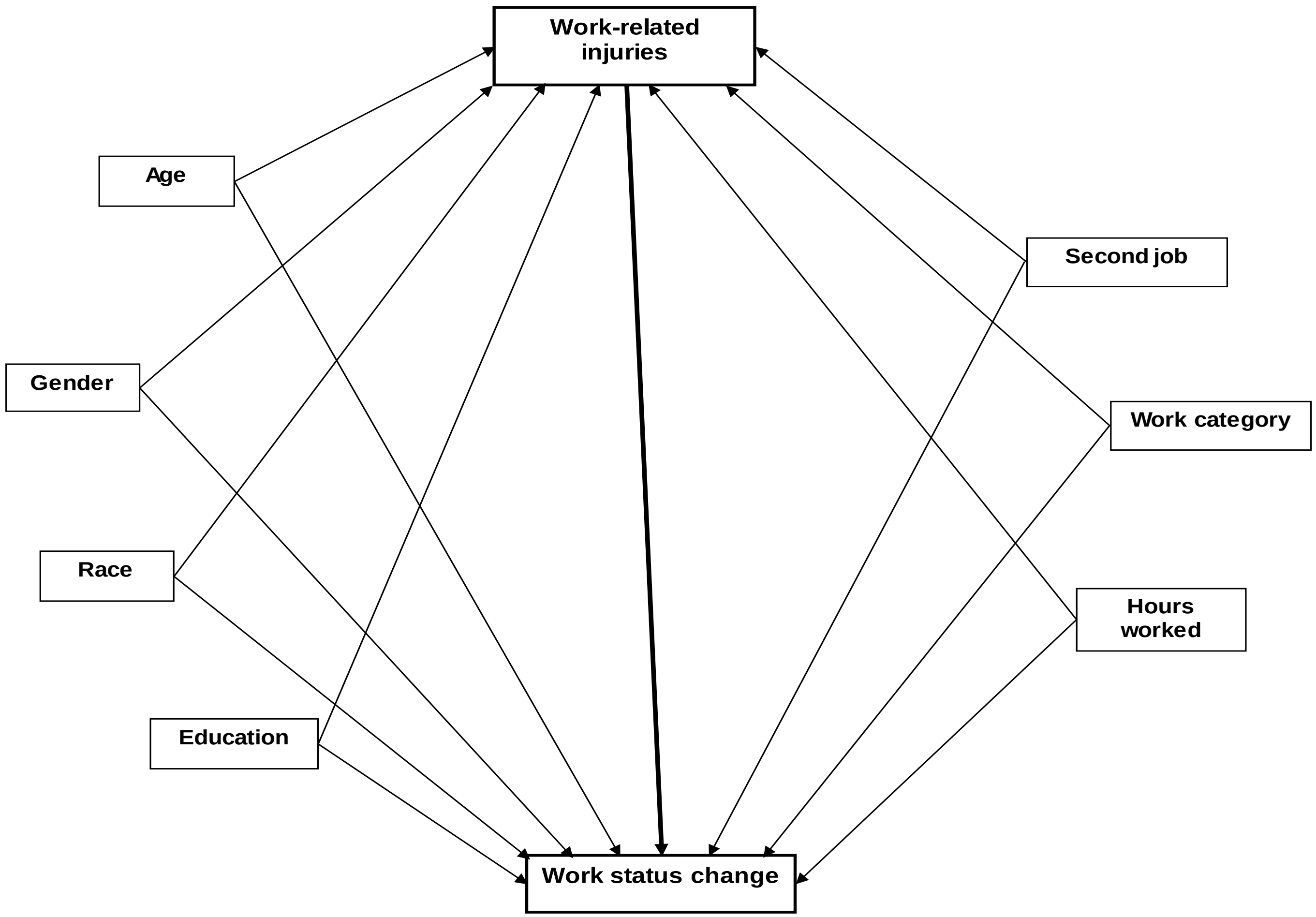

**Figure 4: Directed acyclic graph (DAG) for work-related psychosocial factors as the exposure of interest and work-related injuries as the outcome**

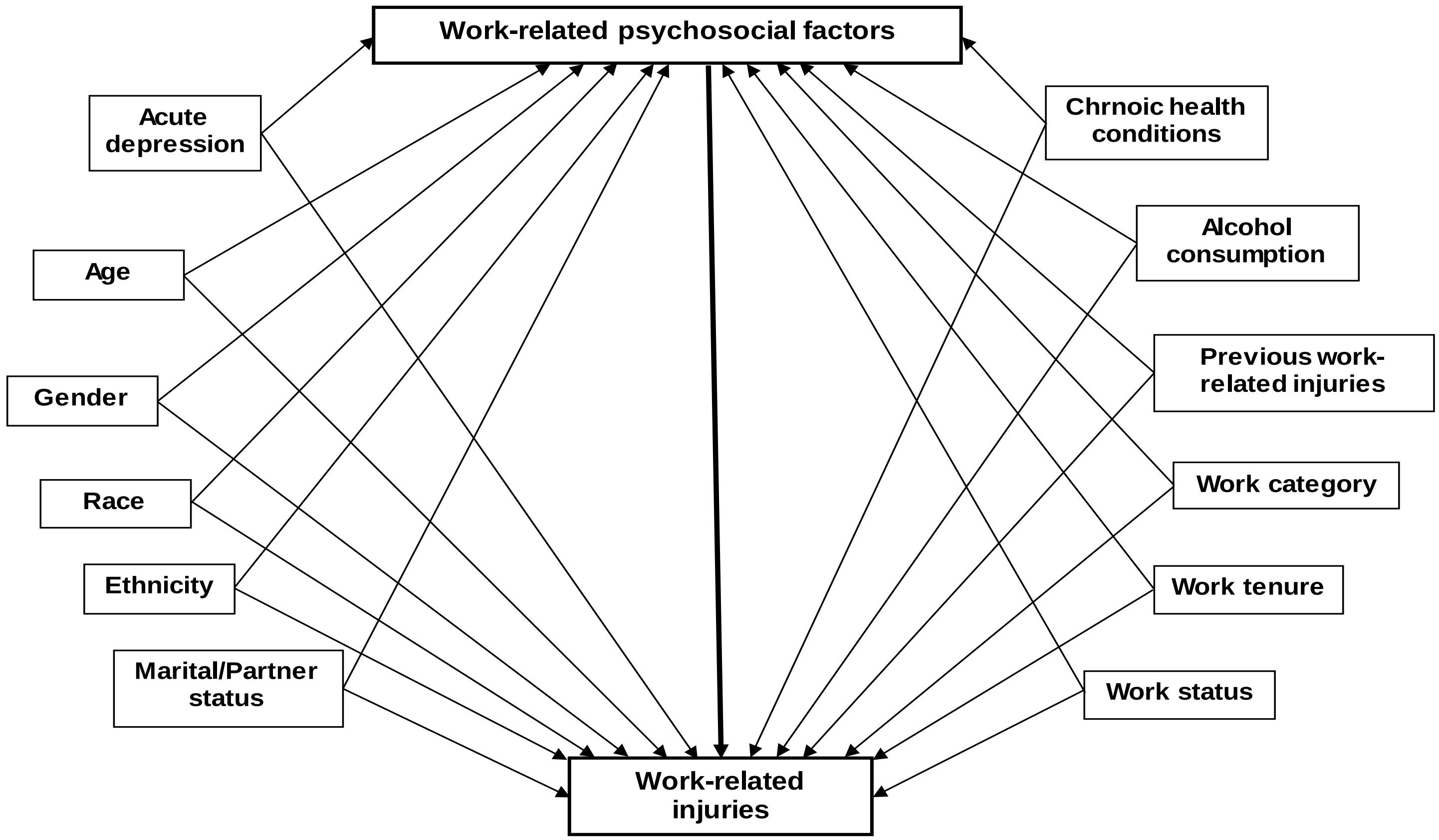

Figure 5: Directed acyclic graph (DAG) for work-requirement factors (excessive physical effort, lifting heavy loads, stooping/kneeling/crouching) as the exposure of interest and work-related injuries as the outcome; marginal structural models approach