BIOMECHANICAL EXPOSURES AND WORK-RELATED MUSCULOSKELETAL DISORDERS AMONG SASKATCHEWAN FARMERS

by

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Abstract

Background: The prevalence of musculoskeletal disorders among farmers is greater than non-farming populations. The burden on Canadian farmers is unknown, however. Research is required to determine the occurrence of these conditions and the work-related tasks that contribute to musculoskeletal pain in prevalent anatomical sites.

Objectives: The objectives of the two studies comprising this thesis were to 1) describe the sample population of Saskatchewan farmers and the prevalence of musculoskeletal disorders, and, 2) explore the strength of associations between biomechanical exposures and work-related musculoskeletal disorders.

Methods: *Objective 1*. Participants received a mail-out survey for the Saskatchewan Farm Injury Cohort. Study outcomes were self-reports of musculoskeletal disorders characterized by presence and severity of musculoskeletal pain in nine anatomical regions. *Objective 2*. A cross-sectional analysis of the experience of musculoskeletal pain in relation to four main biomechanical work exposures was performed. Relationships were determined by modeling the exposures separately using modified Poisson regression.

Results: *Objective 1*. A strong majority of participants (82.2%) reported having musculoskeletal pain in at least one body part over the past year. The lower back was the anatomical site most frequently affected (57.7%), followed by the shoulders (44.0%). *Objective 2.* Results suggest that all biomechanical exposures had a dose-response effect on musculoskeletal outcomes. Shovel or pitchfork use was strongest for lower back pain, while working with arms above head was the greatest risk factor for shoulder pain.

Conclusions: *Objective 1.* Our study suggests that Canadian farmers also experience musculoskeletal pain most frequently in the lower back and shoulders, similar to those in other regions and commodity types. It also found that all farm people are at risk for musculoskeletal disorders, highlighting the need to

target all subgroups and commodity types equally. *Objective 2.* Strong associations between increased biomechanical exposures and pain in the lower back and shoulders support the evidence that these regions are susceptible to the physical exposures of farm work.

Co-Authorship

This thesis presents the work of Michelle McMillan in collaboration with her advisors, Dr. William Pickett and Dr. Catherine Trask.

Manuscript 1: *Prevalence of musculoskeletal disorders among Saskatchewan farmers.* This study was based on the opportunity to research a new topic with key information available in the Saskatchewan Farm Injury Cohort database. The idea of using the newly incorporated measurement for musculoskeletal disorders in the second phase of the survey was Dr. Trask's. The objectives were developed through Dr. Pickett's extensive knowledge of this population, and the ergonomic expertise was provided by Dr. Trask. The writing of the manuscript, statistical analysis, and interpretation of results were Michelle McMillan's work, with the guidance and editorial feedback of Dr. Pickett, Dr. Trask, Dr. James Dosman, and Ms. Louise Hagel.

Manuscript 2: *Biomechanical work exposures associated with prevalent low back and shoulder pain in Saskatchewan farmers.* The specific study questions were suggested by Drs. Pickett and Trask. All analyses, writing, and interpretations were Michelle McMillan's with guidance and editorial feedback from Dr. Pickett and Dr. Trask.

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MSD: Musculoskeletal Disorder

Chapter 1

Introduction

1.1 General Overview

The prevalence of musculoskeletal disorders (MSDs) is reported to be high in many agricultural settings around the world; however, there is extremely limited epidemiological information about work-related MSDs in Canadian farmers.[1] Although repetitive strenuous tasks put all farmers at risk for developing MSDs, each workplace is unique, making some individuals more vulnerable than others. With a breadth of commodities in Canada, it is important to study workers in specific agricultural production settings in order to identify high-risk working conditions, tasks, and exposures. Recognizing the occurrence and severity of MSDs amongst groups of farmers will help to identify individuals who are at high risk. This basic information will not only address the knowledge gap in the Canadian farm industry, but also help to identify those who are susceptible to musculoskeletal disorders as targets for preventive intervention.

Many risk factors associated with the development of musculoskeletal disorders are commonplace in agricultural tasks.[2] There is a need to better understand the nature of risks related to different types of farming activities. Although many biomechanical exposures and strenuous activities have been deemed injurious—with some farm tasks suspected to elicit MSDs—it is uncertain exactly which factors influence the development of these disorders.[3] Obtaining information on musculoskeletal pain and how it relates to time spent performing common farm tasks will assist in understanding such exposure-response relationships. Any associations that are confirmed could help guide effective interventions that would mitigate occupational hazards and ultimately reduce disabling pain that results from work-related exposures on the farm. Results could also direct future longitudinal analyses that confirm potentially causal associations. These findings may potentially impact agricultural/rural health policy and ergonomics strategies that modify exposures and limit MSD outcomes in farmers.

1.2 Agricultural Importance

Identification of risk factors that are specific to Canadian farmers is important, as different geographical regions have a vast diversity of agricultural activities and hence work practices.[4,5] Focusing on farming in the Canadian context will allow for a more pertinent and effective approach in describing farmers' MSD symptoms and the biomechanical exposures that are unique to them; tailored interventions to create safer work environments may successfully reduce risk of musculoskeletal disorders.

This thesis includes two manuscripts that address the following gaps in knowledge: 1) musculoskeletal disorders have been described and investigated in other farming regions and commodity types around the world, but never in Canadian farmers; 2) several works tasks and techniques have been proposed as predictors for musculoskeletal pain, but those specific to crop farmers in Canada and the associated risks need to be identified and explored.

1.3 Objectives and Hypotheses

This study describes the prevalence of musculoskeletal disorders in a population of Canadian farmers. It also investigates relations between specific biomechanical exposures associated with farm work and musculoskeletal pain in the lower back and shoulders. Our specific objectives were to learn about the burden of these conditions and risk factors contributing to their development. Primary hypotheses were that: 1) subgroups such as farm operators would be identified as high risk compared to other participants in the study; 2) the biomechanical exposures would be associated with risks for various work-related musculoskeletal disorders among farmers and farm workers; 3) greater exposure (days) of the specified work tasks would lead to the musculoskeletal disorder(s) being more pronounced (severe pain interrupting work).

1.3.1 Manuscript 1: Prevalence of musculoskeletal disorders among Saskatchewan farmers

The objective of this manuscript was to determine the overall prevalence of musculoskeletal disorders in a sample of Saskatchewan farmers. This study aimed to address an associated knowledge gap in Canadian agriculture, as little is known about the burden of these occupational conditions within this industry. Using the second phase of the Saskatchewan Farm Injury Cohort survey, a descriptive analysis of this population was performed.[6] We anticipated identifying high risk groups and prevalent anatomical regions susceptible to pain. It was hypothesized that prairie farmers would experience musculoskeletal disorders at similar proportions to those farmers in other industrialized countries, based on existing research.

1.3.2 Manuscript 2: Biomechanical work exposures associated with prevalent low back and shoulder pain in Saskatchewan farmers

The objective of this second manuscript was to evaluate the strength and statistical significance of relationships between specific occupational exposures and the occurrence of musculoskeletal disorders. Using data from the second phase of the Saskatchewan Farm Injury Cohort, this study applied a cross-sectional design to baseline information to model relationships between biomechanical work exposures and the outcome of self-reported pain in the lower back and shoulders.[6] It was hypothesized that each of the work exposures would be significantly related to musculoskeletal disorders in these two anatomical regions, with the relationship presenting in a dose-dependent nature.

1.4 Thesis Organization

This thesis conforms to the Queen's University School of Graduate Studies and Research Guideline "General Forms of Thesis". The second chapter is a review of the literature surrounding musculoskeletal disorders and the occupational burden of these conditions in the agriculture industry. The third chapter is Manuscript 1, which describes the sample population by demographics, subgroups, and self-reported musculoskeletal pain. This manuscript is in submission form for the journal *Injury Prevention.* The fourth chapter is the second manuscript which cross-sectionally investigates associations between four main biomechanically-demanding work tasks/exposures and musculoskeletal disorders in the lower back and shoulders. Manuscript 2 is in submission in the journal *Ergonomics*. Chapter 5 contains a summary of both studies, methodological considerations, as well as a general discussion that supports conclusions and guides future research.

References

1. Osborne A, Blake ÃC, Fullen BM, et al. Prevalence of Musculoskeletal Disorders Among Farmers : A Systematic Review. *Am J Ind Med*. 2012;158(October 2011):143-158. doi:10.1002/ajim.21033.

2. Osborne A, Blake ÃC, Fullen BM, et al. Risk Factors for Musculoskeletal Disorders Among Farm Owners and Farm Workers : A Systematic Review. *Am J Ind Med*. 2012;389(December 2011):376-389. doi:10.1002/ajim.22001.

3. Walker-Bone K, Palmer KT. Musculoskeletal disorders in farmers and farm workers. *Occup Med (Lond)*. 2002;52(8):441-50. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12488514.

4. Chapman L, Meyers J. *Ergonomics and Musculoskeletal Injuries in Agriculture: Recognizing and Preventing the Industry's Most Widespread Health and Safety Problem*.; :13.

5. Kirkhorn SR, Earle-Richardson G, Banks RJ. Ergonomic risks and musculoskeletal disorders in production agriculture: recommendations for effective research to practice. *J Agromedicine*. 2010;15(3):281-99. doi:10.1080/1059924X.2010.488618.

6. Pickett W, Day L, Hagel L, et al. The Saskatchewan Farm Injury Cohort: rationale and methodology. *Public Health Rep*. 123(5):567-75. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2496929&tool=pmcentrez&rendertype=abstract.

Chapter 2

Literature Review

2.1 Introduction

The purpose of this chapter is to introduce literature surrounding musculoskeletal disorders in general, as well as how they affect farming populations.

Agricultural work in both Canada and the United States continues to be one of the most hazardous occupations.[1,2] As there is a considerable amount of physical labour in agricultural jobs, ergonomic hazards and associated musculoskeletal disorders have become an increasingly recognized occupational challenge in farmers.[3] MSDs are often the most commonly reported non-fatal injury in farmers, and the associated burden and costs are substantial.[4] Despite agriculture being one of the most dangerous industries in developed countries, farmers are said to have one of the highest return-to-work rates after an injury.[5] Many are likely working with pain. Canada experiences similar work behaviours, as 83.2% of disabled farmers continue to farm after experiencing a severe work-related injury.[6] Unlike other workers who are employed by a company or organization, Canadian farmers are self-employed individuals, working in an unregulated setting where the built environment is minimal.[3] It is therefore challenging to address occupational needs of farmers, but fully understanding their work demands and the causes and consequences of musculoskeletal pain will help reach a viable solution.

2.2 Describing the Issue

Work-related musculoskeletal disorders can result in pain and functional impairment of the affected anatomical region.[7] People are predisposed to work-related MSD development as a result of biomechanical risk factors in their work environment.[8] Biomechanical tasks are typically performed in familiar and set ways, with the individual using the same joints and muscles repeatedly, eventually leading to tissue fatigue and damage.[9] In response to this, individuals often adapt to the pain or impairment by recruiting new muscles and joints to perform the same tasks.[10] These new techniques and positions could affect the body negatively by using inappropriate muscles and joints, or transferring mechanical forces to other areas in attempt to relieve stress on affected tissues.[11]

Musculoskeletal disorders are the most common cause of physical disability and severe long-term pain in working individuals.[12] Population surveys reveal that for a one-month period of recall, up to 50% of people in the general population experience musculoskeletal pain at one or more anatomical sites.[13] MSDs are also responsible for impaired quality of life and have immense socioeconomic costs.[13] Between the years 1996 and 2006, the combined costs from musculoskeletal disorders in Ontario were estimated at 19 billion dollars.[14] In the United States, MSDs comprise over one-third of occupational injuries and illnesses, and account for 50% of worker compensation claims.[8] Industrialized countries have more work absenteeism or disability resulting from MSDs than any other group of ailments; 60% of permanent work incapacity in the US and Europe is a consequence of these disorders.[13] As musculoskeletal disorders threaten worker health and safety as well as economic performance, MSDs may be among the largest work-related problems in occupations worldwide.[15]

2.3 Occurrence of Musculoskeletal Disorders

Conditions affecting the musculoskeletal system are prevalent and pervasive.[7] There are mixed findings regarding the prevalence of MSDs in the general population, and what age group suffers the most or is at greatest risk.[16] Most research suggests that the prevalence of these conditions increases noticeably with age, and the development of musculoskeletal disorders is often modified or worsened by lifestyle factors such as obesity, lack of physical activity or sedentary behaviour.[17] With an increasing proportion of older people in the population, as well as changes in lifestyle, an intensified impact on society is expected.[7]

The descriptive, etiological, and prognostic data that is available mainly focuses on specific anatomical sites. There is emerging evidence now that studies the extent of musculoskeletal symptoms. These newer findings indicate that symptoms confined to a particular anatomical site have a moderate prevalence, ranging from 15-30% for specific anatomical sites. People affected by musculoskeletal symptoms in at least one of many anatomical sites, however, have an estimated burden of one-third in the general population and two thirds in the working population.[12] This same French cross-sectional study found that women had a higher prevalence of multisite musculoskeletal symptoms (68%) compared to men (62%) which is consistent with other studies.[18]

2.4 Defining Musculoskeletal Disorders

Musculoskeletal disorders (MSDs) include a range of inflammatory and degenerative conditions that can affect muscles, tendons, ligaments, joints, peripheral nerves, blood vessels, and supporting structures such as cartilage and vertebral discs.[19] [20] Work-related musculoskeletal disorders may be caused by, aggravated, or precipitated by intense, repeated, or sustained work activities with insufficient recovery.[21] Common types and outcomes of musculoskeletal disorders include sprains, tears, soreness, carpal tunnel syndrome, sciatica, osteoarthritis, and myalgia.[22] The most frequently affected body regions in the working population tend to be the low back, neck, shoulder, forearm, and hand.[8] However, disorders in the lower extremities are also emerging concerns.[8]

Onset mechanisms for musculoskeletal disorders are not clearly established; the manifestation seems to be multifactorial, developing from overuse, such as repetitive minor traumas and cumulative biomechanical stress.[12] Although MSDs can be a consequence of an acute injury, they are more often associated with habitual tasks that contribute to gradual tissue damage.[23] Wear and tear on the body from cumulative trauma may develop initially without warning, but eventually may be observed in terms of pain or other symptoms.[24] Strenuous movements that are repeated may result in macro trauma, or a great amount of tissue damage, that could also lead to disability for some individuals.[24]

2.4.1 Mechanisms of Pain

Pain is the most prominent symptom of a current or impeding musculoskeletal disorder.[25] There are two main types of pain that arise in response to musculoskeletal damage: nociceptive pain after an acute injury, and idiopathic pain when there is no specific or obvious cause.[26] A pain-generating process in the musculoskeletal system is normally present in acute nociceptive pain, but also likely in chronic, widespread, and non-specific pain.[25] Nerve endings on primary afferent sensory neurons, called nociceptors, only issue a response when a stimulus is potentially tissue-damaging.[25] A peripheral sensitization provides a lower threshold for nociceptive activation and a noxious stimulus is no longer needed for the brain to perceive pain. This heightened sensitivity can occur when the tissue experiences a traumatic or inflammatory event.[26] Central sensitization is the result of repeated or prolonged activity in primary afferent neurons. An increased response in the secondary sensory neurons stemming from synapses in the dorsal horns of the spinal cord occurs next, contributing to a referred pain outside of the injured area.[26]

An injury, by definition, means mechanical disruption of tissues resulting in pain.[27] Traumatic injuries occur when a load on the tissue is greater than its load-bearing capacity, resulting in tissue failure.[27] These injuries are due to clear precipitating events and the process is directly linked to the onset of pain and subsequent symptoms.[27] Physical damage may be muscular, ligamentous, or articular, and diagnosis is reasonably straightforward.[9] Symptoms typically peak in the days following the event and heal in a predictable way.[9] Insidious injuries are defined by having no distinctive triggering event.[9] The persistence of symptoms can be acute (less than six weeks), subacute (between six weeks and three months), or chronic (lasts more than three months) in nature.[7] The pattern of symptoms follows a different development than those of traumatic injuries as they do not peak but build up over a gradual period of time.[27] The healing process is less active, with the potential for permanent damage to stabilize at a level of musculoskeletal dysfunction.[9] It is also possible that the injury becomes worse, especially if coping mechanisms and modifying factors are unfavourable.[27]

2.4.2 Diagnosis and Treatment of Musculoskeletal Disorders

Diagnostic technologies are limited when it comes to musculoskeletal disorders. Criteria are not standardized and there can be many inconsistencies with patient diagnosis.[28] One of the issues is the subjectivity of pain and thresholds of individuals, and the wide variety of symptoms and signs reported. Only some MSDs, such as carpal tunnel syndrome and spinal disc herniation have a reliable pathology.[8] As there is no “gold standard” for objective examination techniques, assessment of musculoskeletal disorders typically relies on, and is best captured through, subjective measurement.[29] Although the quality and utility of self-reported pain has been debated, symptoms have been strongly correlated with the established traits of musculoskeletal disorders, suggesting why it is still widely used.[29,30]

The traditional approach to treating most work-related MSD has been to rest the symptomatic area and to reduce soft tissue inflammation.[30] This is typically done by reducing or eliminating worker exposure to the pertinent ergonomic hazards by means of restricted duty, rest breaks, job rotation, or temporary job transfer.[8,30] Although controls through engineering design like tools or workstations are the preferable method to manage or prevent musculoskeletal disorders, they cannot always be installed or may not be available in certain work environments.[30] This is problematic, as most work-related factors but very few non-work-related factors can be modified, especially in farm environments.[31]

2.5 Risk Factors for Musculoskeletal Disorders

Risk factors for the development of musculoskeletal disorders are multifactorial.[8] Occupational exposures related to MSDs include: rapid work pace and repetitive motion patterns, insufficient recovery times, heavy lifting and forceful manual exertions, non-neutral body postures, mechanical pressure concentrations, segmental or whole body exposure to cold, and any of these in combination with each other.[8] Each of these activities can provoke specific types of stress and strain on muscles, causing discomfort, and the harm can often lead to several permanent diseases and disabilities.[32]

Back pain is the most common occupational health problem experienced by much of the world's workforce, with lifetime prevalence estimated anywhere between 60 and 90%, but usually self-reported closer to 70%.[33,34] Although traditionally viewed as an acute event, back disorders are now also thought to be chronic in nature developing as a result of long-term exposure.[12] There is strong growing evidence to support this theory, yet the lack of studies for musculoskeletal disorders in other body regions makes it difficult to compare the severity and prevalence of back pain to these other disorders. For example, as Nonnenmann et al described:

“work-related musculoskeletal disorders of the neck and upper extremity are common among industrial workers, costly, and understudied compared to other MSDs”.[35]

Although neck and upper limb pain are common symptoms in the general population, there seems to be some uncertainty about the distribution and determinants of these debilitating conditions.[31] Some general occupational risk factors have been proposed, but exact biomechanical exposures are not always specified. In particular for shoulder and back disorders, more information is needed on the relationship between risk factors (working exposures) and musculoskeletal disorders. This is true in all occupational environments, including agricultural ones.

2.5.1 Risk Factors for Low Back Disorders

Back injuries or back pain, were for a long time, considered to be acute conditions.[3,36] A growing body of evidence now suggests that back disorders may be more episodic in nature, or viewed as a chronic condition.[37] These injuries are thought to be a result of long-term exposures instead of instantaneous events, as significant effects of peak loads have not been found to be predictive of low back pain.[38] Low back pain is also difficult to define as it is primarily a symptom that patients report, with no external standard by which its presence can be validated.[11] It is characterized by a wide range of severities and pathologies, and there are no standardized clinical tests in place that can evaluate or classify people with low back pain.[39] What makes the diagnosis of back pain even more challenging is that approximately 90% of cases present non-specific low back pain.[28] Many studies have proposed that low back pain is significantly associated with the degeneration of the lumbar discs and it is often described as pain localized below the line of the twelfth rib and above the inferior gluteal folds.[7] However, these abnormalities have also been found to be very common in people who are asymptomatic, making it difficult to establish whether these lesions coincide with low back pain.[28]

2.5.2 Risk Factors for Shoulder Disorders

Work with elevated arms, monotonous repetitive work, and forceful exertions are all occupational exposures that have been associated with shoulder complaints and disorders.[40] Elevation of the arms is thought to cause degenerative changes in the rotator cuff tendons which predispose them to tears.[41] There is debate over what level of elevation is required, and for what duration, before harmful effects occur.[42] It is also unclear whether shoulder pain results more from cumulative exposure or the intensities of exposures.[43] Some studies show that substantial, long-term, cumulative effects are not significantly associated with shoulder disorders, suggesting that short induction periods of arm elevation are a greater predictor of pain in this region.[42] Conflicting evidence from other occupational research, however, suggests that duration of employment (in years) or duration of exposure (in hours) are significant risk factors for the development of musculoskeletal pain in the shoulders.[35]

2.5.3 Non-Occupational Risk Factors

Smoking

The relation between smoking and low back pain is inconclusive, but many studies suggest that there is an association between the two.[44,45–47,48] A meta-analysis done in 2010 systematically reviewed 40 studies (27 cross sectional and 13 cohort) that examined the prevalence of low back pain in ever, former, and current smokers.[49] The overall findings indicated that cigarette smoking does contribute to experiences of chronic low back pain and disabling low back pain. A higher prevalence was also seen in those who currently smoked over those who formerly did. The analysis limited studies that controlled for physical and psychosocial workloads and found that estimates were consistent with previous results, strengthening the observed association between smoking and low back pain.[49]

Although the mechanisms behind low back pain are still not entirely clear, there are some theories as to how smoking may be a risk factor for back pain. It may lead to reduced perfusion and malnutrition of the intervertebral discs via vasoconstriction, and eventually atherosclerosis.[50,46,51] When the blood supply to spinal structures is impaired, it may cause degenerative lesions in the intervertebral discs and prevent or slow healing.[52] Smoking also increases the level of pro-inflammatory cytokines in circulation, which signal the central nervous system and ultimately increases pain levels.[45,44]

Obesity/Body Mass Index

Obesity is a growing health concern as the number of individuals experiencing obesity is dramatically increasing worldwide.[53] A high body mass index has been implicated in the development or progression of a range of disabling musculoskeletal conditions.[16,47,54,55] A systematic review assessed the potential relationship between overweight/obesity and low back pain using meta-analysis.[56] Thirty-three studies met their criteria and results showed that both overweight and obesity increase risks for low back pain. It also reported that the prevalence for women is stronger than men; and proposed that these gender differences may be due to hormonal-related obesity and associated changes in pain sensitivity. Although the association between obesity and low back pain could be bidirectional –it's unclear whether low back pain is a cause or consequence of obesity—they proposed that the relationship may be causal as the observations were seen in both cross-sectional and cohort studies. The hypothesized mechanisms were: 1) obesity could increase the mechanical load on the spine during various activities, 2) systemic chronic inflammation could result from the increased production of cytokines in response to obesity and 3) obesity is associated with disc degeneration and vertebral end plate changes which decreases spinal mobility. The meta-analysis identified obesity as a potential modifiable risk factor for low back pain.[56]

2.6 The Biopsychosocial Model for the Development of Work-Related Musculoskeletal Disorders

Muscle activity is the prerequisite for cumulative muscle tissue disorders; this activity depends on human motor behaviour, which involves an extensive range of postures, movements, and force exertions.[40,57] This performance is dependent on task requirements, yet individual and contextual factors may influence this relationship, allowing them to be referred to as effect modifiers.[58] Taking into account the effect of physical, cognitive, and emotional characteristics of the individual and their work capacity, internal forces result in short-term responses at the system, tissue, and cellular and molecular levels.[59] Muscle activity promotes increased circulation, local muscle fatigue, and numerous physiological responses that cause electrochemical and metabolic changes.[60] The effects of physical load are felt both during and after work, and when insufficient recovery time occurs, these effects may turn into more long-term or even permanent neuromuscular problems.[61] Although much of the time these mechanical loads have negative effects on the worker, positive changes can occur as well, such as improved conditioning and increased capacity for an individual.[60] Given its complex nature, mechanical exposure should therefore be expressed in three components: level, duration, and frequency.[26,42]

The nature of work-related diseases is multifaceted.[29] It is difficult to confirm a relationship between biomechanical exposures in an individual's work setting and the development of musculoskeletal disorders as cause and effect. There are many risk factors that contribute to the development of a work-related musculoskeletal disorder as cognitive and emotional factors interact with how an individual receives sensory input.[26] Attention, interpretation, coping strategies, and behavioural responses can all moderate pain transmission and perception.[9] When assessing risk factors for work-related musculoskeletal disorders, three types are typically investigated: physical, psychosocial, and individual.[25] One of the most frequently-cited models was developed by the National Institute for Occupational Safety and Health (NIOSH, 2001), which proposed that physical activities place individuals at risk for the development of MSDs, but they are influenced by individual, social and organizational factors.[62] The model illustrates that the muscle load an individual is exposed to is dependent upon work requirements, duration of exposure, and the environment.[62] This load is applied to the musculoskeletal system by either internal or external forces, which then result in tissue responses throughout muscles, ligaments, and joint surfaces. The outcomes may include adaptation effects (i.e., increases strength, fitness, or conditioning) or harmful effects (i.e., pain, structural damage) that could lead to painful symptoms, impairment or disability.[58] Every workplace setting is unique, with different physical demands; and that the workers themselves are unique, each having different adaptation responses.[3] The effects of the external load can therefore be regulated by these factors.[30]

2.7 Farming: A Challenging Environment for Musculoskeletal Disorders

Agriculture represents a unique occupation with respect to musculoskeletal disorders. Its physical demands combined with long working hours, especially in planting and harvesting season for Canadian farmers, create a vulnerable set of work conditions compared to other industries.[63] Not only is the demographic unique in farming, but the work context and occupational risk factors are uncontrolled.[3] The productivity of the farm has both economic and scheduling restrictions, as farmers must work when the weather permits.[6,64] Equipment, machinery, and tools also vary between farms, influencing the work processes of farmers.[1] Although similarities exist within regions and types of production agriculture, each farm operation is unique, making it even more difficult to understand occupational hazards and safety conditions.

As there is a major gap of research knowledge on musculoskeletal disorders in Canadian farmers, this study took advantage of investigating this issue in a sample of Saskatchewan farmers. As this province is home to 44,000 individual farms, accounting for 11% of the province's population, it was a good starting point to assess the prevalence and work exposures of Canadian farm dwellers.[65] Although the commodities may differ compared to those of other provinces—with crops being the prominent production in Saskatchewan—this study permitted an analysis of a more homogenous sample of workers. Commodity-specific knowledge will help determine if prevention efforts can be transferrable across the country, or if tailored responses are required for different types of farming.

2.7.1 Prevalence in Farmers

Although farming is often depicted as an idyllic job and way of life, it is actually one of the most physically arduous professions due to its strenuous manual and other demands.[19,31] Farmers experience high risks for developing musculoskeletal disorders and agricultural workers have a higher prevalence of musculoskeletal symptoms than do non-farmers.[66] Lifetime prevalence has been estimated around 90% by many studies, with a 1 year period prevalence of MSD estimated at 76.9% (95% CI 69.8-82.7) in a systematic review.[19,67] However, occupational studies may suffer from The Healthy Worker Effect, where those who are chronically ill or disabled are removed from the workforce, leaving healthier individuals to be assessed in workplace studies and ultimately lower the prevalence of any disease or disorder.[8] There is substantial evidence to suggest that out of all occupational non-fatal injuries and illnesses in farmers, musculoskeletal disorders are the most common and therefore biggest health concern in this population.[19]

Farmers are particularly vulnerable to occupational exposures that may harm their bodies and lead to musculoskeletal disorders such as osteoarthritis of the hip and knee, low back pain, upper limb disorders, and hand-arm vibration syndrome.[32] Low back pain and other musculoskeletal disorders were investigated in Kansas farmers and 60.0% of workers had experienced a farm-work related MSD symptom in at least one anatomical site over the previous 12 months.[10] The spinal region, typically the low back, has been the most heavily researched body part in farm workers. Low back pain has been identified as the most common musculoskeletal disorder, with a 1-year prevalence of 47.8% (95% CI 40.2-55.5) and lifetime prevalence of 75.0% (95.0% CI 67.0-81.5).[19] A study comparing back pain in male farmers from Iowa with the U.S. general working male population found that back pain in the past 12 months was reported by 31.0% of farmers and only 18.5% in non-farmers.[34]

The second most common region for MSDs in farmers is the upper extremities, with one study reporting a prevalence of 25.9% in the shoulders of Kansas farmers and another at 54.0% for Iowa dairy farmers.[22,35] Fewer studies are available on musculoskeletal disorders in the lower extremities: the suspected range is 10-41% but more findings are needed to refine the accuracy of these estimates.[19]

Over the last few decades, there has been increasing evidence that farmers have an elevated risk for hip osteoarthritis and suffer up to 10 times the rate of hip joint arthrosis compared to the general population.[31,66] Swedish farmers producing a range of commodities were found to have a prevalence of 33% for hip symptoms.[66] Little is known about neck symptoms and pain in the wrist/hand but a few studies have evaluated self-reported farm work-related MSDs. Thirty-five percent of farmers working on dairy farms in New York state reported neck/shoulder musculoskeletal symptoms and 22% of Southeast Kansas farmers had work-related pain.[10,35] An Australian study reported that 34% of male farmers experienced neck pain at least once per week, and of those, 17% of participants suffered from some neck pain every day.[68] Although the most prevalent disorders have been identified, and high risk mechanisms proposed, exposure-response relationships for anatomical sites vulnerable to musculoskeletal disorders have yet to be established.[22]

2.7.2 Risk Factors for Musculoskeletal Disorders in Farming

Agriculture is recognized as one of the most dangerous industries as farmers and farm workers are exposed to a multitude of risk factors for MSDs.[69] There has been an increasing effort to assess musculoskeletal disorders in farmers and understand the biomechanics behind them. With heterogeneity between studies, however, it is difficult to compare and identify different risk factors that contribute to different types of MSDs.[22,31] Everyday work exposures put farmers at particular risk for both acute and chronic injury and it has yet to be determined exactly which mechanisms result in chronic pain in the musculoskeletal system. Evaluation of disabilities among a cohort of farmers revealed that 51% were purported to be disabled due to a single acute incident and the other 49% had a disability as an outcome of cumulative exposure to working conditions.[69]

Farmers' work involves many physically demanding tasks with frequent combinations of high postural load, manual materials handling, and the use of muscular force.[20] Manual materials handling, for example, is thought to trigger activity of erector spinal muscles and compressive forces on the vertebral discs.[20] As low back disorder is reported as the most common MSD, there has been an effort to identify the risk factors contributing to these symptoms in farmers. Substantial evidence exists to suggest that tractor driving exposes farmers to high enough doses of whole body vibration that low back pain would develop [31,68,70] (OR=2.39; 95% CI=1.57-3.66).[71] Tractor driving is also suspected to promote neck pain due to frequent twisting by drivers to look behind (OR=2.29; 95% CI=1.09-4.80).[35,68,71] Back pain may also be brought on by repeated activities like lifting, pushing, pulling, bending, twisting, or reaching (OR=2.74; 95% CI=1.36-5.49).[33] In addition, back pain is known to be age-related, with more farmers experiencing episodes of pain between the ages of 45-59 than any other age group.[34]

Although the low back is currently considered the most frequently-affected site, farmers are vulnerable to developing musculoskeletal disorders in other body regions as well. Manual tasks such as working with arms overhead, shoveling and scraping, and carrying heavy objects can all play a prominent role in the onset and aggravation of MSDs in the neck, shoulders, elbows, wrists and hands.[22,34,35,68] The one-year prevalence of shoulder musculoskeletal disorders ranges from 25.9-71.4%, and symptoms in the wrist and hand have been associated with manually cleaning animal stalls (OR=1.96; 95% CI=1.06-3.63).[35] However, research on upper extremities in farmers is limited and inconsistent, with uncertainty about which occupational exposures increase risk for musculoskeletal disorders.[22,68] Even less information is available for MSDs in the lower extremities. It is therefore important to address pain experienced in other body regions as well as the back, in an attempt to detect possible relationships between specific farm activities and musculoskeletal disorders.

2.7.3 Individual and Economic Burden

Farmers and farm workers in North America, Australia, New Zealand, and many European countries have lower mortality and morbidity than other occupational groups and the general population.[67] With significant differences in many main illnesses, farmers have only reported higher diagnosis rates for musculoskeletal disorders.[67] Farmers are said to view pain as a normal part of work, and often do not seek care until the conditions become too severe or disabling. [69] However, disability resulting from musculoskeletal disorders can end up being a life-altering event for a farmer, as well as for their family and their business.[69]

Consequences of these symptoms can be considerable for the farm and surrounding communities. They can include reduced income for the household and business, and at a more macro level sustainability and growth in rural areas. A study conducted on Irish farmers revealed that only 10% of operators reporting disability indicated that disability had no impact on the farm business.[69] Although some disability was due to cardiovascular problems, the majority of farmers reported arthritis or back pain as the leading cause of disability.[69] Farms with disabled farmers were found to be similar in size to non-disability farms, but they recorded less financial success: lower gross output per hectare (less €213/ha), lower gross margins per hectare (less €171/ha), and consequently lower family farm income per hectare (less €123/ha).[69] The study also found that 20% of disabled farmers cease off-farm employment primarily because they feel they are no longer capable of completing the tasks that they previously performed.[69] Discontinuation of any off-farm work has serious implications in terms of household income and well-being. It may also present constraints in terms of resources and the continuation of farm operations if the extra money was depended on.

Musculoskeletal disorders not only disable farmers to the point where decreased work impacts farm output and profitability, but they also cause personal pain, suffering, illness and possibly further injury.[4] These outcomes clearly affect their quality of life and could quite possibly contribute to a decline in mental health.[4] Musculoskeletal disorders can have substantial adverse effects on not only the farmer but their family, healthcare resources, and broader community, yet the extent of this issue among Canadian farmers remains largely unknown.

2.8 Challenges of Researching Occupational Health and Safety in Farming

Most Canadian agricultural workers are protected by occupational health and safety laws.[72] As farming is one of the most hazardous industries, farmers and farm workers require this coverage to inform them about safety rights.[72,73] Not only does it give farmers rights, but it also authorizes the state to use enforcement to survey occupational hazards and prevent work-related injuries.[72] Provinces like British Columbia, Ontario, and Prince Edward Island extended the occupational Health and Safety to Farmers in the mid-2000s. However, worker compensation boards do not govern all farmers in Canada, as some workers can be exempted from coverage if they opt out.[72] In addition, working conditions on the farm are largely unknown due to rural and remote locations; it is impractical for site visits for enforcement, resulting in an unobserved occupation with poorly regulated health and safety guidelines. The Canadian Agriculture Injury Reporting program has studied national data on fatal and hospitalized agricultural injuries, yet risk factors are rarely well documented; musculoskeletal disorders are usually not recorded as acute injuries resulting in hospitalization are not typically identified in this database.[65] Mechanical and non-mechanical causes of unintentional injury are perhaps easier to monitor, as the acute harm requires immediate health care attention.[65] Chronic occupational exposures, however, leading to musculoskeletal pain may not be well reported because the cause is likely unknown. Despite surveillance efforts for injury prevention in farmers, repetitive and cumulative work practices require better documentation for appropriate ergonomic intervention.

Alberta remains the only Canadian province that excludes agricultural operations from its Occupational Health and Safety Act, and all that it encompasses. The exclusion of resident and migrant farm workers from protective legislation dates back to the beginning of the 20th century.[74] Farmers lobbied to exclude themselves from workers' compensation for reasons such as cost and wage ceilings.[74] There has been increasing criticism about Alberta's exclusion in recent years, however.[72] Due to high fatality rates and even higher rates of occupational diseases and injuries, there is reason for concern regarding the health and safety of farmers.

Although Alberta is resistant to regulating farm practice, the policy implications for the rest of Canada may potentially improve musculoskeletal conditions and other injury outcomes.[75] With the exception of Alberta, farmers across the country have the means to receive guidelines about safety standards and new legislation.[76] Farm owners, operators, and managers are responsible for knowing and applying best management practices and laws to ensure the health and safety of those on the farm.[76] Education and training are components to injury reduction, and legislation ensures that health and safety standards are applied to farm workers and will be followed.[77]

2.9 Summary

Although the potential biomechanical causes, symptoms, and burden of musculoskeletal disorders have been extensively studied in different occupational groups, farmers, and the general population, there is little known about the prevalence and exposure-response relationship in the Canadian agriculture industry. The opportunity to build on established research about these conditions and to be able to compare this population to those elsewhere is a novel contribution to the literature. Not only will valuable information become available to health and safety groups, but additional findings will help ascertain the development of work-related musculoskeletal disorders and understand the nature of pain in farmers and farm workers.

References

1. Voaklander D, Day ÃL, Dosman J, Hagel L, Pickett W. Older Farmers and Machinery Exposure — Cause for Concern ? *Am J Ind Med*. 2012;1050:1044-1050. doi:10.1002/ajim.22111.

2. Voaklander DC, Hartling L, Pickett W, Dimich-Ward H, Brison RJ. Work-related mortality among older farmers in Canada. *Can Fam Physician*. 1999;45:2903-10. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2328502&tool=pmcentrez&rendertype=abstract. Accessed April 8, 2014.

3. Kirkhorn SR, Earle-Richardson G, Banks RJ. Ergonomic risks and musculoskeletal disorders in production agriculture: recommendations for effective research to practice. *J Agromedicine*. 2010;15(3):281-99. doi:10.1080/1059924X.2010.488618.

4. Fathallah F a. Musculoskeletal disorders in labor-intensive agriculture. *Appl Ergon*. 2010;41(6):738-43. doi:10.1016/j.apergo.2010.03.003.

5. Young AE, Strasser R, Murphy GC. Agricultural workers' return to work following spinal cord injury: a comparison with other industry workers. *Disabil Rehabil*. 2004;26(17):1013-22. doi:10.1080/09638280410001702432.

6. Molyneaux-Smith L, Townsend E, Guernsey JR. Occupation Disrupted: Impacts, Challenges, and Coping Strategies For Farmers with Disabilities. *J Occup Sci*. 2003;10(1):14-20. doi:10.1080/14427591.2003.9686506.

7. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. *Bull World Health Organ*. 2003;81(9):646-56. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2572542&tool=pmcentrez&rendertype=abstract.

8. Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *J Electromyogr Kinesiol*. 2004;14(1):13-23. doi:10.1016/j.jelekin.2003.09.015.

9. Wilson A. Understanding musculoskeletal injury: developing a management plan for complex injuries. *J Bodyw Mov Ther*. 2002;6(4):237-247. doi:10.1054/jbmt.2002.0278.

10. Rosecrance J, Rodgers G. Low Back Pain and Musculoskeletal Symptoms Among Kansas Farmers. *Am J Ind Med*. 2006;556(49):547-556. doi:10.1002/ajim.20324.

11. Forde MS, Punnett L, Wegman DH. Prevalence of musculoskeletal disorders in union ironworkers. *J Occup Environ Hyg*. 2005;2(4):203-12. doi:10.1080/15459620590929635.

12. Parot-Schinkel E, Descatha A, Ha C, Petit A, Leclerc A, Roquelaure Y. Prevalence of multisite musculoskeletal symptoms: a French cross-sectional working population-based study. *BMC Musculoskelet Disord*. 2012;13(1):122. doi:10.1186/1471-2474-13-122.

13. Curwin S, Allt J, Szpilfogel C, Makrides L. The Healthy LifeWorks Project: The Effect of a Comprehensive Workplace Wellness Program on the Prevalence and Severity of Musculoskeletal Disorders in a Canadian Government Department. *J Occup Environ Med*. 2013;55(6):628-33. doi:10.1097/JOM.0b013e31829889c1.

14. D'Astolfo CJ, Humphreys BK. A record review of reported musculoskeletal pain in an Ontario long term care facility. *BMC Geriatr*. 2006;6:5. doi:10.1186/1471-2318-6-5.

15. Vos T, Flaxman AD, Naghavi M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012;380(9859):2163-96. doi:10.1016/S0140-6736(12)61729-2.

16. McPhail SM, Schippers M, Marshall AL. Age, physical inactivity, obesity, health conditions, and health-related quality of life among patients receiving conservative management for musculoskeletal disorders. *Clin Interv Aging*. 2014;9:1069-80. doi:10.2147/CIA.S61732.

17. Bergman S. Public health perspective--how to improve the musculoskeletal health of the population. *Best Pract Res Clin Rheumatol*. 2007;21(1):191-204. doi:10.1016/j.berh.2006.08.012.

18. Treaster DE, Burr D. Gender differences in prevalence of upper extremity musculoskeletal disorders. *Ergonomics*. 2004;47(5):495-526. doi:10.1080/00140130310001638171.

19. Osborne A, Blake ÃC, Fullen BM, et al. Prevalence of Musculoskeletal Disorders Among Farmers : A Systematic Review. *Am J Ind Med*. 2012;158(October 2011):143-158. doi:10.1002/ajim.21033.

20. Nevala-Puranen N. Effects of occupationally-oriented rehabilitation on farmers' work techniques, musculoskeletal symptoms, and work ability. *J Occup Rehabil*. 1996;6(3):191-200. doi:10.1007/BF02110755.

21. Yang N Bin. Application of Ergonomics Principles in the Packaging Machinery Design. *Appl Mech Mater*. 2012;215-216:378-381. doi:10.4028/www.scientific.net/AMM.215-216.378.

22. Osborne A, Blake ÃC, Fullen BM, et al. Risk Factors for Musculoskeletal Disorders Among Farm Owners and Farm Workers : A Systematic Review. *Am J Ind Med*. 2012;389(December 2011):376-389. doi:10.1002/ajim.22001.

23. Lau BHF, Lafave MR, Mohtadi NG, Butterwick DJ. Utilization and cost of a new model of care for managing acute knee injuries: the Calgary Acute Knee Injury Clinic. *BMC Health Serv Res*. 2012;12:445. doi:10.1186/1472-6963-12-445.

24. Costa BR. Risk Factors for Work-Related Musculoskeletal Disorders : A Systematic Review of Recent Longitudinal Studies. *Am J Ind Med*. 2010;323:285-323. doi:10.1002/ajim.20750.

25. Winkel J, Mathiassen SE. Assessment of physical work load in epidemiologic studies: concepts, issues and operational considerations. *Ergonomics*. 1994;37(6):979-88. doi:10.1080/00140139408963711.

26. Bergman S. Management of musculoskeletal pain. *Best Pract Res Clin Rheumatol*. 2007;21(1):153-66. doi:10.1016/j.berh.2006.10.001.

27. Kumar S. Theories of musculoskeletal injury causation. *Ergonomics*. 2001;44(1):17-47. doi:10.1080/00140130120716.

28. Balagué F, Mannion AF, Pellisé F, Cedraschi C. Non-specific low back pain. *Lancet*. 2012;379(9814):482-91. doi:10.1016/S0140-6736(11)60610-7.

29. Punnett L. Musculoskeletal disorders and occupational exposures: how should we judge the evidence concerning the causal association? *Scand J Public Health*. 2014;42(13 Suppl):49-58. doi:10.1177/1403494813517324.

30. Yassi a. Work-related musculoskeletal disorders. *Curr Opin Rheumatol*. 2000;12(2):124-30. Available at: http://www.ncbi.nlm.nih.gov/pubmed/10751015.

31. Walker-Bone K, Palmer KT. Musculoskeletal disorders in farmers and farm workers. *Occup Med (Lond)*. 2002;52(8):441-50. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12488514.

32. Vyas R. Mitigation of musculoskeletal problems and body discomfort of agricultural workers through educational intervention. *Work*. 2012;41 Suppl 1:2398-404. doi:10.3233/WOR-2012-0473-2398.

33. Xiang H, Stallones L, Keefe TJ. Back pain and agricultural work among farmers: an analysis of the Colorado Farm Family Health and Hazard Surveillance Survey. *Am J Ind Med*. 1999;35(3):310-6. Available at: http://www.ncbi.nlm.nih.gov/pubmed/9987565.

34. Park H, Sprince NL, Whitten ÃPS, Burmeister LF, Zwerling C. Risk Factors for Back Pain Among Male Farmers : Analysis of Iowa Farm Family Health and Hazard Surveillance Study. *Am J Ind Med*. 2001;654:646-654. doi:10.1002/ajim.10025.

35. Nonnenmann MW, Anton D, Gerr F, Merlino L, Donham K. Musculoskeletal Symptoms of the Neck and Upper Extremities among Iowa Dairy Farmers. *Am J Ind Med*. 2008;451:443-451. doi:10.1002/ajim.20582.

36. Trask C, Bath B, McCrosky J, Lawson J. A profile of farmers and other employed canadians with chronic back pain: a population-based analysis of the 2009-2010 canadian community health surveys. *J Rural Health*. 2014;30(3):300-10. doi:10.1111/jrh.12062.

37. Papageorgiou a C, Croft PR, Thomas E, Ferry S, Jayson MI, Silman a J. Influence of previous pain experience on the episode incidence of low back pain: results from the South Manchester Back Pain Study. *Pain*. 1996;66(2-3):181-5. Available at: http://www.ncbi.nlm.nih.gov/pubmed/8880839.

38. Marras WS. The case for cumulative trauma in low back disorders. *Spine J*. 2003;3(3):177-179. doi:10.1016/S1529-9430(03)00032-9.

39. Andersson GB. Epidemiological features of chronic low-back pain. *Lancet*. 1999;354(9178):581-5. doi:10.1016/S0140-6736(99)01312-4.

40. Chopp JN, Fischer SL, Dickerson CR. The impact of work configuration, target angle and hand force direction on upper extremity muscle activity during sub-maximal overhead work. *Ergonomics*. 2010;53(1):83-91. doi:10.1080/00140130903323232.

41. Nimbarte AD, Aghazadeh F, Ikuma L, Sun Y. Evaluation of the Loading of Neck and Shoulder Musculature in Overhead Pushing and Pulling Exertions. *Hum Factors Ergon Manuf Serv Ind*. 2012;22(4):317-327. doi:10.1002/hfm.

42. Svendsen SW, Bonde JP, Mathiassen SE, Stengaard-Pedersen K, Frich LH. Work related shoulder disorders: quantitative exposure-response relations with reference to arm posture. *Occup Environ Med*. 2004;61(10):844-53. doi:10.1136/oem.2003.010637.

43. Dempsey PG, Mathiassen SE. On the evolution of task-based analysis of manual materials handling, and its applicability in contemporary ergonomics. *Appl Ergon*. 2006;37(1):33-43. doi:10.1016/j.apergo.2004.11.004.

44. Yanbaeva DG, Dentener M a, Creutzberg EC, Wesseling G, Wouters EFM. Systemic effects of smoking. *Chest*. 2007;131(5):1557-66. doi:10.1378/chest.06-2179.

45. O'Loughlin J, Lambert M, Karp I, et al. Association between cigarette smoking and C-reactive protein in a representative, population-based sample of adolescents. *Nicotine Tob Res*. 2008;10(3):525-32. doi:10.1080/14622200801901997.

46. Shiri R, Viikari-Juntura E, Leino-Arjas P, et al. The association between carotid intima-media thickness and sciatica. *Semin Arthritis Rheum*. 2007;37(3):174-81. doi:10.1016/j.semarthrit.2007.03.001.

47. Rubin DI. Epidemiology and risk factors for spine pain. *Neurol Clin*. 2007;25(2):353-71. doi:10.1016/j.ncl.2007.01.004.

48. Manninen P, Riihimäk H, Heliövaara M. Incidence and risk factors of low-back pain in middle-aged farmers. *Occup Med (Lond)*. 1995;45(3):141-6. Available at: http://www.ncbi.nlm.nih.gov/pubmed/7605976.

49. Shiri R, Karppinen J, Leino-Arjas P, Solovieva S, Viikari-Juntura E. The association between smoking and low back pain: a meta-analysis. *Am J Med*. 2010;123(1):87.e7-35. doi:10.1016/j.amjmed.2009.05.028.

50. Felson LIKTMSEPWDKD. Disc Degeneration/Back Pain and Calcification of the Abdominal Aorta. *Spine (Phila Pa 1976)*. 1997;22(14):1642-1649.

51. Korkiakoski a, Niinimäki J, Karppinen J, et al. Association of lumbar arterial stenosis with low back symptoms: a cross-sectional study using two-dimensional time-of-flight magnetic resonance angiography. *Acta Radiol*. 2009;50(1):48-54. doi:10.1080/02841850802587862.

52. Uematsu Y, Matuzaki H, Iwahashi M. Effects of nicotine on the intervertebral disc: an experimental study in rabbits. *J Orthop Sci*. 2001;6(2):177-82. doi:10.1007/s0077610060177.

53. Gotay CC, Katzmarzyk PT, Janssen I, Dawson MY, Aminoltejari K, Bartley NL. Updating the Canadian obesity maps: an epidemic in progress. *Can J Public Health*. 2013;104(1):e64-8. Available at: http://www.ncbi.nlm.nih.gov/pubmed/23618109.

54. Anandacoomarasamy a, Caterson I, Sambrook P, Fransen M, March L. The impact of obesity on the musculoskeletal system. *Int J Obes (Lond)*. 2008;32(2):211-22. doi:10.1038/sj.ijo.0803715.

55. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: the evidence. *CMAJ*. 2006;174(6):801-9. doi:10.1503/cmaj.051351.

56. Shiri R, Karppinen J, Leino-Arjas P, Solovieva S, Viikari-Juntura E. The association between obesity and low back pain: a meta-analysis. *Am J Epidemiol*. 2010;171(2):135-54. doi:10.1093/aje/kwp356.

57. Health A, Viii M. Module VIII CHRONIC MUSCULOSKELETAL DISORDERS IN AGRICULTURE FOR. :1-39.

58. Hernandez AM, Peterson AL. Handbook of Occupational Health and Wellness. Gatchel RJ, Schultz IZ, eds. *Handbooks Heal Work Disabillity*. 2012. doi:10.1007/978-1-4614-4839-6.

59. Coenen P, Kingma I, Boot CRL, Twisk JWR, Bongers PM, van Dieën JH. Cumulative low back load at work as a risk factor of low back pain: a prospective cohort study. *J Occup Rehabil*. 2013;23(1):11-8. doi:10.1007/s10926-012-9375-z.

60. Hamberg-van Reenen HH, Ariëns GAM, Blatter BM, van Mechelen W, Bongers PM. A systematic review of the relation between physical capacity and future low back and neck/shoulder pain. *Pain*. 2007;130(1-2):93-107. doi:10.1016/j.pain.2006.11.004.

61. Straker L, Mathiassen SE. Increased physical work loads in modern work--a necessity for better health and performance? *Ergonomics*. 2009;52(10):1215-25. doi:10.1080/00140130903039101.

62. Sig CR. *Research Topics for the Next Decade*. Cincinnati, OH; 2001.

63. Jill A, Sachs MI, Dahlgren KA, Tinguely SJ. Accidental Farm Injuries in Children Eighty-three. *Am J Dis Child*. 1987;141.

64. Heaton K, Azuero A, Reed D. The effects of arthritis , mobility , and farm task on injury among older farmers. *Nurs Res Rev*. 2012:9-16.

65. Paton GR, Hagel L, Fourney DR. Hospitalized head and spine injuries on Saskatchewan farms. *Can J Neurol Sci*. 2014;41(4):436-41. Available at: http://www.ncbi.nlm.nih.gov/pubmed/24878466.

66. Torén a, Oberg K, Lembke B, Enlund K, Rask-Andersen a. Tractor-driving hours and their relation to self-reported low-back and hip symptoms. *Appl Ergon*. 2002;33(2):139-46. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12009120.

67. Thelin N, Holmberg S, Nettelbladt P, Thelin A. Mortality and morbidity among farmers, nonfarming rural men, and urban referents: a prospective population-based study. *Int J Occup Environ Health*. 15(1):21-8. Available at: http://www.ncbi.nlm.nih.gov/pubmed/19267123.

68. Scutter S, Türker KS, Hall R. Headaches and neck pain in farmers. *Aust J Rural Health*. 1997;5(1):2-5. Available at: http://www.ncbi.nlm.nih.gov/pubmed/9437926.

69. Whelan S, Ruane DJ, McNamara J, Kinsella A, McNamara A. Disability on Irish farms--a real concern. *J Agromedicine*. 2009;14(2):157-63. doi:10.1080/10599240902813078.

70. Walker-Bone K, Reading I, Coggon D, Cooper C, Palmer KT. The anatomical pattern and determinants of pain in the neck and upper limbs: an epidemiologic study. *Pain*. 2004;109(1-2):45-51. doi:10.1016/j.pain.2004.01.008.

71. Bovenzi M, Betta a. Low-back disorders in agricultural tractor drivers exposed to whole-body vibration and postural stress. *Appl Ergon*. 1994;25(4):231-41. Available at: http://www.ncbi.nlm.nih.gov/pubmed/15676973.

72. Barnetson BOB. No Right to be Safe: Justifying the Exclusion of Alberta Farm Workers from Health and Safety Legislations. *Social Stud*. 2012;8(2):134-162.

73. Marlenga B, Berg RL, Linneman JG, Brison RJ, Pickett W. Changing the child labor laws for agriculture: impact on injury. *Am J Public Health*. 2007;97(2):276-82. doi:10.2105/AJPH.2005.078923.

74. Thompson JH, Seager A. Workers, Growers and Monopolists: The “Labour Problem” in the Alberta Beet Sugar Industry during the 1930s. *Labour / Le Trav*. 1978;3:153. doi:10.2307/25139911.

75. Kim J, Arrandale VH, Kudla I, Mardell K, Lougheed D, Holness DL. Educational intervention among farmers in a community health care setting. *Occup Med (Lond)*. 2012;62(6):458-61. doi:10.1093/occmed/kqs129.

76. *Precarious Employment: Understanding Labour Market Insecurity in Canada*. McGill-Queen's Press - MQUP; 2006:485. Available at: http://books.google.com/books?hl=en&lr=&id=8oj-MocTC8gC&pgis=1. Accessed April 30, 2014.

77. Hagel LM, Pickett W, Pahwa P, et al. Prevention of agricultural injuries: an evaluation of an education-based intervention. *Inj Prev*. 2008;14(5):290-5. doi:10.1136/ip.2008.018515.

Chapter 3

Supplemental Methods

3.1 Background on Modeling Methods

Risk is intuitive and easy to communicate to knowledge users and the general public. Although relative risks are preferred for such communications, odds ratios are often reported.[1] This chapter presents the rationale for the decision to use modified Poisson regression approaches to obtain estimates of relative risk. Measures of association were calculated using the approach that modeled musculoskeletal disorders as a binary outcome. Logistic, log-binomial, and modified Poisson regression were performed and the risk estimates from each were interpreted and compared.

3.1.1 Logistic Regression

Logistic regression has been the most commonly used method for studying relationships that have a binary outcome.[2] Using the logit link function, this model directly yields an odds ratio.[3] When the outcome is rare (prevalence less than 10 percent), the odds ratio accurately estimates the risk or prevalence ratio.[4] However, as the outcome becomes more common (as is found in MSD outcomes), the odds ratio should not be interpreted as risk ratios as the odds ratio will generally overestimate the strength of such effects.[2] As relative risk is typically the desired risk estimate, the odds ratios obtained from logistic regression are often interpreted this way.[3] Despite this, it is incorrect to use these estimates interchangeably; the exaggerated risk estimate delivered by the odds ratio may be misleading when these measures of association are used and referred to. [5]

3.1.2 Log-Binomial Regression

As the use of logistic regression in prospective studies and cross-sectional studies has been questioned, log-binomial regression has often been proposed as an alternative method for binary outcomes.[2] Both models are similar, however, instead of applying a logit link function, a log link is used. The benefit of log-binomial regression models is that the coefficients can directly estimate risk and prevalence ratios. Although this model is known to have convergence issues, it estimates smaller standard errors (SEs) and therefore narrower confidence intervals.[3] However, the model may not converge to the correct estimate due to restrictions on the parameter space and therefore giving chance to the maximum likelihood estimate occurring on the boundary. This is often an issue when the prevalence is high and the prevalence ratio is large; or alternatively, poor starting values that are not in the restricted parameter space.[6]

3.1.3 Modified Poisson Regression

When Poisson regression is applied to binary data, it has similar parameters to that of log-binomial data, yet the model assumes a Poisson distribution for the outcome.[7] Although this distribution is typically used to describe rare events, Poisson can also be used as an approximation of the binomial distribution.[7] However, the Poisson regression is conservative for binary outcomes, as the model produces wide confidence intervals when based on outcomes that are not rare. The modified Poisson was proposed by Zou to model outcomes of binary data that are common.[4] This approach incorporates a sandwich estimator to obtain robust error variance.[4]

Binomial regression and Poisson regression are suggested models of obtaining the preferred relative risk.[7] Log-binomial often fails to converge, and ordinary Poisson tends to specify wider confidence intervals as a result of misspecification of the outcome distribution. A modified Poisson regression model has been shown to estimate relative risk and confidence intervals for independent binary outcomes.[4] The modified Poisson version that was originally proposed by Zou did not account for outcomes within a cluster, making it suitable for data that is collected independently.[4] An extension of this modified regression was developed to analyze correlated or clustered data, with the purpose of obtaining the average effect of the exposure on the outcome variable.[8] By applying an extension of the sandwich variance estimator to binary data, both the clustering effects and the use of the Poisson as a working model for binary data are accounted for.[8] Rather than placing an individual identifier within the REPEATED statement used in SAS, the cluster identifier is included.[7]

The performance of the modified Poisson regression approach for estimating relative risks has been advocated as appropriate for observational studies where clustering is present as a result of multiple subjects within groups. Despite incomplete evidence on the use and adequacy of modified Poisson—especially for clustered data—the application of this method is becoming more common.[5] The studies that have used this relatively new strategy are supportive, but also recommend further investigation to ensure this method is valid.[5,3]

3.1.4 Comparison

Deddens and Petersen acknowledged the advantages and disadvantages of odds ratios and prevalence ratios, especially in occupational studies involving common outcomes. They compared the estimates produced from logistic regression, log-binomial regression, and the modified Poisson regression in order to make recommendations for appropriate model use in studies where the outcome is not rare.[2]

Their results stated that 1) for very high prevalence and moderate sample size, the modified Poisson method yields a less-biased estimate of the prevalence ratios than the log-binomial method; 2) for moderate prevalence and moderate sample size, the log-binomial methods yields slightly higher power and smaller standard errors than the modified Poisson method. Their final conclusion recommended that if there are no convergence problems, to apply the log-binomial model to obtain the adjusted relative risk. However, if there is a convergence issue, the modified Poisson regression should be used instead. Logistic regression should not be used when analyzing data with common outcomes, as the odds ratio estimate is only adequate when the outcome is rare.

3.2 Model Outcome Results from the Present Study

Although not the main objective of this paper, a component of this analysis involved comparing approaches to modeling musculoskeletal disorders as the outcome variable in a cross-sectional study. Application of logistic, log-binomial, and the modified Poisson regression models utilized the binary nature of musculoskeletal pain to obtain estimates that revealed the risk for MSD associated with biomechanically-demanding work. These model outcomes show the potential for Poisson/negative binomial regression models to: 1) provide an alternative way to analyze musculoskeletal disorders as a discrete and common outcome; and 2) yield readily interpretable measures of associations, rather than the traditional use of odds ratios.

Tables 1 and 2 show that logistic regression provides strong estimates, with some odds ratios greater than 2.00. If these are interpreted as relative risks, however, as they often times are for non-rare events, they inflate/exaggerate the estimates greatly, making the relationship seem stronger than it truly is.[3] Tables 3 and 4 show the model outcomes for log-binomial regression. The relative risks are comparable to those provided by the modified Poisson, but in a few cases, the models did not converge. As generalized linear models are fit by maximizing the log-likelihood function, failed convergence often occurs whenever this process fails to find the maximum likelihood estimate. Estimates may not be determined due to challenges of parameter space, where the true maximum can be located in one of three mutually exclusive locations: the boundary, in the limit, or inside.[1] It is often assumed to be a boundary issue when convergence fails in a log-binomial model.[1] For example, a model may fail to converge when boundaries or parameter values of linear predictors or multiple covariates is constrained. Different starting points were explored to overcome this issue, by finding a valid Maximum Likelihood Estimate, but convergence remained unresolved and could not be addressed. As some log-binomial models were unstable, the next best option was to use the modified Poisson regression with robust variance.[4]

3.3 Conclusion

Although this is a fairly new method for directly estimating relative risks of dichotomous outcomes, the estimates produced in the modified Poisson analysis were plausible, accounted for the clustered nature of the data, and rectified the problem of overestimated error, resulting in narrow confidence intervals.[8] Until future research determines reliable solutions to deal with failed convergence in log-binomial models, the modified Poisson method offers a simple alternative for approximating the solution, without the inflated estimates offered by logistic. As non-convergent models are practically non-existent when using the Poisson method, this approach for estimating relative risks is receiving more attention in the literature and growing in use.[1] It is possible that the advantages of the modified Poisson will make it more suitable for modeling relationships with common binary outcomes in future studies, and become the preferred method for naturally estimating relative risks.

References

1. Williamson T, Eliasziw M, Fick GH. Open Access Log-binomial models : exploring failed convergence. *Emerg. Themes Epidemiol.* 2013;10(14):1-10.

2. Deddens J a, Petersen MR. Approaches for estimating prevalence ratios. *Occup. Environ. Med.* 2008;65(7):481, 501-6. doi:10.1136/oem.2007.034777.

3. Fekedulegn D, Andrew M, Violanti J, Hartley T, Charles L, Burchfiel C. Comparison of statistical approaches to evaluate factors associated with metabolic syndrome. *J. Clin. Hypertens. (Greenwich).* 2010;12(5):365-73. doi:10.1111/j.1751-7176.2010.00264.x.

4. Zou G. A Modified Poisson Regression Approach to Prospective Studies with Binary Data. *Am. J. Epidemiol.* 2004;159(7):702-706. doi:10.1093/aje/kwh090.

5. Yelland LN, Salter AB, Ryan P. Performance of the modified Poisson regression approach for estimating relative risks from clustered prospective data. *Am. J. Epidemiol.* 2011;174(8):984-92. doi:10.1093/aje/kwr183.

6. Skov T, Deddens J, Petersen MR, Endahl L. Prevalence proportion ratios: estimation and hypothesis testing. *Int. J. Epidemiol.* 1998;27(1):91-5. Available at: http://www.ncbi.nlm.nih.gov/pubmed/9563700.

7. Zhao K. *Proper Estimation of Relative Risk Using PROC GENMOD in Population Studies*. Los Angeles, CA; :1-14.

8. Zou GY, Donner A. Extension of the modified Poisson regression model to prospective studies with correlated binary data. *Stat. Methods Med. Res.* 2013;22(6):661-70. doi:10.1177/0962280211427759.

Table 1. Logistic Regression for Lower Back Pain

	ANY LOWER BACK PAIN				WORK-INTERRUPTING PAIN				
	Unadjusted		***Adjusted*** [1]			***Unadjusted***		***Adjusted*** [2]	
Work Task Exposure	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**	**%**	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**
Lift, lower, or carry heavy objects									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.54 (1.22, 1.94)	0.0003	1.60 (1.24, 2.07)	0.0004	8	1.57 (1.15, 2.14)	0.0044	1.48 (1.06, 2.06)	0.0213
11-20 days/year	1.92 (1.35, 2.73)	0.0003	2.10 (1.43, 3.90)	0.0002	17	1.44 (0.91, 2.29)	0.1169	1.45 (0.88, 2.37)	0.1426
20+ days/year	1.93 (1.55, 2.40)	<.0001	2.01 (1.54, 2.62)	<.0001	19	1.69 (1.27, 2.26)	0.0004	1.50 (1.07, 2.10)	0.0186
Use a shovel or pitchfork									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.68 (1.36, 2.07)	<.0001	1.89 (1.49, 2.30)	<.0001	18	1.57 (1.14, 2.01)	0.0047	1.51 (1.11, 2.05)	0.0088
11-20 days/year	2.36 (1.70, 3.27)	<.0001	2.79 (1.92, 4.05)	0.0009	20	1.73 (1.16, 2.57)	0.0071	1.70 (1.11, 2.60)	0.0155
20+ days/year	1.95 (1.52, 2.51)	<.0001	2.14 (1.59, 2.88)	0.0001	17	1.47 (1.05, 2.04)	0.0238	1.29 (0.88, 1.89)	0.1856
Work with hands over shoulder height									
0 days/year	1.00 (Reference)		1.00 (Reference)		14	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.60 (1.30, 1.96)	<.0001	1.77 (1.40, 2.24)	<.0001	17	1.28 (0.97, 1.68)	0.0796	1.27 (0.94, 1.71)	0.1213
11-20 days/year	1.99 (1.36, 2.92)	0.0004	2.09 (1.35, 3.21)	0.0009	16	1.18 (0.72, 1.94)	0.5058	1.08 (0.64, 1.82)	0.7671
20+ days/year	1.91 (1.41, 2.59)	<.0001	2.05 (1.43, 2.94)	0.0001	20	1.52 (1.04, 2.20)	0.0300	1.30 (0.84, 1.99)	0.2373
Operate power tools with the hand									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.53 (1.23, 1.89)	0.0001	1.57 (1.23, 2.01)	0.0003	16	1.23 (0.91, 1.65)	0.1774	1.16 (0.84, 1.60)	0.3821
11-20 days/year	2.22 (1.63, 3.05)	<.0001	2.25 (1.58, 3.20)	<.0001	22	1.94 (1.33, 2.82)	0.0006	1.76 (1.17, 2.65)	0.0072
20+ days/year	1.90 (1.45, 2.41)	<.0001	2.01 (1.52, 2.72)	<.0001	19	1.53 (1.12, 2.09)	0.0878	1.24 (0.86, 1.80)	0.2478

[1] Adjusted models controlled for tractor operation, Body Mass Index, medication status, and comorbidity status
[2] Adjusted models controlled for age, tractor operation, farm injuries, comorbidity status, and relation to owner

Table 2. Logistic Regression for Shoulder Pain

	ANY SHOULDER PAIN				WORK-INTERRUPTING PAIN				
	Unadjusted		*Adjusted* [1]			*Unadjusted*		*Adjusted* [2]	
Work Task Exposure	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**	**%**	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**
Lift, lower, or carry heavy objects									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.44 (1.14, 1.82)	0.0001	1.25 (0.97, 1.61)	0.0895	8	0.99 (0.63, 1.55)	0.9688	0.91 (0.57, 1.47)	0.7100
11-20 days/year	1.63 (1.16, 2.29)	0.0055	1.52 (1.07, 2.28)	0.0208	17	0.77 (0.37, 1.59)	0.4771	0.82 (0.37, 1.78)	0.6073
20+ days/year	2.01 (1.61, 2.49)	0.0020	1.68 (1.32, 2.14)	<.0001	19	1.57 (1.08, 2.28)	0.0172	1.48 (0.99, 2.22)	0.0575
Use a shovel or pitchfork									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.33 (1.08, 1.64)	0.0081	1.23 (0.98, 1.56)	0.0784	18	0.98 (0.65, 1.46)	0.9007	1.01 (0.66, 1.55)	0.9630
11-20 days/year	1.64 (1.20, 2.28)	0.0019	1.68 (1.20, 2.36)	0.0029	20	1.31 (0.77, 2.23)	0.3240	1.36 (0.76, 2.42)	0.2957
20+ days/year	1.91 (1.50, 2.45)	<.0001	1.72 (1.31, 2.26)	0.0001	17	1.35 (0.89, 2.07)	0.1625	1.35 (0.85, 2.15)	0.1990
Work with hands over shoulder height									
0 days/year	1.00 (Reference)		1.00 (Reference)		14	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.63 (1.33, 2.00)	<.0001	1.51 (1.20, 1.89)	0.0004	17	1.25 (0.86, 1.82)	0.2369	1.27 (0.85, 1.90)	0.2363
11-20 days/year	1.74 (1.20, 2.51)	0.0033	1.47 (0.98, 2.20)	0.0615	16	1.07 (0.53, 2.16)	0.8429	0.98 (0.46, 2.06)	0.9480
20+ days/year	1.96 (1.46, 2.63)	<.0001	1.86 (1.34, 2.59)	0.0002	20	1.46 (0.88, 2.40)	0.1418	1.47 (0.86, 2.51)	0.1575
Operate power tools with the hand									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.32 (1.07, 1.64)	0.0113	1.07 (0.85, 1.37)	0.5576	16	1.02 (0.68, 1.52)	0.9360	0.89 (0.58, 1.37)	0.5967
11-20 days/year	1.53 (1.14, 2.07)	0.0054	1.25 (0.90, 1.75)	0.1824	22	1.36 (0.81, 2.28)	0.2386	1.26 (0.73, 2.19)	0.4051
20+ days/year	1.59 (1.26, 2.01)	0.0878	1.28 (0.98, 1.67)	0.0694	19	1.02 (0.66, 1.59)	0.9138	0.83 (0.51, 1.36)	0.4649

[1] Adjusted models controlled for farm injuries, Body Mass Index, comorbidity status, and relation to owner
[2] Adjusted models controlled for farm injuries, medication status, comorbidity status, and relation to owner

Table 3. Log-Binomial Regression for Lower Back Pain

	ANY LOWER BACK PAIN				WORK-INTERRUPTING PAIN				
	Unadjusted		*Adjusted* [1]			*Unadjusted*		*Adjusted* [2]	
Work Task Exposure	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**	**%**	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**
Lift, lower, or carry heavy objects									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.15 (0.90, 1.47)	0.2527	1.21 (0.94, 1.55)	0.1374	8	0.98 (0.91, 1.06)	0.6324	1.00 (0.93, 1.08)	0.9606
11-20 days/year	1.44 (1.15, 1.80)	0.0013	1.47 (1.16, 1.86)	0.0015	17	1.05 (0.98, 1.13)	0.1454	1.05 (0.98, 1.12)	0.1680
20+ days/year	1.44 (1.26, 1.64)	<.0001	1.42 (1.22, 1.66)	<.0001	19	1.08 (1.03, 1.13)	0.0012	1.06 (1.01, 1.11)	0.0150
Use a shovel or pitchfork									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.31 (1.05, 1.64)	0.0168	1.31 (1.03, 1.66)	.0250	18	1.03 (0.95, 1.11)	0.5058	1.03 (0.91, 1.06)	0.6123
11-20 days/year	1.71 (1.38, 2.12)	<.0001	1.76 (1.40, 2.21)	<.0001	20	1.09 (1.02, 1.17)	0.0122	1.09 (1.02, 1.17)	0.0153
20+ days/year	1.43 (1.22, 1.68)	<.0001	1.46 (1.22, 1.75)	<.0001	17	1.06 (1.00, 1.11)	0.0331	1.03 (0.98, 1.08)	0.2334
Work with hands over shoulder height									
0 days/year	1.00 (Reference)		1.00 (Reference)		14	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.13 (0.87, 1.49)	0.3529	1.06 (0.80, 1.41)	0.6671	17	0.98 (0.91, 1.07)	0.6940	0.98 (0.91, 1.06)	0.6123
11-20 days/year	1.46 (1.13, 1.89)	0.0037	1.42 (1.09, 1.86)	0.0104	16	1.03 (0.95, 1.11)	0.4984	1.03 (0.96, 1.10)	0.4706
20+ days/year	1.45 (1.20, 1.76)	0.0001	1.45 (1.16, 1.81)	0.0012	20	1.07 (1.00, 1.15)	0.0393	1.06 (0.99, 1.13)	0.1027
Operate power tools with the hand									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.29 (1.04, 1.59)	0.0200	1.25 (1.00, 1.56)	0.0455	16	1.08 (1.00, 1.17)	0.0307	1.06 (0.99, 1.14)	0.0830
11-20 days/year	1.43 (1.24, 1.65)	<.0001	1.47 (1.16, 1.86)	0.0015	22	1.07 (1.02, 1.12)	0.0095	1.03 (0.98, 1.08)	0.3180
20+ days/year	1.43 (1.24, 1.65)	<.0001	1.42 (1.22, 1.66)	<.0001	19	1.07 (1.02, 1.12)	0.0095	1.03 (0.98, 1.08)	0.3180

[1] Adjusted models controlled for tractor operation, Body Mass Index, medication status, and comorbidity status
[2] Adjusted models controlled for age, tractor operation, farm injuries, comorbidity status, and relation to owner

Table 4. Log Binomial Regression for Shoulder Pain

	ANY SHOULDER PAIN				WORK-INTERRUPTING PAIN				
	Unadjusted		*Adjusted* [1]			*Unadjusted*		*Adjusted* [2]	
Work Task Exposure	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**	**%**	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**
Lift, lower, or carry heavy objects									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.06 (0.89, 1.25)	0.5264	1.10 (0.93, 1.29)	0.2646	8	0.99 (0.95, 1.03)	0.5082	-	-
11-20 days/year	1.23 (1.06, 1.44)	0.0069	1.19 (1.02, 1.39)	0.0231	17	0.99 (0.95, 1.02)	0.4585	-	-
20+ days/year	1.38 (1.25, 1.52)	<.0001	1.22 (1.11, 1.35)	<.0001	19	1.04 (1.01, 1.07)	0.0167	-	-
Use a shovel or pitchfork									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.11 (0.96, 1.28)	0.1756	1.14 (0.99, 1.31)	0.0713	18	1.03 (0.98, 1.07)	0.2842	1.01 (0.98, 1.05)	0.5258
11-20 days/year	1.25 (1.09, 1.44)	0.0014	1.21 (1.06, 1.38)	0.0048	20	1.02 (0.98, 1.07)	0.3238	1.01 (0.97, 1.04)	0.6669
20+ days/year	1.35 (1.21, 1.51)	<.0001	1.24 (1.11, 1.38)	0.0002	17	1.02 (0.99, 1.06)	0.1513	1.01 (0.97, 1.03)	0.6898
Work with hands over shoulder height									
0 days/year	1.00 (Reference)		1.00 (Reference)		14	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.03 (0.85, 1.23)	0.7920	0.99 (0.83, 1.17)	0.8966	17	0.99 (0.94, 1.04)	0.6278	1.01 (0.96, 1.06)	0.7735
11-20 days/year	1.27 (1.06, 1.51)	0.0082	1.15 (0.98, 1.36)	0.0848	16	1.00 (0.96, 1.05)	0.8562	1.01 (0.95, 1.06)	0.7393
20+ days/year	1.37 (1.19, 1.58)	<.0001	1.29 (1.13, 1.47)	0.0002	20	1.03 (0.99, 1.07)	0.1401	1.01 (0.98, 1.04)	0.4192
Operate power tools with the hand									
0 days/year	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	1.08 (0.93, 1.24)	0.3208	1.07 (0.93, 1.22)	0.3420	16	1.02 (0.98, 1.07)	0.3076	-	-
11-20 days/year	1.21 (1.06, 1.39)	0.0044	1.10 (0.97, 1.24)	0.1307	22	1.02 (0.98, 1.07)	0.2710	-	-
20+ days/year	1.24 (1.11, 1.37)	<.0001	1.10 (0.99, 1.21)	0.0712	19	1.00 (0.97, 1.03)	0.8997	-	-

[1] Adjusted models controlled for farm injuries, Body Mass Index, comorbidity status, and relation to owner
[2] Adjusted models controlled for farm injuries, medication status, comorbidity status, and relation to owner

Chapter 4

Prevalence of Musculoskeletal Disorders among Saskatchewan Farmers

4.1 Abstract

Background Work-related musculoskeletal disorders (MSD) are a significant occupational health problem in many industries. The extent of the MSD problem is not well understood among Canadian farmers, and little too is known about their etiology. The purpose of this study was therefore to: 1) determine the prevalence of MSD among farmers in one Canadian province; and 2) describe the types and severities of these disorders, and patterns in their occurrence.

Methods This cross-sectional analysis was conducted within a prospective study called the Saskatchewan Farm Injury Cohort Study. Reports of MSDs were available for 2,595 adult participants from 1,212 farms in Saskatchewan, Canada. Information included demographic and health-related variables, farm-related injuries, and economic conditions of individual farms. Relationships between MSD symptoms and time spent doing farm work were investigated using tests of association.

Results The participation rate was 48.8%. A strong majority of participants (82.2%) reported having musculoskeletal pain in at least one body part over the past year. The lower back was the anatomical site most frequently affected (57.7%), followed by the shoulders (44.0%), and neck (39.6%). Additionally, 27.9% of people had more serious pain that prevented them from performing regular work activities. The prevalence of MSDs did not vary by gender, commodity type, or by total hours of farm work completed. However, MSDs were significantly related to time spent performing biomechanically demanding tasks such as heavy lifting, shoveling, working with arms overhead, and use of power tools.

Conclusions Findings indicate that low back pain was the most common MSD in farmers, followed by pain in the upper and then lower extremities. Although we aimed to identify high

risk groups, demographic analyses did not show large differences, suggesting that the majority of farmers seem to be at risk for MSDs.

4.2 Introduction

The varied and strenuous nature of agricultural work exposes farmers to a number of risk factors that have been associated with musculoskeletal disorders.[1] Although farmers experience musculoskeletal disorders at rates higher than the general working population, they may be less likely to seek care, waiting until the pain becomes sufficiently disabling that they cease work.[2] The consequences of musculoskeletal disorders can be both clinically and economically significant, impacting the individual and the farm.[1,2] It is therefore important to understand the extent of this problem within specific agricultural populations. There is a substantial body of evidence on the prevalence of musculoskeletal pain in farmers internationally; however, very little information exists on how prevalent MSDs are in Canadian farmers.[2,3,4,5,6]

With a breadth of agricultural commodities in Canada, it is important to study workers in specific agricultural production settings in order to identify high-risk working conditions, tasks, and exposures. This study examined the self-reported prevalence of musculoskeletal disorders in a Saskatchewan farming population. Our hope is that this foundational information will identify salient occupational hazards associated with farming and to recognize the groups that are most vulnerable to musculoskeletal disorders. An understanding of MSD prevalence and the origins and patterns of symptoms will help lead to the development of targeted intervention strategies and guide future research surrounding the occupational health of farmers.

4.3 Methods

The Saskatchewan Farm Injury Cohort Study (SFIC)

The SFIC is an ongoing health study aimed at understanding farm peoples' health and its potential determinants. The cross-sectional component of the study involved baseline questionnaires that were sent out to farm families in participating rural municipalities across the province. A cohort of working farms was originally assembled in 2005 with the purpose of understanding contextual determinants of farm injury, as well as the interaction between individual and contextual determinants in the etiology of injury.[7] The self-reported baseline questionnaires were administered to a single representative on each farm, and were used to compile information on the causes and consequences of health and injury, characteristics of the study participants, their farm culture and economy, and specific safety conditions on the farm.[7]

The first phase of the study was undertaken between 2007 and 2012, sampling 50 rural municipalities throughout major agricultural regions in the province of Saskatchewan. A second phase began in winter 2013 with the distribution of a modified version of the baseline questionnaire. These were sent to an additional 24 rural municipalities, increasing the sampling frame from 50 to 74 municipalities.

Mail out packages with questionnaires and project information were sent to operating farms in February 2013 and returned by April 2013. Baseline data collection followed the Dillman Total Design Method in an attempt to achieve high response rates.[8] This approach for self-administered questionnaires follows precise steps for recruiting participants by giving personal attention, attracting attention, and being persistent with follow-up. The total number of questionnaires filled out and returned was 1, 212 and this consisted of both new farms entering into the cohort (n=560) and returning farms from the 2007 survey (n=662) that continued to participate from the first phase. The response rate at the farm level among known eligible farms was 48.8%; a reasonable sample considering the goal was to obtain a number of farms to develop a cohort. For this analysis we included adults aged 19 years or older who were living on active farm operations in the province of Saskatchewan as of January 1, 2013.

Separate ethics applications were submitted to the Queen's University Research Ethics Board and the Behavioural Ethics Board at The University of Saskatchewan and this study was approved by both bodies.

Study Variables

Musculoskeletal Symptoms

The main outcome of musculoskeletal disorders was assessed using the Standardized Nordic Questionnaire which is a validated instrument commonly used to document the prevalence of musculoskeletal symptoms in the workplace.[9,10] This measurement was added to the survey in Phase 2. It evaluates self-reported musculoskeletal symptoms by having respondents report (yes/no) any 'ache, pain, or discomfort' during the previous 12 months in nine body regions including neck, one or both shoulders, one or both elbows, one or both hands, upper back, lower back, one or both hips/thighs, one or both knees, and one or both ankles. If the answer "yes" was indicated for experiencing symptoms at any anatomical site, the respondent was asked to indicate whether those symptoms had prevented that person from undertaking their normal work activities. The latter is referred to as 'interrupting pain' in this analysis as it represents a level of clinically-relevant disability or work impairment.[11]

Demographic and Health Characteristics

The following information was obtained for each participant: sex (male, female); age in years (grouped into 19-39, 40-59, 60-79, ≥80); highest level of completed education *("less than high school", "completed high school", "technical/community college", "completed university")*; main occupation (*"farmer/farm worker", "retired", "student", "other"*), relationship to farm operator (*"primary owner", "spouse", "child", "parent*", *"other"*); agricultural training (*yes, no*); off-farm occupation (*yes, no*). Individual health characteristics were also available: smoking (*yes, no);* use of alcohol (*yes, no*); Body Mass Index (kg/m^2) eye sight (*good, fair, poor*); comorbidities (*0, 1, >2*); and medication use (*pain and anti-inflammatories*).

<u>Farm Level Characteristics</u>

Information available for each farm operation included commodity type (*"grain crops", "beef cattle", "dairy cattle", "pigs", "poultry", "vegetable/fruit", "other animals"*) that were later categorized as "crop only", "livestock only", "both crop and livestock"; total acreage (*0-500, 501-1500, 1501-2500, >2500);* operating arrangement (*"individual family farm", "family corporation", "partnership", "other type"*)*;* family size (*1 or 2, 3 or 4, >4*); hired workers (*none, 1 worker, 2 or more workers*).

<u>Exposure to Farm Work</u>

Participants estimated their average hours of work per week for each of the four seasons. Only spring and fall were considered in this analysis and an average of the two were taken. Biomechanically-demanding physical work tasks were assessed by asking *"how many days per year"* they were exposed to these biomechanical factors. These included: *"lift, lower, or carry heavy objects (over 20 lbs.) more than 1 hour over the day"; "using a shovel or pitchfork more than 1 hour over the day"; "work with hands over shoulder height for more than 1 hour over the day"; "operate power tools with the hands more than 1 hour over the day*". These items were developed specifically for the cohort study and were subject to multiple pilot tests for face validity.[7]

Statistical Analysis

All analyses were descriptive and conducted in SAS 9.3.[12] Univariate analyses including frequency counts and measures of central tendency were used to describe the sample demographically, as well as the twelve-month period prevalence of reported musculoskeletal pain (both overall and interrupting) for each of the 9 anatomical sites. Cross-tabulations were used to explore patterns in these MSD (any and also interrupting pain) by key operational and demographic factors: gender (male vs. female); relationships to the farm owner (farm worker, operator, spouse, retired, other occupation); commodity type (only crop, only livestock, both crop and livestock); hours of farm work (0 hrs/wk, <30 hrs/wk, 30-59 hrs/wk, 60-79 hrs/wk, >80 hrs/wk; and farm tasks (0 days, 1-10 days, 11-20 days, >20 days).

This analysis also controlled for the clustered nature of the data structure (people nested with farms) when performing tests of association. Rao-Scott Chi-Square tests were performed on row percentages to determine if there were differences between sub-groups for musculoskeletal pain, while controlling for clustering at the farm level.[13]

4.4 Results

The sample consisted of a total of 2,595 farmers aged 19 and older from 1, 212 participating farms.

Farms

Most of the participating farms (88.5%, 95% CI 87.1-89.9) reported crop (grain) production (Table 5). Forty-five percent (95% CI 42.8-47.2) of farms raised some kind of livestock, with beef and cattle being the most common. Almost half (45.8%, 95% CI 43.5-48.1) of the farms had more than 1,500 acres of land, with many farms operating as an individual family farm (56%, 95% CI 53.7-58.3) and most not hiring any extra help (70%, 95% CI 67.9-72.1).

Individuals on farms

Table 5 also describes the characteristics of adult farm people in the sample. Of the 2,595 participants, approximately 60% (95% CI 57.7-62.3) were male. The majority of respondents were part of the working population, with almost 45% (95% CI 42.8-47.2) between the ages of 40 and 59, and the mean age being 54.4 years. Two thirds (66%, 95% CI 63.9-68.1) reported being a "farmer" or "farm worker" as their main occupation and 47% (95% CI 44.7-49.3) of respondents were the primary owner or operator of the farm. Thirty-four percent (95% CI 31.8-36.2) of participants had received some form of agricultural training and many individuals (40%) reported having an off-farm job. Very few persons smoked (8.3%, 95% CI 7.0-9.6), and 40% (95% CI 37.7-42.3) reported some binge drinking (defined as having 5 or more drinks on a single occasion).[14] There was a high level of reported overweight (BMI 25.0 to 29.9) and obese (BMI ≥ 30.0), and most participants reported one or more health conditions.[15] Approximately 10% regularly took pain medications, and 10% regularly used anti-inflammatories (95% CI 8.6-11.4).

Prevalence of musculoskeletal disorders among Saskatchewan farmers

A strong majority of participants (82.2%) reported having musculoskeletal pain in at least one body part over the past year (Table 6). Prevalence levels in males were similar to those in females (83.2% and 81.4%, respectively). Just over a quarter of adults (27.9% 95% CI 25.8-30.0) had more serious musculoskeletal pain during the past year—interrupting pain that prevented them from performing normal work activities. Again, females and males reported experiencing such interrupting pain in any body part in a similar way, with 26.7% and 28.7% being affected, respectively. Table 7 profiles the reports of MSDs by relationship to the farm owner. Eighty-five percent (95% CI 83.3-86.6) of both farmers and retired individuals reported having at least one musculoskeletal disorder, whereas farmers experienced the greatest burden of pain in the lower back ($p<0.001$) as well as the shoulders ($p=0.001$). Musculoskeletal disorders were also described by commodity type. 82.1% of crop farmers and 88.0% of livestock farmers had at least one MSD (Table 8). Farmers who reported having both crops and livestock also had similar musculoskeletal outcomes, as 82.8% experienced pain in at least one body region. Table 9 presents musculoskeletal disorders by average hours worked per week during spring and autumn seasons. Reports of musculoskeletal pain were fairly evenly distributed across all categories of work hours, with no significant differences in prevalence identified.

The twelve month prevalence of interrupting pain was also analyzed by the number of days performing specific farm work tasks for at least one hour (Figure 1). The majority of people reported performing these tasks 0 days per year, yet still reported anatomical pain that prevented them from participating in normal activities. Interrupting musculoskeletal pain in the lower back was significantly more common for 'heavy lifting' ($p<0.01$), 'shoveling' ($p=0.01$), and 'using power tools' ($p<0.01$). 'Hands above head' appeared to be the only biomechanical task which showed no significant relationship with musculoskeletal disorders across the number of days exposed.

4.5 Discussion

In this study of Saskatchewan farm adults, 82.2% reported musculoskeletal symptoms. A substantial percentage (27.9%) reported pain in at least one anatomical site that was interruptive, or interfering with their ability to participate in regular activities. The reported one-year prevalence of 82.2% concurs with other reports of musculoskeletal disorders in farmers, albeit slightly higher than the average of 77.0% reported in a recent systematic review.[5] Consistent with other findings, this study found that pain in the lower back was the most common MSD (57.7%), followed by shoulder pain (44.0%).

Females are often found to have a high prevalence of musculoskeletal disorders compared to men; however, it is suspected that women will report the pain or seek treatment more readily over men.[16,17] These differences are not supported by the current findings, however, as 83.2% of males and 81.4% of females reported at least one MSD. This is consistent with increasing severity; 28.7% of men and 26.7% of women report having interrupting pain. Observing no gender differences in reports of MSDs is an important finding because it suggests that men and women share equally in risks for these conditions, and both sexes should be targeted equally for preventive measures.

Previous research suggests that farmers experience MSDs at greater rates than do non-farmers.[18] Our findings are consistent with this observation; those who self-identified as a farmer or owner-operator of the farm had higher prevalence of pain at almost every musculoskeletal site than those participants who identified as a spouse or having another occupation. Retired individuals had similar reports of 'any pain' and 'interrupting pain' to current farmers, consistent with their ongoing contributions to farm work.[19] Whether the presence of these symptoms is due to similar exposures to their young counterparts, or is a cumulative result of a lifetime of farming, this speaks to the chronic demands of a very physical occupation.

Ergonomic interventions are typically introduced when the occurrence of musculoskeletal disorders become linked to specific work tasks or commodities.[20] Commodity specific interventions may be successful when there are considerable differences between equipment and machinery used, making ergonomic design the most realistic solution. However, if a set of biomechanical exposures were established as risk factors across commodities, it may be favourable to develop an intervention that targets the work process or individual behaviour.

Although farm-level interventions are preferable as they focus on materials rather than behaviour modification, they may be ineffective as many farmers are unable to replace and update expensive machinery and tools.[20] Individual behaviour interventions are more challenging to implement, but new skill acquisition and ergonomic methods have low cost, and will be adopted by those workers who are motivated to reduce their risk of MSDs.

There were no significant differences in rates of 'any musculoskeletal disorder' when comparing crop farmers, livestock farmers, and those with both types of commodities. If farmers experience similar rates of MSDs regardless of commodity type, it suggests the possibility of wide-reaching preventive initiatives that target all Canadian farmers rather than tailored interventions for each sector. However, subgroups of animal and crop production agriculture and their occurrence of musculoskeletal disorders will have to be assessed before a uniform approach is taken.

Although evidence exists that exposure to physical work-related factors may contribute to the development of musculoskeletal disorders, there is inconclusive research on the mechanical and physiological responses of the body to many types of farm tasks.[4] It has been hypothesized that an imbalance between exposure to physical factors and physical capacity may lead to MSDs, or that physical capacity could be an effect modifier in the relationship between physical work exposures and musculoskeletal pain.[21,22] Muscle strength, muscle endurance, and joint mobility have been proposed to be predictors of pain in the lower back and neck/shoulders so it possible that high or low levels of capacity could influence the development of MSDs.[21] With that in mind, we decided to look at the work profile of farmers in terms of average hours worked in their busiest seasons (previously described) as well as days exposed to common farm-related work tasks.[23]

We in fact observed no significant differences in the prevalence of interrupting pain by hours of work time. This observation could be interpreted in different ways. It may be that participants who report musculoskeletal pain are farmers who have disabling symptoms and must limit themselves to what types of tasks they can engage in and the duration of that work. Some of the pattern may be masked by pain caused by off-farm employment and recreational activities. It is also possible that other factors such as their physical condition and physical activity or inactivity may be the main determinants of these musculoskeletal outcomes. The highest percentages of MSDs seem to be in the 30-80 hour/week range, with a lower prevalence seen in those who had greater than 80 hour work weeks. This observation may indicate that there is no trend or relationship between hours worked and MSD outcome; it may even indicate that work volume is not a good indicator of musculoskeletal pain, especially if sedentary work does not correlate with MSD symptoms. The issue may therefore lie more within the nature of the variable, as it is not specific enough to capture the type of work performed in the hours that make up a work week.

The last way that we profiled participants was by days exposed to four biomechanically-demanding farm activities. These were chosen because of the anticipated association of musculoskeletal disorders with specific biomechanical aspects of work. For each task (heavy lifting, shoveling, working with hands above head, and the use of power tools), there were some musculoskeletal symptoms experienced more frequently in association with the reported time engaged in the tasks. These relationships were illustrated by plotting the prevalence (%) from each category for each anatomical site (Figure 1). There were no linear relationships between days exposed to biomechanical tasks and the prevalence of interrupting pain. It was, however, often observed that each task had a similar pattern of MSD prevalence, regardless of the anatomical region. For example, working with hands above head seemed to have similar effects on lower back pain and elbow pain, as they follow similar outcome patterns across categories of exposure. Lower back symptoms were a significant outcome for every biomechanical task, whereas a different MSD was significant for each of the other tasks. There is biomechanical plausibility behind these findings, as we would expect strain and stress in these structures when considering the movements involved.[24]

Strengths and Limitations

This large, cross-sectional, population-based study of farmers in Saskatchewan is one of the first to describe the prevalence of musculoskeletal symptoms in the Canadian farm industry. It suggests that the majority of farm people are at risk for disorders of the musculoskeletal system which is important for preventive measures. Although identifying as the owner or operator was associated with greater risk, the occurrence of these conditions were substantial within other subgroups, and therefore should be taken into account when considering target populations for interventions or further study. Even though musculoskeletal health is multidimensional, these findings may illustrate the increased risk that is accompanied with working or living on a farm.

A possible weakness of the study is the potential for response bias, as the data were obtained from self-reports. Participants with either current or recent pain may be able to respond with more accuracy than those who have experienced musculoskeletal pain almost a year ago. In a similar respect, the survey may also only appeal to households who have encountered injuries, as farms that have not been affected by injuries may not see the value in filling out the questionnaire. With a response rate of 48.8%, there may also be limited representativeness of the sample in terms of acquiring complete coverage of musculoskeletal disorders in this population.

Implications

This paper emphasizes that Saskatchewan farmers have poor musculoskeletal health, suggesting that these disorders are likely an occupational issue that requires attention. As the prevalence and burden have now been identified, next steps could focus on the risk factors and contributors of MSDs in this population. It will be important to improve knowledge on why and how farm people develop these conditions in order to guide management and intervention.

As ergonomic design, engineering controls, and behaviour modification cannot be recommended at this moment, it would be beneficial to explore means of health promotion and education. These findings did not identify vulnerable subgroups as intended; rather, the results suggest that MSDs are prevalent in all farm people. Given this information, awareness could be built in researchers, occupational health and safety groups, and even in those who plan and deliver health services. Knowing that these disorders are a widespread issue is an important starting point when considering health promotion strategies. However, remembering that farmers are unique from other industries—set in an uncontrolled environment—is essential too, as solutions that are applied elsewhere may not be effective in this occupation.

Building awareness in farmers may result in the outcome of attitude change, however, caution should be used during this process. An integral component when disseminating this information will be to incorporate farmers as much as possible, as they tend to be resistant to outside intervention. Farmers themselves are concerned about the safety practices on their farm, but there are certain aspects to farming that are customary.[25] There will always be a manual component to farming so to inform these people to perform tasks differently—or not as often—to prevent musculoskeletal disorders, may be a weak approach to intervening.[1] They are autonomous workers, meaning this population cannot be targeted in the same way as other industries.[26] It may require interaction, cooperation, and new perspectives in order to obtain voluntary interest and concern from farmers. If these barriers can be overcome, it may be possible to increase knowledge on the risk of musculoskeletal disorders and effectively reduce the outcomes associated with these conditions.

4.6 Conclusions

82.2% of farmers in this population reported that they experienced MSD symptoms. We also considered how severe the pain was by measuring whether or not it prevented them from engaging in regular work activities; 27.9% were found to experience interrupting pain in at least one musculoskeletal region. This study population experienced lower back pain, and MSD in the upper and lower extremities at similar proportions to other groups of farmers previously studied. This basic knowledge can inform occupational health guidelines and help target preventative strategies to reduce the occurrence of these disorders in Canadian farmers. Future research could investigate the prevalence of MSD in other Canadian farmers whose profile may be quite different, such as Ontario dairy farmers.

References

1. Fathallah F a. Musculoskeletal disorders in labor-intensive agriculture. *Appl. Ergon.* 2010;41(6):738-43. doi:10.1016/j.apergo.2010.03.003.

2. Whelan S, Ruane DJ, McNamara J, Kinsella A, McNamara A. Disability on Irish farms--a real concern. *J. Agromedicine* 2009;14(2):157-63. doi:10.1080/10599240902813078.

3. Walker-Bone K, Palmer KT. Musculoskeletal disorders in farmers and farm workers. *Occup. Med. (Lond).* 2002;52(8):441-50. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12488514.

4. Osborne A, Blake ÃC, Fullen BM, et al. Risk Factors for Musculoskeletal Disorders Among Farm Owners and Farm Workers : A Systematic Review. *Am. J. Ind. Med.* 2012;389(December 2011):376-389. doi:10.1002/ajim.22001.

5. Osborne A, Blake ÃC, Fullen BM, et al. Prevalence of Musculoskeletal Disorders Among Farmers : A Systematic Review. *Am. J. Ind. Med.* 2012;158(October 2011):143-158. doi:10.1002/ajim.21033.

6. Rosecrance J, Rodgers G. Low Back Pain and Musculoskeletal Symptoms Among Kansas Farmers. *Am. J. Ind. Med.* 2006;556(49):547-556. doi:10.1002/ajim.20324.

7. Pickett W, Day L, Hagel L, et al. The Saskatchewan Farm Injury Cohort: rationale and methodology. *Public Health Rep.* 123(5):567-75. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2496929&tool=pmcentrez&rendertype=abstract.

8. Dillman DA. THE DESIGN AND ADMINISTRATION OF MAIL SURVEYS. *Annu. Rev. Sociol.* 2014;17(1991):225-249.

9. Dickinson CE, Campion K, Foster a F, Newman SJ, O'Rourke a M, Thomas PG. Questionnaire development: an examination of the Nordic Musculoskeletal questionnaire. *Appl. Ergon.* 1992;23(3):197-201. Available at: http://www.ncbi.nlm.nih.gov/pubmed/15676868.

10. Palmer K, Smith G, Kellingray S, Cooper C. Repeatability and validity of an upper limb and neck discomfort questionnaire: the utility of the standardized Nordic questionnaire. *Occup. Med. (Lond).* 1999;49(3):171-5. Available at: http://www.ncbi.nlm.nih.gov/pubmed/10451598.

11. Manniche C, Asmussen K, Lauritsen B, Vinterberg H, Kreiner S, Jordan a. Low Back Pain Rating scale: validation of a tool for assessment of low back pain. *Pain* 1994;57(3):317-26. Available at: http://www.ncbi.nlm.nih.gov/pubmed/7936710.

12. Bailer AJ. *Statistical Programming in SAS (Google eBook)*. SAS Institute; 2010:444. Available at: http://books.google.com/books?hl=en&lr=&id=snejkVlVWhQC&pgis=1. Accessed April 8, 2014.

13. Rao JNK and AJS. NIELS KEIDING A Simple Method for the Analysis of Clustered Binary Data. *Biometrics* 2014;48(2):577-585.

14. Rudolph KE, Glass T a, Crum RM, Schwartz BS. Neighborhood psychosocial hazards and binge drinking among late middle-aged adults. *J. Urban Health* 2013;90(5):970-82. doi:10.1007/s11524-013-9790-2.

15. Lemieux S, Mongeau L, Paquette M, Laberge S, Lachance B. Health Canada's new guidelines for body weight classification in adults: challenges and concerns. *Comment. - Quebec Prov. Work. Gr. Weight Relat. Issues* 2004;171(11):1361-1363.

16. Strazdins L, Bammer G. Women, work and musculoskeletal health. *Soc. Sci. Med.* 2004;58(6):997-1005. doi:10.1016/S0277-9536(03)00260-0.

17. Treaster DE, Burr D. Gender differences in prevalence of upper extremity musculoskeletal disorders. *Ergonomics* 2004;47(5):495-526. doi:10.1080/00140130310001638171.

18. Torén a, Oberg K, Lembke B, Enlund K, Rask-Andersen a. Tractor-driving hours and their relation to self-reported low-back and hip symptoms. *Appl. Ergon.* 2002;33(2):139-46. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12009120.

19. Voaklander D, Day ÃL, Dosman J, Hagel L, Pickett W. Older Farmers and Machinery Exposure — Cause for Concern ? *Am. J. Ind. Med.* 2012;1050:1044-1050. doi:10.1002/ajim.22111.

20. Kirkhorn SR, Earle-Richardson G, Banks RJ. Ergonomic risks and musculoskeletal disorders in production agriculture: recommendations for effective research to practice. *J. Agromedicine* 2010;15(3):281-99. doi:10.1080/1059924X.2010.488618.

21. Hamberg-van Reenen HH, Ariëns GAM, Blatter BM, van Mechelen W, Bongers PM. A systematic review of the relation between physical capacity and future low back and neck/shoulder pain. *Pain* 2007;130(1-2):93-107. doi:10.1016/j.pain.2006.11.004.

22. Winkel J, Mathiassen SE. Assessment of physical work load in epidemiologic studies: concepts, issues and operational considerations. *Ergonomics* 1994;37(6):979-88. doi:10.1080/00140139408963711.

23. Jill A, Sachs MI, Dahlgren KA, Tinguely SJ. Accidental Farm Injuries in Children Eighty-three. *Am. J. Dis. Child.* 1987;141.

24. Costa BR. Risk Factors for Work-Related Musculoskeletal Disorders : A Systematic Review of Recent Longitudinal Studies. *Am. J. Ind. Med.* 2010;323:285-323. doi:10.1002/ajim.20750.

25. Vyas R. Mitigation of musculoskeletal problems and body discomfort of agricultural workers through educational intervention. *Work* 2012;41 Suppl 1:2398-404. doi:10.3233/WOR-2012-0473-2398.

26. Voaklander DC, Hartling L, Pickett W, Dimich-Ward H, Brison RJ. Work-related mortality among older farmers in Canada. *Can. Fam. Physician* 1999;45:2903-10. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2328502&tool=pmcentrez&rendertype=abstract. Accessed April 8, 2014.

Table 5. Individual and farm level characteristics of adult participants in the SFIC

Individual characteristics	**N=2,595**
Age, yrs.	
Mean ± SD	54.4 ± 14.8
Min-Max	19-98
Age group, yrs. (%)	
19-39	445 (17.2)
40-59	1,157 (44.6)
60-79	891 (34.3)
80+	102 (3.9)
Sex, no. (%) male	1,545 (59.7)
Highest level of completed education, no. (%)	
Less than high school	375 (14.5)
Completed high school	943 (36.5)
Technical/community college	707 (27.4)
Completed university	558 (21.6)
Missing	12
Main occupation, no. (%)	
Farmer/farm worker	1,697 (66.1)
Retired	200 (7.7)
Student	43 (1.7)
Other	629 (24.5)
Missing	26
Relationship to farm operator, no. (%)	
Primary Owner	1,198 (46.7)
Spouse	945 (36.9)
Child	284 (11.0)
Parent	76 (3.0)
Other	61 (2.4)
Missing	31
Agricultural training, no. (%) yes	873 (33.9)
Missing	23
Off farm occupation, no. (%) yes	1,025 (39.7)
Missing	14
Current smoker, no. (%) yes	213 (8.3)
Missing	17
Current use of alcohol, no. (%)	
Never	1,536 (59.6)
At most once a month	815 (31.6)
At most once a week	161 (6.3)
More than once a week	65 (2.5)
Missing	18
Current Body Mass Index (BMI), by age group, mean ± SD	
19-39	26.2 ± 4.8
40-59	27.7 ± 5.2

60-79	28.0 ± 4.8
80+	26.8 ± 4.9
Missing	180
Eye sight	
Good	2,253 (87.3)
Fair	306 (11.7)
Poor	21 (1.0)
Missing	15
Comorbidities, no. (%)	
0	1,139 (46.4)
1	664 (27.0)
2 or more	654 (26.6)
Missing	138
Current use of specific medications, no. (%)	
Pain medication	248 (9.6)
Anti-inflammatories	279 (10.8)
Farm Characteristics	**N=1, 212**
Commodity , no. farms (%)	
Crop only	647 (54.2)
Livestock only	120 (10.1)
Both crop and livestock	426 (35.7)
Missing	19
Total acreage, no. (%)	
0-500	223 (19.5)
501-1500	364 (31.9)
1501-2500	231 (20.2)
>2500	324 (28.4)
Missing	70
Operating arrangement, no. (%)	
Individual Family Farm	658 (55.9)
Family Corporation	303 (25.8)
Partnership	199 (16.9)
Other Type	17 (1.4)
Missing	35
Farm size, no. family members (%)	
1 or 2	879 (72.5)
3 or 4	257 (21.2)
>4	76 (6.3)
Hired workers, no. (%)	
None	842 (71.5)
1 worker	279 (23.7)
2 or more workers	56 (4.8)
Missing	35

Table 6. Twelve-month prevalence of musculoskeletal disorders overall and by gender.

Body Site	ANY PAIN[1]				INTERRUPTING PAIN[2]			
	Overall N=2,587	**Males** N=1, 545	**Females** N=1,042	***p value***	**Overall** N=2,587	**Males** N=1,545	**Females** N=1,042	***p value***
Neck	1014 (39.6)	579 (37.5)	435 (41.7)	0.027	130 (5.1)	69 (4.5)	61 (5.9)	0.10
Shoulder	1127 (44.0)	671 (43.4)	456 (43.8)	0.85	177 (6.9)	102 (6.6)	75 (7.2)	0.52
Elbow	392 (15.3)	251 (16.2)	141 (13.5)	0.033	55 (2.2)	30 (1.9)	25 (2.4)	0.41
Hand	722 (28.2)	248 (27.8)	294 (28.2)	0.85	112 (4.4)	56 (3.6)	56 (5.4)	0.032
Upper back	524 (20.5)	286 (18.5)	238 (22.8)	0.0021	90 (3.5)	41 (2.7)	49 (4.7)	0.0052
Lower back	1478 (57.7)	927 (60.0)	551 (52.9)	0.0001	393 (15.1)	251 (16.2)	143 (13.7)	0.054
Hip/thigh	788 (37.0)	423 (27.4)	365 (35.0)	<.0001	162 (6.3)	87 (5.6)	75 (7.2)	0.083
Knee	948 (37.0)	582 (37.7)	366 (35.1)	0.15	183 (7.2)	113 (7.3)	70 (6.7)	0.56
Ankle	598 (23.3)	335 (21.7)	263 (25.2)	0.028	125 (4.8)	71 (4.6)	54 (5.2)	0.46
At least one body part	2127 (82.2)	1285 (83.2)	848 (81.4)	0.17	721 (27.9)	444 (28.7)	278 (26.7)	0.22

[1] Reports of any ache, pain, or discomfort in that body region. [2] Severe pain that prevented the individual from doing their normal work.

Table 7. Twelve-month prevalence of musculoskeletal disorders by occupation and relationship to owner/operator.

	ANY PAIN						INTERRPTING PAIN					
Body Part	**Farmer/ Farm Worker**	**Spouse**	**Retired**	**Owner/ Operator**	**Other Occupation**	***p value***	**Farmer/ Farm Worker**	**Spouse**	**Retired**	**Owner/ Operator**	**Other Occupation**	***p value***
	N=1,681	N=935	N=196	N=1,190	N=618		N=1,681	N=935	N=196	N=1,190	N=618	
Neck	683 (40.0)	413 (44.2)	66 (33.7)	521 (43.8)	249 (40.3)	0.070	79 (4.7)	64 (6.8)	13 (6.6)	57 (4.8)	35 (5.7)	0.63
Shoulder	782 (46.5)	437 (46.7)	81 (41.3)	597 (50.1)	243 (39.3)	0.024	114 (6.8)	73 (7.8)	17 (8.7)	87 (7.3)	43 (7.0)	0.61
Elbow	276 (16.4)	134 (14.3)	23 (11.7)	234 (19.7)	85 (13.8)	0.25	39 (2.3)	23 (2.5)	3 (1.5)	29 (2.4)	54 (8.7)	0.43
Hand	489 (29.1)	260 (27.8)	55 (28.1)	393 (33.0)	162 (26.2)	0.69	68 (4.0)	46 (4.9)	13 (6.6)	48 (4.0)	26 (4.2)	0.42
Upper back	359 (21.4)	221 (23.6)	36 (18.4)	244 (20.5)	121 (19.6)	0.44	59 (3.5)	42 (4.5)	9 (4.6)	36 (3.0)	20 (3.2)	0.79
Lower back	1031 (61.3)	510 (54.5)	110 (56.1)	796 (64.6)	314 (50.8)	0.0001	280 (16.7)	140 (15.0)	25 (12.8)	209 (17.6)	84 (13.6)	0.12
Hip/ thigh	529 (31.5)	349 (37.3)	65 (33.1)	384 (32.2)	180 (29.1)	0.42	100 (5.9)	76 (8.1)	17 (8.7)	74 (6.2)	41 (6.6)	0.49
Knee	657 (39.1)	350 (37.4)	80 (40.8)	516 (43.4)	197 (31.9)	0.019	137 (8.1)	67 (7.2)	13 (6.6)	98 (8.2)	28 (4.5)	0.059
Ankle	407 (24.2)	246 (26.3)	46 (23.5)	292 (24.5)	134 (21.7)	0.59	89 (5.3)	54 (5.8)	12 (6.1)	61 (5.1)	24 (3.9)	0.44
At least one body part	1435 (85.4)	785 (84.0)	167 (85.2)	1,066 (89.6)	482 (80.0)	0.0001	501 (29.8)	258 (25.6)	54 (27.6)	375 (31.5)	154 (24.9)	0.15

Table 8. Twelve-month prevalence of musculoskeletal disorders by commodity type.

Body Part	ANY PAIN				INTERRUPTING PAIN			
	Only Crop	**Only Livestock**	**Both Crop and Livestock**	***p value***	**Only Crop**	**Only Livestock**	**Both Crop and Livestock**	***p value***
Neck	510 (37.9)	120 (47.8)	376 (40.2)	0.033	73 (5.4)	11 (4.4)	45 (4.8)	0.70
Shoulder	588 (43.8)	129 (51.4)	396 (42.3)	0.071	91 (6.8)	19 (7.6)	65 (6.9)	0.91
Elbow	192 (14.3)	53 (21.1)	145 (15.5)	0.043	26 (1.9)	5 (1.9)	23 (2.5)	0.69
Hand	351 (26.1)	88 (35.0)	275 (29.4)	0.022	50 (3.7)	13 (5.2)	47 (5.0)	0.25
Upper back	272 (20.2)	70 (27.9)	176 (18.8)	0.021	55 (4.1)	10 (3.9)	24 (2.6)	0.14
Lower back	771 (57.4)	151 (60.1)	537 (57.4)	0.75	200 (14.9)	40 (15.9)	148 (15.8)	0.84
Hip/thigh	392 (29.2)	90 (35.8)	296 (31.6)	0.11	88 (6.5)	15 (5.9)	55 (5.9)	0.82
Knee	486 (36.2)	99 (39.4)	350 (37.4)	0.59	90 (6.7)	24 (9.5)	67 (7.2)	0.32
Ankle	293 (21.8)	69 (27.5)	229 (24.5)	0.13	58 (4.3)	11 (4.4)	55 (5.9)	0.24
At least one body part	1,103 (82.1)	221 (88.0)	775 (82.8)	0.094	971 (72.2)	176 (70.1)	273 (29.2)	0.64

Table 9. Twelve-month prevalence of interrupting pain by farm hours worked.[1]

Body Site	**0 hours/week** N=180	**<30 hours/week** N= 719	**30-59 hours/week** N=589	**60-79 hours/week** N= 473	**>80 hours/week** N=461	***p value***[2]
Neck	11 (6.1)	41 (5.7)	30 (5.1)	28 (5.9)	16 (3.5)	0.41
Shoulder	10 (5.5)	52 (7.2)	44 (7.5)	34 (7.2)	31 (6.7)	0.92
Elbow	2 (1.1)	16 (2.2)	14 (2.4)	10 (2.1)	12 (2.6)	0.85
Hand	6 (3.3)	36 (5.0)	31 (5.3)	21 (4.4)	15 (3.3)	0.49
Upper back	6 (3.3)	34 (4.7)	24 (4.1)	14 (3.0)	10 (2.2)	0.17
Lower back	19 (10.6)	113 (15.7)	95 (16.1)	76 (16.1)	75 (16.2)	0.45
Hip/thigh	14 (7.8)	52 (7.2)	46 (7.8)	26 (5.5)	20 (4.3)	0.12
Knee	10 (5.5)	47 (6.5)	48 (8.1)	34 (7.2)	36 (7.8)	0.69
Ankle	10 (5.5)	34 (4.7)	37 (6.3)	19 (4.0)	19 (4.1)	0.41
At least one body part	50 (27.8)	194 (27.0)	184 (31.2)	131 (27.7)	134 (29.1)	0.52

[1] Hours per week is the average of the two busiest seasons, spring and fall. [2] Rao-Scott Chi Square for Interrupting Pain.

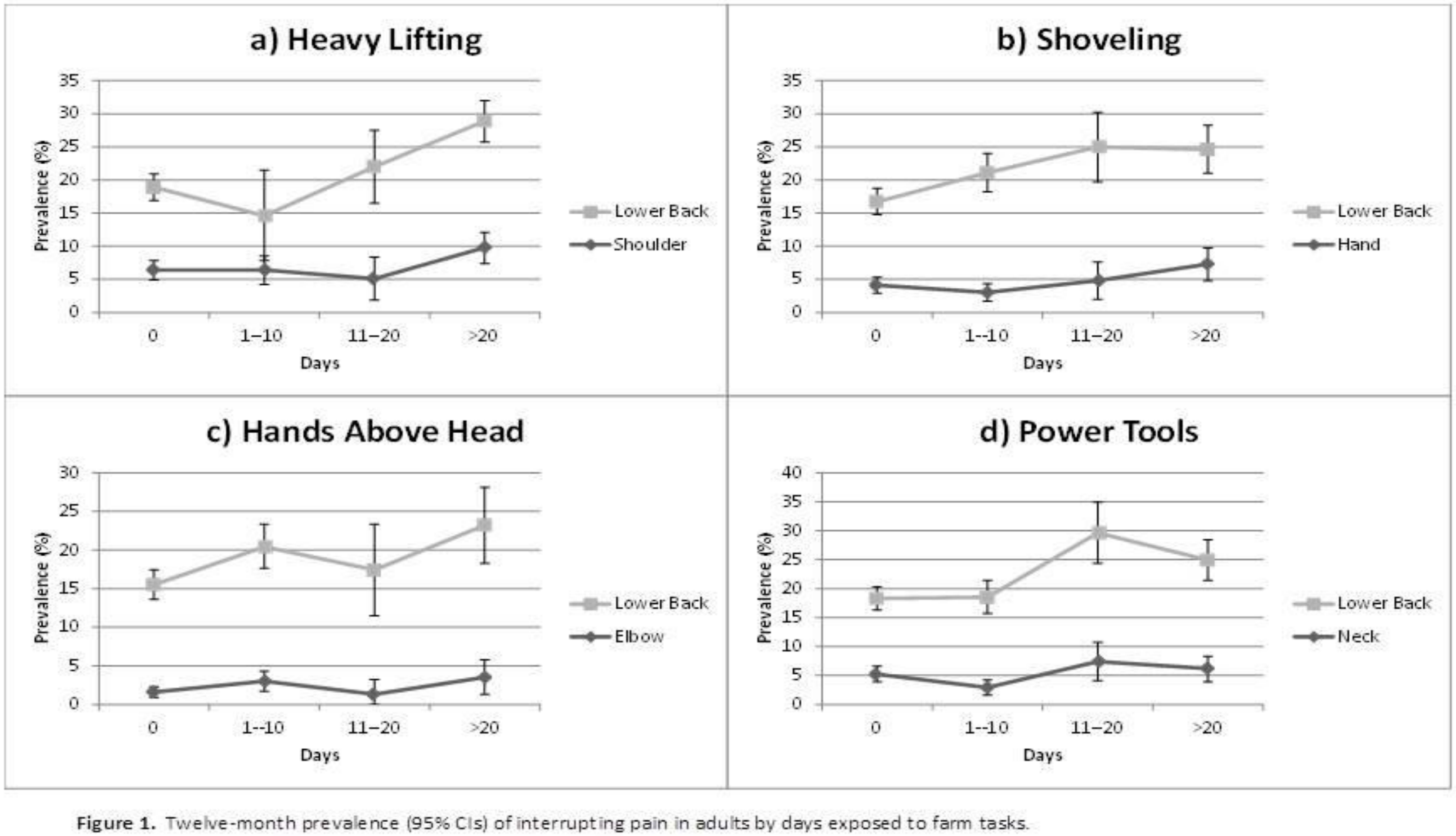


Figure 1. Twelve-month prevalence of interrupting pain in adults by days exposed to farm tasks

Chapter 5

Biomechanical Work Exposures Associated with Prevalent Low Back and Shoulder Pain in Saskatchewan Farmers

5.1 Abstract

Agricultural work has been linked to a number of adverse health conditions including musculoskeletal disorders. The low back and shoulders have been identified as the most common sites for musculoskeletal pain in farmers. The purpose of this cross-sectional study was to investigate selected biomechanical work tasks that are associated with lower back and shoulder pain in a sample of Canadian farmers. Self-administered questionnaires were mailed to active farms in the province of Saskatchewan. Demographics, site-specific musculoskeletal pain, and farm operation information was obtained. Relative risks and 95% confidence intervals were estimated with modified Poisson regression adjusting for potential confounders. Strong and consistent associations between increased biomechanical tasks and pain in the low back and shoulders support the finding that these regions are susceptible to the physically demanding farm work. Further investigation into interrupting pain, detailed tasks exposures, and impacts of symptoms on work are required for accurate and effective interventions.

Practitioner Summary: In one of the first studies on Canadian farmers, cross-sectional measures of biomechanical work tasks were significantly associated with prevalent musculoskeletal disorders. The strongest association for shoulder pain was working with hands over shoulder height, while the greatest risk factor for low back pain was using a shovel or pitchfork.

5.2 Introduction

Agricultural work has been linked to a number of adverse health conditions including musculoskeletal disorders (MSD).[1,2] These disorders typically have a gradual onset and are thought to develop from cumulative long term exposure to adverse or demanding work conditions.[3] As repetitive, prolonged, or forceful stress can lead to tissue damage and the onset of symptoms, relations between such work exposures and musculoskeletal pain require investigation. Many biomechanical tasks and strenuous activities have been deemed injurious—and farm work is particularly prone to these types of hazardous exposures.[4,5] However, the types of work tasks and associated risk factors for MSDs have rarely been investigated in a systematic manner, and more specifically among the types of family farm operations that are typical of the Canadian plains.[6]

We recently observed a one-year prevalence for MSDs of 82% among farmers and based upon such evidence many might presume that musculoskeletal disorders are an unavoidable consequence of farm labour.[7] However, the root of this occupational problem lies in the lack of knowledge on high risk exposures to guide technology development and implementation of resources for effective ergonomic interventions.[8] If the magnitude and potential causes of the most common musculoskeletal disorders (the low back and shoulders) could be understood, it would provide foundational information from which effective work interventions can be proposed.[7] In an occupation where MSD consequences include work impairment, disability, and impacts on farm revenue, it is important to identify major risk factors in the farm work environment that should be targeted for such intervention.[9,10]

We had a unique opportunity to study MSDs and their potential work-related causes on Saskatchewan farms in a systematic manner. The objective of this study was to therefore evaluate the strength, consistency and statistical significance of relationships between specific biomechanical exposures and the occurrence of work-related musculoskeletal disorders among adult farmers and farm workers in Saskatchewan. We chose to focus on disorders of the low back and shoulders due to their prevalence in farmers as well as their long-term consequences to health and productivity.[7] Any associations that are confirmed could not only guide effective interventions, but also direct future longitudinal analyses that may ascertain causal relationships.

5.3 Methods

The Saskatchewan Farm Injury Cohort Study (SFIC)

The SFIC is an ongoing health study aimed at understanding farm peoples' health and its many varying determinants.[11] Cross-sectional components of the study involved administration of baseline questionnaires that were sent out to farm families in participating rural municipalities. One aim of the SFIC was to develop a large and diverse sample of farms in order to study relationships between individual and contextual factors and a variety of health and injury outcomes.

The first phase of the study was undertaken between 2007 and 2012, and involved a sample of 50 rural municipalities throughout major agricultural regions in the Canadian province of Saskatchewan. A second phase began in winter 2013 with farms who agreed to continue from Phase 1, plus a new sample that was selected from an additional 24 rural municipalities. The current analysis is therefore based upon a baseline health questionnaire sent to farms in these 74 municipalities.

The Phase 2 baseline questionnaire was administered using the Dillman Total Design Method in an attempt to achieve high response rates.[12] The latter was achieved by giving personal attention to potential respondents via personalized correspondence and being persistent and systematic with follow-up. The total number of questionnaires filled out and returned was

1, 212, consisting of both new farms entering into the cohort (n=560) and returning farms from the 2007 survey (n=662) that continued to participate from the first phase. The response rate at the farm level among known eligible farms was 54.9%. The current analysis focused on adult members of the cohort (age >18) as of January 1, 2013.

The study protocol and this analysis were approved by the Health Sciences and Affiliated Teaching Hospitals Research Ethics Board at Queen's University, as well as the Behavioural Research Ethics Board at The University of Saskatchewan.

Outcome Variables Outcomes of musculoskeletal disorders were assessed using the *Standardized Nordic Questionnaire*.[1,2] The primary outcome was pain within the lower back or shoulders and was measured by the question: *"Have you at any time in the last 12 months had trouble (ache, pain, discomfort) in (body part)".* A second outcome addressed the severity of reported disorders by asking: *"Have you at any time in the last 12 months been prevented from doing your normal work (at home or away from home) because of the trouble?"* We refer to positive responses to this question as "work-interrupting pain". Responses to each question were considered in a dichotomous (yes/no) fashion. No additional information was available in terms of occurrence, when symptoms arose, or if the biomechanical or other cause of each MSD was known.

Biomechanical Exposures in Farm Work Environments Biomechanical exposures for each participant were assessed as follows in days/year: 1) *"Lift, lower, or carry heavy objects (over 20 lbs) more than 1 hour over the day?"* 2) *"Use a shovel or pitchfork more than 1 hour over the day?"* 3) *"Work with hands over shoulder height for more than 1 hour over the day?"* 4) *"Operate power tools with the hands more than 1 hour over the day*?" These are all established risk factors for musculoskeletal disorders in occupational settings.[5,14,15,16] Each of the four main exposures were categorized into a range of four groups, informed by quartiles from the data. Exposure categories were created for the purpose of analysis, and to isolate the experiences of high risk groups and hence facilitate recommendations for prevention.

Covariates

The primary relations under study were those between the biomechanical farm work exposures and reports of MSDs in the shoulders and lower back. Potential confounders and effect modifiers of these relations were identified.

<u>*Socio-demographic Factors*</u>

Established confounding variables included age (*19-39, 40-59, 60-79, 80+*), Body Mass Index (*<25 kg/m^2, 25-29.9 kg/m^2, and ≥30 kg/m^2*), and sex (*male/female*) were considered, as well as each individual's role on the farm (*primary farm operator, spouse, parent, child, other relative*).[15,17,18] Comorbid conditions such as depression (*0, 1, ≥2 comorbidities based on a list provided*)[19,20] and health behaviours like smoking (*currently smoking yes/no*)[21,22] were also examined. Tractor operation (*hrs/year*) was also considered in the model building process, as it is known to contribute to low back complaints and MSD severity.[23,24]

<u>*Individual Factors*</u>

Reports of acute traumatic injuries (*yes/no in the past 12 months*) were considered for both confounding and effect modification as such injuries could have played an intricate role in the exposure-response relationship. These included any injuries that resulted from events in the farm environment, regardless of whether the individual was working or not. Subsequent symptoms from prior injuries could either be a risk factor for shoulder and lower back pain, making the MSD more likely to occur; or the effects could interact physiologically with the mechanisms involved in the exposure, exaggerating the pain to a level beyond normal response.[25]

Farm Operational Factors

Commodity type ("*grain", "livestock" or "both"*), operating arrangement (*"individual family farm", "partnership", "family corporation", "other type"*, farm size *(1-2, 3-4, >4 family members)* and acreage *(0-500, 501-1500, 1501-2500, >2500)* were considered as potential farm-level covariates; off-farm employment (*yes/no*) were each considered as an individual level covariates. Seasonal farm work, measured by average hours per week in the spring and fall, (*<30, 30-59, 60-79, >80*) was also tested for confounding as time spent doing physical work could greatly contribute to the development of MSD. Other interaction terms (e.g., by age group, gender, commodity) were also explored in additional analyses of potential interactions.

Statistical Analysis

Statistical analyses were conducted using SAS 9.3.[26] We first profiled characteristics of the study population at both the individual and farm levels. Next, prevalence levels of "any pain" and "work-interrupting (more severe) pain" in the lower back and shoulders were described for each level of the four main biomechanical work exposures. Categorization of these exposures was as follows: 0 days/year, 1-10 days/year, 11-20 days/year, and >20 days/year, with the referent group set to 0 days of work exposure. This descriptive analysis was mainly used to identify patterns in symptom occurrence by level of engagement in farm work tasks.

We then extended this analysis using a series of regression analyses. After testing three link functions (logistic regression, log binomial, and modified Poisson) the modified Poisson regression was selected for reasons of convergence and its ability to estimate relative risk directly. We used the SAS procedure PROC GENMOD to account for the multi-level and clustered nature of the data (individuals nested within farms; the clustering effects of rural municipalities accounted for virtually none of the variance in these models). Our model building involved the change in estimate approach described by Rothman, which requires that potential confounders included in the final models change the beta estimate for main effects by 10% when compared a model that did not include these factors.[27] For comparability of models between MSD sites, we (conservatively) included any variable that was found to confound a main effect in any of the models; hence a standard set of covariates was maintained for each of the models. A limited number of effect modifiers (acute farm injury during the past 12 months; gender) were also explored based on previous studies.[17,28,29]

A priori power calculations suggested that, based upon anticipated outcomes of MSD that ranged between 25-35%, we had at least 90% power to detect absolute difference of at least 10% in MSD between the highest vs. lowest groups in all comparisons (alpha=0.05, 2 sided).

5.4 Results

Following exclusions, the sample consisted of 2,595 farmers aged 19 and older from 1,212 participating farms. In Table 10 we describe the study population by individual and farm-level characteristics.

Models examining relations between the farm work exposures and any lower back pain are summarized in Table 11. In both the unadjusted and adjusted models, increased reported duration of each type of biomechanical task was related to an increased risk of any lower back pain. Manual tasks (using a shovel or a pitchfork for at least one hour more than 20 days a year) were most strongly related to low back pain, with a 46% increase in risk relative to the non-exposed group. The other three work tasks—lifting ,working above shoulder height, and using power tools—had similar associated risk for any lower back pain in the highest exposure level, ranging from 35%-37% increases in relative risk. The adjusted models for work-interrupting lower back pain (our more severe MSD outcome) did not, however, indicate consistent increases in risk with increasing biomechanical exposure.

Table 12 presents the relative risk estimates from the Modified Poisson regression for shoulder pain. All unadjusted and adjusted models showed an increased risk with elevated exposure levels, but the largest increase in risk for any shoulder pain was working with hands over shoulder height (increase of 25%). Using a shovel or pitchfork was found to be related to any shoulder pain (23% increase in risk for highest vs. non-exposed groups), followed by lifting, lowering, or carrying heavy objects (21%). Operating power tools had the lowest associated increase in risk (11%). Similar to interrupting pain in the lower back, the models for interrupting shoulder pain showed almost no statistically significant relations with the biomechanical work exposures.

5.5 Discussion

The primary objective of this study was to examine relations between engagement in common biomechanical work tasks on farms and reports of prevalent MSDs of the shoulders and low back. Musculoskeletal pain was reported frequently by farm people for these two anatomical sites, and reported pain increased consistently with higher levels of biomechanical exposure. This finding is congruent with other occupational and agricultural studies that show that biomechanical tasks are associated with work-related musculoskeletal pain.[4,6,30,31,32,33] Our analyses confirm that as time exposed to manual labour increases, so do the risks for MSD in the low back and shoulders.

We believe that this basic analysis is helpful from both a methodological and a preventive point of view. Methodologically, estimates of relations between work exposures and MSD outcomes have typically been made by performing logistic regression analysis and expressing risks in terms of relative odds.[4,31,34] However, if the intent of modeling is to infer relative risks, this modeling method can be misleading when outcomes are common and hence violate the rare disease assumption.[35] Because we used a modelling approach that permitted the estimation of relative risk directly, we feel that our estimates of effect are more accurate as expressions of risk. Second, from a prevention standpoint, the consistency of our findings for "any pain" across two body sites and different types of work tasks is notable. This provides foundational evidence surrounding the possible musculoskeletal effects of manual work conditions, and to identify those work tasks which are consistently most hazardous in terms of MSDs.

Although statistically significant relationships between all biomechanical tasks and outcomes of "any pain" in the low back and shoulders were observed, risk estimates for "work-interrupting pain" did not follow a similar pattern. These differences deserve attention, as there may be an important underlying message for prevention. The high prevalence of "any pain" but very low "work-interrupting pain" reflects the finding from Swedish research where low back pain was quite prevalent in farmers, yet the rates of sick leave due to the MSD were very low.[36]

A mixed methods study on New Zealand farmers investigated the lived experience of farming with low back pain.[37] They highlighted that the seasonal demands and cycles through the year are challenging to cope with, and as a result, farmers respond by downplaying both MSD symptoms and physical workload, convincing those around them that they are minor. This resilience and stoicism contributes to their "can do" attitude, and their firm beliefs that farming is, and always has been, a "way of life".[37] This coping style may explain the low (and accurate) reports of work-interrupting pain in our study; even though farmers experience musculoskeletal pain, farmers continue to work because it is valued by their culture. However, an important finding from the New Zealand study was that farmers were cognisant of the inherent hazards of farming and reacted by finding innovative ways to modify their work practices.[37] Similar results from a qualitative study with Irish farmers were identified. Despite considerable pain, Irish farmers continued to engage in ongoing work.[38] Developing and applying coping strategies such as task modification support the argument that farmers may under-report any severe pain because it doesn't prevent them from performing their normal work activities.[38] This identifies another challenge of intervening with self-employed farmers, in that it is their independent responsibility to make changes to reduce MSD occurrence, rather than relying on an employer to regulate and respond to hazardous work exposures.

MSD of the Low Back

The occupational exposure with the greatest associated risk for low back MSD was using a shovel or pitch fork. This is mechanistically plausible as it involves an awkward posture of twisting and forward flexion of the trunk, activating spinal muscles and causing compression and shear stress on vertebral discs, forces which are known risk factors for low back disorder.[39] The lumbar spine (low back) regularly experiences a combination of loading modes including compressive forces that press discs together (instigated by lifting heavy or bulky objects), and torsional forces which are essentially rotational movements.[40,41] The long-term effects of such forces and stresses can be substantial. To illustrate, farmers who used a shovel or pitchfork for at least one hour over 20 days a year had a reported 46% increased risk for any low back pain compared to those who had no biomechanical exposure. This task has rarely been assessed in other population-based studies, making it difficult to understand if Saskatchewan farmers are unique in their vulnerability to this movement and type of work (this is probably unlikely), and also whether such tasks are a clear risk factor that requires consideration as a priority MSD hazard.

Intervention strategies are indeed possible to address the potential work-related causes of this MSD pattern[42]. Ergonomic tools that have been modified for certain occupations or sized to fit an individual are available, but perhaps their use could be promoted or made more readily available in the agricultural industry. This is a challenging problem, however, as shovels that complement one worker's size, strength, and ability may not be effective for others, as equipment is not inherently ergonomic but rather optimizing the fit with the worker and task.[43] Targeted health promotion and awareness-building campaigns on safer shoveling techniques could promote behaviour modification, resulting in safer ways to carry out necessary chores.[5] However, adjustment in work habits may be difficult to achieve due to resistance to change and cultural aspects of an autonomous nature rooted in the farming lifestyle.[44] If modified task performance is too difficult or unrealistic to instil, the development and design of machinery may also become an option to alleviate these tasks.[38] Mechanized equipment to manage jobs such as hay and sand transfer, moving feed, or livestock cleanup could eventually be implemented, but it is impossible (and likely undesirable) to relieve a farmer from all manual labour.[45]

Although strongest for manual shovel tasks, strong and significant relationships were also observed between the other three biomechanical work tasks and MSD in the low back. This is supportive of the idea that MSD outcomes are the result of cumulative types and levels of exposure.[46] A recent study of Colorado farmers reinforced this point, in which low back pain was more prevalent in those who farmed 10-29 years versus 1-9 years.[19] Although many factors play into the development of MSD symptoms, such as physical capacity, recovery time, and mechanical load, it is valuable to know that the duration of biomechanical exposures matters to

MSD outcomes in the low back. If the total exposure time cannot be reduced due to job demands, interventions could promote rest pauses or task rotation during and after prolonged and repetitive tasks which will allow for muscular recovery.[47]

MSD of the Shoulders

Consistent and statistically significant relationships for all four biomechanical exposures were also observed with the outcome of musculoskeletal pain in the shoulders. Working with hands over shoulder height was the strongest risk factor, followed by shovel and pitchfork use. Working with the arms overhead is a task known to cause sustained static muscle contractions; this can lead to degenerative changes.[48] A recent systematic review of prospective studies on the relation between physical capacity and the risk of MSD reported that there was inconclusive evidence for a relation between muscle strength or endurance of the neck/shoulder muscles and the risk of pain in this region, suggesting that pain may develop primarily from external exposures[49]. If this is the case, preventative measures on how to safely perform a task while minimizing overhead work may be an applicable solution to all farmers, rather than customizing for varying strengths and abilities.

Recognizing that different agricultural commodities may have different job demands is also informative for prevention initiatives. Findings from this study confirm that lifting, lowering, or carrying heavy objects, shovel or pitchfork use, and working with hands over shoulder height all significantly increase risk for shoulder pain. It will be important to determine if this is specific to farming practices in Saskatchewan, where grain and pulse crop production is most common. For example, a study investigating associations between dairy operations and work activities found no increased risk of shoulder MSD when comparing different milking facilities that required different tasks and therefore had different ergonomic exposures.[32] It was expected to find, based on task performance, that individuals who elevated their shoulder at or above 90° more frequently would report more MSD symptoms, as shoulder elevation in this range increases static loads of the shoulder girdle and is a known risk factor associated with shoulder pain.[32]

Studies conducted within other commodities and agricultural regions support the finding that working with elevated arms or hands over head is associated with shoulder pain, as seen in small-scale South African cotton farms. In that setting female workers were found to experience an increased risk for upper extremity pain when working with hands above shoulder height.[50] During the intensive harvesting of crops, women are required to have their arms at high elevation for an extended period of time. If shoulder pain is consistently observed in commodities where working with hands over shoulder height is necessary, then all farmers could be educated about the risks associated with arm elevation in general; however, specialized interventions that address load, task, and duration for crop and livestock farmers may be efficacious.

A number of epidemiological studies have implicated overhead exertions as a physical risk factor associated with neck and shoulder MSDs.[48] This movement could be intensified by different loads, elevations, or forceful motions, such as pushing or pulling; unfortunately our study, like many others assessing shoulder pain, did not identify which tasks were completed with hands above shoulder height.[51] If the nature of overhead work in farmers was found to be consistent, however, some recommendations could be made based on muscle requirements of different activities. Overhead pushing exertions are significantly more strenuous for the neck and shoulder musculature than pulling exertions, since pulling requires contraction of trunk and mid-back muscles, allowing for considerably less force and activation of neck and shoulder muscles.[52] If the kinematics of different actions elicits distinct responses, this needs to be considered when targeting overhead work.

As certain tasks can be challenging to avoid in farm work environments, it can be proposed that workers change directions of force periodically to prevent sustained loading of one muscle group and ultimately fatigue and musculoskeletal damage.[51] However, when intervening with work techniques it is necessary to recognize that working conditions may constrain workers to using awkward postures, and different levels of strength and exerted forces to handle equipment of different weights and sizes. The overall motions may appear the same, but the performance by each individual is influenced by both personal and contextual factors that may not be modifiable.[53]

Traditional ergonomics considers optimal work to have reduced metabolic overload, fatigue, and biomechanical strain, with a “less is better” approach. As a result, many occupations have focused on eliminating high physical workloads to protect workers from musculoskeletal disorders.[45] However, it is now acknowledged that sufficient levels of physical work/activity contribute to improved health, such as higher metabolism, more muscle activation, faster joint movements, increased demand for coordinated motor patterns, and greater forces on the bones.[45,54,55] It is therefore also important to recognize the positive effects of manual labour on farmers’ health, such as those associated with physical activity. It has been suggested that work needs to be designed to provide sufficient dose and variation of physical stress to reduce the risk of injury and enhance health and capacity.[45] Agriculture is an industry that may still be appropriate to emphasize physical stress and exposure reductions, as farmers will never become stationary. However, ergonomics will be faced with developing interventions that still achieve adequate, health-promoting levels of physical activity. As the physical health of farmers is heavily impacted by climate variability, changing agricultural practices, increasing sedentary work, and non-work activities, it will be challenging to incorporate all aspects for an effective prevention strategy.[56] Acknowledging that repetitive and strenuous chores are required, but also potentially reduce the risk of obesity, needs to be factored into preventive strategies. Striking a balance between the risk and benefits of biomechanical work may address the tension surrounding decreased work exposure and decreased sedentary activity.

Strengths and Limitations

Strengths of this study warrant comment. First, this study provides new and original information on a common occupational health problem facing North American farmers, namely MSDs to the lower back and shoulder. Second, we confirmed the relative strength and consistency of relationships between common biomechanical work exposures and these MSDs in order to provide foundational knowledge for prevention. Lastly, we measured the severity of pain by assessing whether the symptoms prevented the individual from performing normal work activities. The low reports of interrupting pain were unexpected but perhaps speak to the differences between farming and other occupations. The behaviour effects of continuing to work with pain or discomfort that would be debilitating to workers in other occupations is unique to farmers, as taking time off or modifying their work load may not be an option. The uncertainty could inspire future studies to investigate the impact of symptoms on disability and work tasks within an ergonomically unregulated farm industry.

Limitations of this study must also be recognized. First, the nature of the cross-sectional baseline data and subsequent temporality issues mean that some care should be taken in interfering causation. The duration of exposure and time of onset is unknown, which only allows for prevalent disorders to be assessed. Potential associations between musculoskeletal pain and frequency of biomechanical tasks can be identified but the direction of the relationship remains unclear. However, the suggestive dose-response relationship does not work moving in a backwards direction where pain dictates work engagement, which is perhaps indicative of these tasks in fact contributing to the development of musculoskeletal disorders. Second, data were collected through self-reported measures, which introduce misclassification and recall errors. Farm people may have inaccurately estimated days of exposure over the past year, leading to differential misclassification as some evidence suggests that those experiencing MSDs will report higher exposure as a result of their pain.[57] Third, with an individual response rate of 48.8%, it is possible that the sample may not be representative of all Saskatchewan farmers. As the project was developed with an injury focus, the respondents could be those who have encountered farm injuries and see the importance of safety prevention; meanwhile others could have been deterred from participating because they fear occupational control and legislation and not wish to support the research. Lastly, as only one person was requested to complete the household survey, personal information and interpretation of pain may not have been accurate. This form of information bias has the potential to distort the relationship between exposures and outcomes.

5.6 Conclusions

This study confirmed previous findings that common farm tasks are risk factors for work-related musculoskeletal disorders. Although causation could not be inferred, strong associations between increased biomechanical exposure and pain in the low back and shoulders support the evidence that these regions are susceptible to the physical exposures of farm work. Those reporting MSDs but no exposure warrant further investigation, as it may denote a cumulative effect resulting in complete work disability; it is also possible that they have different responsibilities and tasks that were not asked about. Preventative actions will require full consideration of the psychosocial context, including coping strategies, job design, individual and contextual factors, and the reality of intense seasonal demands in agriculture. Addressing economic issues that may arise from MSD outcomes could also make farmers more receptive and adherent to interventions.

References

1. Fathallah F a. Musculoskeletal disorders in labor-intensive agriculture. *Appl. Ergon.* 2010;41(6):738-43. doi:10.1016/j.apergo.2010.03.003.

2. Walker-Bone K, Palmer KT. Musculoskeletal disorders in farmers and farm workers. *Occup. Med. (Lond).* 2002;52(8):441-50. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12488514.

3. Yassi a. Work-related musculoskeletal disorders. *Curr. Opin. Rheumatol.* 2000;12(2):124-30. Available at: http://www.ncbi.nlm.nih.gov/pubmed/10751015.

4. Park H, Sprince NL, Whitten ÃPS, Burmeister LF, Zwerling C. Risk Factors for Back Pain Among Male Farmers : Analysis of Iowa Farm Family Health and Hazard Surveillance Study. *Am. J. Ind. Med.* 2001;654:646-654. doi:10.1002/ajim.10025.

5. Kirkhorn SR, Earle-Richardson G, Banks RJ. Ergonomic risks and musculoskeletal disorders in production agriculture: recommendations for effective research to practice. *J. Agromedicine* 2010;15(3):281-99. doi:10.1080/1059924X.2010.488618.

6. Osborne A, Blake ÃC, Fullen BM, et al. Risk Factors for Musculoskeletal Disorders Among Farm Owners and Farm Workers : A Systematic Review. *Am. J. Ind. Med.* 2012;389(December 2011):376-389. doi:10.1002/ajim.22001.

7. McMillan M, Trask C, Dosman J, Hagel L, Pickett W. Prevalence of musculoskeletal disorders among Saskatchewan farmers. *J. Rural Heal.* 2014;(C).

8. Davis KG. Understanding the Ergonomic Risk for Musculoskeletal Disorders in the United States Agricultural Sector. *Am. J. Ind. Med.* 2007;511:501-511. doi:10.1002/ajim.20479.

9. Thelin N, Holmberg S, Nettelbladt P, Thelin A. Mortality and morbidity among farmers, nonfarming rural men, and urban referents: a prospective population-based study. *Int. J. Occup. Environ. Health* 15(1):21-8. Available at: http://www.ncbi.nlm.nih.gov/pubmed/19267123.

10. Whelan S, Ruane DJ, McNamara J, Kinsella A, McNamara A. Disability on Irish farms--a real concern. *J. Agromedicine* 2009;14(2):157-63. doi:10.1080/10599240902813078.

11. Pickett W, Day L, Hagel L, et al. The Saskatchewan Farm Injury Cohort: rationale and methodology. *Public Health Rep.* 123(5):567-75. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2496929&tool=pmcentrez&rendertype=abstract.

12. Dillman DA. THE DESIGN AND ADMINISTRATION OF MAIL SURVEYS. *Annu. Rev. Sociol.* 2014;17(1991):225-249.

13. Kuorinka I. Standardized Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl. Ergon.* 1987;(18.3):233-237.

14. Costa BR. Risk Factors for Work-Related Musculoskeletal Disorders : A Systematic Review of Recent Longitudinal Studies. *Am. J. Ind. Med.* 2010;323:285-323. doi:10.1002/ajim.20750.

15. Videman T, Gibbons LE, Kaprio J, Battié MC. Challenging the cumulative injury model: positive effects of greater body mass on disc degeneration. *Spine J.* 2010;10(1):26-31. doi:10.1016/j.spinee.2009.10.005.

16. Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *J. Electromyogr. Kinesiol.* 2004;14(1):13-23. doi:10.1016/j.jelekin.2003.09.015.

17. De Zwart BC, Frings-Dresen MH, Kilbom a. Gender differences in upper extremity musculoskeletal complaints in the working population. *Int. Arch. Occup. Environ. Health* 2001;74(1):21-30. Available at: http://www.ncbi.nlm.nih.gov/pubmed/11196077.

18. Lemieux S, Mongeau L, Paquette M, Laberge S, Lachance B. Health Canada's new guidelines for body weight classification in adults: challenges and concerns. *Comment. - Quebec Prov. Work. Gr. Weight Relat. Issues* 2004;171(11):1361-1363.

19. Xiang H, Stallones L, Keefe TJ. Back pain and agricultural work among farmers: an analysis of the Colorado Farm Family Health and Hazard Surveillance Survey. *Am. J. Ind. Med.* 1999;35(3):310-6. Available at: http://www.ncbi.nlm.nih.gov/pubmed/9987565.

20. Bergman S. Public health perspective--how to improve the musculoskeletal health of the population. *Best Pract. Res. Clin. Rheumatol.* 2007;21(1):191-204. doi:10.1016/j.berh.2006.08.012.

21. Uematsu Y, Matuzaki H, Iwahashi M. Effects of nicotine on the intervertebral disc: an experimental study in rabbits. *J. Orthop. Sci.* 2001;6(2):177-82. doi:10.1007/s0077610060177.

22. Shiri R, Karppinen J, Leino-Arjas P, Solovieva S, Viikari-Juntura E. The association between smoking and low back pain: a meta-analysis. *Am. J. Med.* 2010;123(1):87.e7-35. doi:10.1016/j.amjmed.2009.05.028.

23. Torén a, Oberg K, Lembke B, Enlund K, Rask-Andersen a. Tractor-driving hours and their relation to self-reported low-back and hip symptoms. *Appl. Ergon.* 2002;33(2):139-46. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12009120.

24. Bovenzi M, Betta a. Low-back disorders in agricultural tractor drivers exposed to whole-body vibration and postural stress. *Appl. Ergon.* 1994;25(4):231-41. Available at: http://www.ncbi.nlm.nih.gov/pubmed/15676973.

25. Forde MS, Punnett L, Wegman DH. Prevalence of musculoskeletal disorders in union ironworkers. *J. Occup. Environ. Hyg.* 2005;2(4):203-12. doi:10.1080/15459620590929635.

26. Bailer AJ. *Statistical Programming in SAS (Google eBook)*. SAS Institute; 2010:444. Available at: http://books.google.com/books?hl=en&lr=&id=snejkVlVWhQC&pgis=1. Accessed April 8, 2014.

27. Pearce N. [Traditional epidemiology, modern epidemiology and public health]. *Epidemiol. Prev.* 1996;21(2):92-9. Available at: http://www.ncbi.nlm.nih.gov/pubmed/9378189.

28. Treaster DE, Burr D. Gender differences in prevalence of upper extremity musculoskeletal disorders. *Ergonomics* 2004;47(5):495-526. doi:10.1080/00140130310001638171.

29. Strazdins L, Bammer G. Women, work and musculoskeletal health. *Soc. Sci. Med.* 2004;58(6):997-1005. doi:10.1016/S0277-9536(03)00260-0.

30. Punnett L. Musculoskeletal disorders and occupational exposures: how should we judge the evidence concerning the causal association? *Scand. J. Public Health* 2014;42(13 Suppl):49-58. doi:10.1177/1403494813517324.

31. Rosecrance J, Rodgers G. Low Back Pain and Musculoskeletal Symptoms Among Kansas Farmers. *Am. J. Ind. Med.* 2006;556(49):547-556. doi:10.1002/ajim.20324.

32. Nonnenmann MW, Anton D, Gerr F, Merlino L, Donham K. Musculoskeletal Symptoms of the Neck and Upper Extremities among Iowa Dairy Farmers. *Am. J. Ind. Med.* 2008;451:443-451. doi:10.1002/ajim.20582.

33. Kolstrup CL. Work-related musculoskeletal discomfort of dairy farmers and employed workers. *J. Occup. Med. Toxicol.* 2012;7(1):23. doi:10.1186/1745-6673-7-23.

34. Croft P, Coggon D, Cruddas M, Cooper C. Osteoarthritis of the hip: an occupational disease in farmers. *BMJ* 1992;304(6837):1269-72. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1881870&tool=pmcentrez&rendertype=abstract.

35. Deddens J a, Petersen MR. Approaches for estimating prevalence ratios. *Occup. Environ. Med.* 2008;65(7):481, 501-6. doi:10.1136/oem.2007.034777.

36. Holmberg S, Thelin A, Stiernstr??m E-L, Sv??rdsudd K. Psychosocial Factors and Low Back Pain, Consultations, and Sick Leave Among Farmers and Rural Referents: A Population-Based Study. *J. Occup. Environ. Med.* 2004;46(9):993-998. doi:10.1097/01.jom.0000137715.33662.02.

37. Dean SG, Hudson S, Hay-Smith EJC, Milosavljevic S. Rural workers' experience of low back pain: exploring why they continue to work. *J. Occup. Rehabil.* 2011;21(3):395-409. doi:10.1007/s10926-010-9275-z.

38. Osborne A, Blake C, Meredith D, McNamara J, Phelan J, Cunningham C. The lived experience of low back pain among Irish farmers: case studies. *J. Agromedicine* 2014;19(2):181-90. doi:10.1080/1059924X.2014.884381.

39. Burdorf A, Sorock G. Positive and negative evidence of risk factors for back disorders. *Scand. J. Work. Environ. Health* 1997;23(4):243-256. doi:10.5271/sjweh.217.

40. Coenen P, Kingma I, Boot CRL, Bongers PM, van Dieën JH. Cumulative mechanical low-back load at work is a determinant of low-back pain. *Occup. Environ. Med.* 2014;71(5):332-7. doi:10.1136/oemed-2013-101862.

41. Gallagher S, Marras WS. Tolerance of the lumbar spine to shear: a review and recommended exposure limits. *Clin. Biomech. (Bristol, Avon)* 2012;27(10):973-8. doi:10.1016/j.clinbiomech.2012.08.009.

42. Baron S. *Simple Solutions: Ergonomics for Farm Workers*. Cincinnati, OH; 2001.

43. Counties S. Ergonomics in Agriculture : Commentary and Literature Review. *J. Agromedicine* 2001;8(1):9-18.

44. Hagel LM, Pickett W, Pahwa P, et al. Prevention of agricultural injuries: an evaluation of an education-based intervention. *Inj. Prev.* 2008;14(5):290-5. doi:10.1136/ip.2008.018515.

45. Straker L, Mathiassen SE. Increased physical work loads in modern work--a necessity for better health and performance? *Ergonomics* 2009;52(10):1215-25. doi:10.1080/00140130903039101.

46. Marras WS. The case for cumulative trauma in low back disorders. *Spine J.* 2003;3(3):177-179. doi:10.1016/S1529-9430(03)00032-9.

47. Das B, Gangopadhyay S. An ergonomics evaluation of posture related discomfort and occupational health problems among rice farmers. *Occup. Ergon.* 2011;10:25-38. doi:10.3233/OER-2011-0190.

48. Svendsen SW, Bonde JP, Mathiassen SE, Stengaard-Pedersen K, Frich LH. Work related shoulder disorders: quantitative exposure-response relations with reference to arm posture. *Occup. Environ. Med.* 2004;61(10):844-53. doi:10.1136/oem.2003.010637.

49. Hamberg-van Reenen HH, Ariëns GAM, Blatter BM, van Mechelen W, Bongers PM. A systematic review of the relation between physical capacity and future low back and neck/shoulder pain. *Pain* 2007;130(1-2):93-107. doi:10.1016/j.pain.2006.11.004.

50. Naidoo S, Kromhout ÃH, London L, Naidoo RN, Burdorf A. Musculoskeletal Pain in Women Working in Small-Scale Agriculture in South Africa. *Am. J. Ind. Med.* 2009;209(October 2008):202-209. doi:10.1002/ajim.20662.

51. Chopp JN, Fischer SL, Dickerson CR. The impact of work configuration, target angle and hand force direction on upper extremity muscle activity during sub-maximal overhead work. *Ergonomics* 2010;53(1):83-91. doi:10.1080/00140130903323232.

52. Nimbarte AD, Aghazadeh F, Ikuma L, Sun Y. Evaluation of the Loading of Neck and Shoulder Musculature in Overhead Pushing and Pulling Exertions. *Hum. Factors Ergon. Manuf. Serv. Ind.* 2012;22(4):317-327. doi:10.1002/hfm.

53. Dempsey PG, Mathiassen SE. On the evolution of task-based analysis of manual materials handling, and its applicability in contemporary ergonomics. *Appl. Ergon.* 2006;37(1):33-43. doi:10.1016/j.apergo.2004.11.004.

54. McPhail SM, Schippers M, Marshall AL. Age, physical inactivity, obesity, health conditions, and health-related quality of life among patients receiving conservative management for musculoskeletal disorders. *Clin. Interv. Aging* 2014;9:1069-80. doi:10.2147/CIA.S61732.

55. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: the evidence. *CMAJ* 2006;174(6):801-9. doi:10.1503/cmaj.051351.

56. Brumby S, Chandrasekara A, McCoombe S, Kremer P, Lewandowski P. Farming fit? Dispelling the Australian agrarian myth. *BMC Res. Notes* 2011;4(March):89. doi:10.1186/1756-0500-4-89.

57. Hansson G-Å, Balogh I, Byström J, et al. Questionnaire versus direct technical measurements in assessing postures and movements of the head, upper back, arms and hands. *Scand. J. Work. Environ. Health* 2001;27(1):30-40. doi:10.5271/sjweh.584.

Table 10. Saskatchewan Farm Injury Cohort Study Participant Characteristics

Individual Characteristics	**N=2,595**
Sex, no. (%)	
Male	1,545 (60.0)
Female	1,042 (40.0)
Age group, yrs, no. (%)	
19-39	445 (17.2)
40-59	1,157 (44.6)
60-79	891 (34.3)
80+	102 (3.9)
Highest level of completed education, no. (%)	
Less than high school	375 (14.5)
Completed high school	943 (36.5)
Technical/community college	707 (27.4)
Completed university	558 (21.6)
Missing	12
Main Occupation, no. (%)	
Farmer/farm worker	1,697 (66.1)
Retired	200 (7.7)
Student	43 (1.7)
Other	629 (24.5)
Missing	26
Relationship to farm operator, no. (%)	
Primary owner	1,198 (46.7)
Spouse	945 (36.0)
Child	284 (11.0)
Parent	76 (3.0)
Other	61 (2.4)
Missing	31
Off farm occupation, no. (%) yes	1,025 (39.7)
Missing	14
Body Mass Index (BMI) by age group, mean ± SD	
19-39	26.2 ± 4.8
40-59	27.7 ± 5.2
60-79	28.0 ±4.8
80+	26.8 ± 4.9
Missing	180
Comorbidities, no. (%)	
0	1,139 (46.4)
1	664 (27.0)
2	654 (26.6)
Farm Characteristics	**N=1,212**
Commodity, no. farms (%)	
Crop only	647 (54.2)
Livestock only	120 (10.1)
Both crop and livestock	426 (35.7)
Missing	19

Table 11. Modified Poisson Regression for Lower Back Pain

N=2,595		ANY LOWER BACK PAIN				INTERRUPTING PAIN				
		Unadjusted		*Adjusted* [1]			*Unadjusted*		*Adjusted* [2]	
Work Task Exposure	**%**	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**	**%**	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**
Lift, lower, or carry heavy objects		(213)*		(566)*			(220)*		(437)*	
0 days/year	51	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	61	1.11 (1.07, 1.15)	<.0001	1.12 (1.07, 1.16)	<.0001	8	1.04 (1.01, 1.06)	0.0010	1.03 (1.00, 1.05)	0.0183
11-20 days/year	66	1.24 (1.15, 1.33)	<.0001	1.26 (1.16, 1.37)	<.0001	17	1.06 (1.08, 1.11)	0.0054	1.05 (1.01, 1.10)	0.0230
20+ days/year	66	1.33 (1.21, 1.46)	<.0001	1.35 (1.22, 1.50)	<.0001	19	1.10 (1.04, 1.16)	0.0001	1.08 (1.02, 1.15)	0.0061
Use a shovel or pitchfork		(195)*		(561)*			(202)*		(432)*	
0 days/year	50	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	62	1.11 (1.07, 1.16)	<.0001	1.13 (1.07, 1.18)	<.0001	18	1.03 (1.01, 1.05)	0.0317	1.02 (0.99, 1.04)	0.1523
11-20 days/year	70	1.29 (1.19, 1.38)	<.0001	1.33 (1.22, 1.44)	<.0001	20	1.07 (1.02, 1.11)	0.0022	1.01 (1.01, 1.11)	0.0115
20+ days/year	65	1.40 (1.27, 1.53)	<.0001	1.46 (1.32, 1.62)	<.0001	17	1.10 (1.04, 1.16)	0.0004	1.09 (1.03, 1.16)	0.0027
Work with hands over shoulder height		(240)*		(596)*			(247)*		(471)*	
0 days/year	52	1.00 (Reference)		1.00 (Reference)		14	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	63	1.11 (1.06, 1.17)	<.0001	1.12 (1.06, 1.19)	<.0001	17	1.03 (1.00, 1.06)	0.0365	1.02 (0.99, 1.05)	0.2143
11-20 days/year	67	1.24 (1.14, 1.35)	<.0001	1.25 (1.14, 1.38)	<.0001	16	1.04 (0.99, 1.10)	0.0792	1.03 (0.98, 1.08)	0.3036
20+ days/year	67	1.34 (1.20, 1.48)	<.0001	1.37 (1.22, 1.54)	<.0001	20	1.06 (1.01, 1.13)	0.0309	1.05 (0.98, 1.12)	0.1387
Operate power tools with the hand		(200)*		(565)*			(207)*		(438)*	
0 days/year	50	1.00 (Reference)		1.00 (Reference)		13	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	60	1.11 (1.07, 1.15)	<.0001	1.12 (1.07, 1.17)	<.0001	16	1.03 (1.08, 1.05)	0.0088	1.02 (0.99, 1.04)	0.2119
11-20 days/year	69	1.27 (1.18, 1.36)	<.0001	1.28 (1.18, 1.38)	<.0001	22	1.08 (1.04, 1.13)	0.0001	1.06 (1.02, 1.11)	0.0086
20+ days/year	65	1.36 (1.24, 1.49)	<.0001	1.37 (1.24, 1.52)	<.0001	19	1.10 (1.04, 1.15)	0.0002	1.07 (1.02, 1.14)	0.0132

[1] Controlled for tractor operation, BMI, medication status, comorbidity status [2] Controlled for age, tractor operation, farm injuries, comorbidity status, and relation to owner.

*Number of individuals with missing data.

Table 12. Modified Poisson Regression for Shoulder Pain

		ANY SHOULDER PAIN				INTERRUPTING PAIN				
N=2,595		***Unadjusted***		***Adjusted*** [1]			***Unadjusted***		***Adjusted*** [2]	
Work Task Exposure	**%**	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**	**%**	**RR (95% CI)**	**p value**	**RR (95% CI)**	**p value**
Lift, lower, or carry heavy objects		(213)*		(494)*			(219)*		(401)*	
0 days/year	37	1.00 (Reference)		1.00 (Reference)		6	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	46	1.12 (1.08, 1.16)	<.0001	1.09 (1.05, 1.13)	<.0001	6	1.02 (1.00, 1.03)	0.0162	1.02 (1.00, 1.03)	0.0433
11-20 days/year	49	1.21 (1.13, 1.29)	<.0001	1.13 (1.09, 1.25)	<.0001	5	1.01 (0.99, 1.04)	0.4103	1.01 (0.98, 1.04)	0.4405
20+ days/year	54	1.28 (1.18, 1.39)	<.0001	1.21 (1.11, 1.32)	<.0001	10	1.01 (0.98, 1.04)	0.5197	1.01 (0.97, 1.04)	0.6643
Use a shovel or pitchfork		(195)*		(481)*			(201)*		(387)*	
0 days/year	38	1.00 (Reference)		1.00 (Reference)		7	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	45	1.11 (1.07, 1.15)	<.0001	1.09 (1.05, 1.13)	<.0001	6	1.03 (1.00, 1.05)	0.0317	1.01 (0.99, 1.03)	0.1838
11-20 days/year	50	1.20 (1.13, 1.29)	<.0001	1.19 (1.11, 1.27)	<.0001	9	1.07 (1.02, 1.11)	0.0022	1.03 (0.99, 1.06)	0.0969
20+ days/year	54	1.26 (1.16, 1.37)	<.0001	1.23 (1.13, 1.34)	<.0001	9	1.10 (1.04, 1.16)	0.0004	1.03 (0.99, 1.06)	0.1668
Work with hands over shoulder height		(181)*		(519)*			(246)*		(426)*	
0 days/year	38	1.00 (Reference)		1.00 (Reference)		6	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	50	1.12 (1.06, 1.17)	<.0001	1.11 (1.06, 1.16)	<.0001	8	1.03 (1.00, 1.06)	0.0365	1.01 (0.99, 1.04)	0.1650
11-20 days/year	51	1.21 (1.12, 1.32)	<.0001	1.17 (1.08, 1.27)	0.0001	7	1.04 (0.99, 1.10)	0.0792	1.01 (0.98, 1.05)	0.3787
20+ days/year	55	1.31 (1.20, 1.44)	<.0001	1.25 (1.14, 1.38)	<.0001	9	1.06 (1.01, 1.13)	0.0309	1.02 (0.99, 1.06)	0.2187
Operate power tools with the hand		(200)*		(486)*			(206)*		(393)*	
0 days/year	39	1.00 (Reference)		1.00 (Reference)		7	1.00 (Reference)		1.00 (Reference)	
1-10 days/year	46	1.08 (1.04, 1.12)	<.0001	1.04 (1.01, 1.09)	0.0229	7	1.03 (1.01, 1.05)	0.0088	0.99 (0.98, 1.01)	0.4120
11-20 days/year	50	1.15 (1.08, 1.23)	<.0001	1.09 (1.02, 1.17)	0.0110	9	1.08 (1.04, 1.13)	0.0001	1.00 (0.98, 1.03)	0.8119
20+ days/year	51	1.21 (1.12, 1.31)	<.0001	1.11 (1.02, 1.21)	0.0174	7	1.07 (1.03, 1.11)	0.0012	1.00 (0.96, 1.04)	0.9972

[1] Controlled for farm injuries, BMI, comorbidity status, and relation to owner [2] Controlled for tractor operation, farm injuries, comorbidity status, and relation to owner.

*Number of individuals with missing data.

Chapter 6

General Discussion

6.1 Summary of Key Findings

The purpose of this thesis was to describe the occurrence of musculoskeletal disorders among farmers, and specific biomechanical exposures that are associated with increased risks for these conditions.

The first manuscript explored the prevalence of musculoskeletal symptoms in nine major body regions, as well as an indicator describing the severity of reported pain. Patterns of musculoskeletal disorder occurrence were described by individual- and farm-level variables. Over eighty percent of farm people reported having musculoskeletal pain in at least one anatomical site during the past year. The most frequently affected site was the lower back (57.7%), followed by the shoulders (44.0%), reflecting results observed in other farming populations.[1] Severity of pain was assessed by whether or not the condition(s) prevented them from performing regular work activities, to which 28% reported in the affirmative. Although the prevalence of musculoskeletal disorders did not vary by gender, commodity type, or by total hours of farm work, a significant relation to biomechanically-intensive work exposures was observed. High-risk groups were not identified through demographic analysis, suggesting that musculoskeletal disorders are an important health issue experienced by the majority of farmers.

The second manuscript used a cross-sectional design to explore relations between biomechanical farm work exposures and musculoskeletal pain in the lower back and shoulders. Associations were remarkably consistent. Farmers are susceptible to musculoskeletal disorders in response to physical demands, as risk increased in a dose-dependent way with more time spent on each specified task. Although all biomechanically-demanding work tasks investigated require ergonomic attention, using a shovel or pitchfork was found to have the strongest association with lower back pain, while working with hands over head seemed to contribute the most to shoulder pain. However, work-interrupting pain was not related significantly with these exposures, identifying the need for further understanding of the impact of these more serious symptoms in terms of coping strategies and ability to work.

The combined work in these manuscripts provides insight into an understudied population: farm operators. The basic analyses served as a starting point to understand the extent to which musculoskeletal disorders are an issue in the Canadian farm industry, and where preventive action may be focused.

6.2 Internal Validity

Internal validity refers to the degree in which results of a study are correct for the sample of participants being studied.[2] It is determined by design, data collection and analyses, but threatened by selection and information bias, as well as confounding and chance. These sources of systematic error will now be evaluated in terms of how they may have speciously affected measures estimates in this thesis.

6.2.1 Selection Bias

Manuscript 1

The first phase of the study recruited participants in a systematic manner, stratifying agricultural regions by soil type and then performing sampling within participating municipalities.[3] The second phase of the study, however, endeavored to increase study population by inviting farms from Phase 1 that were willing to continue, as well as additional farms from a number of new rural municipalities. As manuscript 1 used only data from the second phase, representativeness of the sample may have been limited by selection bias (in this situation defined as bias related to obtaining a non-representative sample due to selection). This form of selection bias could have occurred due to reasons such as: willingness or unwillingness to participate, no longer an active farm, or change in residence. Sampling alone could have led to differences in selection of participants into or out of the study. The farms from Phase 1 that were willing to continue may not be representative. Some regions may have had higher response and interest in the study, some farms may have not been given the chance to participate because their municipality decided against it, or some farmers were lost to follow up because they chose to be removed from the cohort.

Manuscript 2

Traditionally, selection bias is more classically described as a misrepresentation of effect estimates as a result of how participants were selected into or out of a study. The low response rate (48%) raises concern for bias in non-responders, as there may have been differences between those farms agreeing to participate and those who did not, and this participation might be related to both exposure and outcome. With the study focus being injury, farm people could have either been reluctant to report injuries in their farm environment out of fear of external control and regulation, or they may have recognized the need for surveillance and understanding of a hazardous work setting. Although there is no evidence that those who responded are systemically different than those who did not, it is possible that results suggest that selection bias did occur by those exposed being more likely to respond. In turn, high proportions of reported musculoskeletal pain may have consequently affected the risk estimate by inflating any association between occupational exposures and musculoskeletal disorders.

6.2.2 Information Bias

As both analyses used the same data, they both potentially suffered from misclassification. With only one person filling out each household survey, variables like personal information, interpretation of pain, and exposure estimates were subject to inaccuracy. Information bias is therefore a likely issue that needs to be considered when interpreting these results. Self-reports as well as reports on other household members were subject to recall error for outcome measurements, and recall bias for exposure measurements.

Random Misclassification

Although the Standardized Nordic Questionnaire has been deemed a valid and reliable tool in the assessment of musculoskeletal symptoms, it is possible that random misclassification occurred as a result of recall error. With a recall period of 12 months, it is reasonable to assume that reports of pain could be inaccurately measured either due to 1) unawareness of the presence of pain in a family member or 2) inability to remember occurrences of pain if they were not chronic, severe, or recent. It is also possible that location of pain could have been incorrectly recorded, such as differences between the upper and lower back. Severity of pain, or whether the pain interrupted their regular work activities, could have also been poorly reported, as there may have been instances where the individual was prevented from performing a task but was unable to remember. These errors leading to misclassification likely occurred in a non-differential way by any covariate examined, however, affecting all participants equally.

Non-random Misclassification

Differential recall of biomechanical exposures among people who did or did not report symptoms could have introduced bias and therefore impinged on effect estimates in the analysis in the second manuscript. It is possible that individuals with musculoskeletal pain overestimated work exposures because they were convinced that certain tasks contributed to their symptoms.

This inflation of the effect estimate makes it difficult to establish any dose- response relationship if one does exist. Given the high prevalence of musculoskeletal pain in this sample, resulting non-random misclassification may have exaggerated the contrast between exposure groups. As exposure was originally a continuous variable categorized for analysis, it could have easily facilitated erroneous classification of people, again falsely biasing the estimates of effect away from the null. In addition, measurements that asked about duration to biomechanical exposure in number of days have precedents in the literature, and did have reasonable face and content validity when undergoing pilot testing.[3] However, how well these questions quantify the truth is unknown and should be taken into consideration. As exposure to any of the four specific tasks had to be estimated in number of days over the past year in which they performed the activity for at least one hour could easily have been miscalculated. The question also does not state whether this was a consecutive or cumulative hour, further complicating the accuracy of the results, and classifying individuals in a category that may not be the truth.

6.2.3 Other Measurement Considerations – The Standardized Nordic Questionnaire

The Standardized Nordic Questionnaire (SNQ) is a standardized instrument used to analyze musculoskeletal symptoms in an ergonomic or occupational health context.[4] The questionnaire was developed as a simple survey tool that consisted of structured, forced, binary or multiple choice variants that could be answered through self-administration or interview.[5] It may be used as a diagnostic tool for analysing the work environment, work station, and tool design, but it is not meant to serve in clinical diagnosis of musculoskeletal disorders.[5] Although objective measures may be more useful in confirming a diagnosis, subjective measures are valuable as they capture patient impact. In addition, self-reports offer individual perspectives of painful and debilitating symptoms that may be not captured by technical assessment.[6] Compared to other pain measurement tools like the Numerical Rating Scale or Visual Analogue Scale, the Standardized Nordic Questionnaire has limitations surrounding the intensity of pain, unable to differentiate between mild, moderate, and severe musculoskeletal pain.[10]

The Standardized Nordic Questionnaire is appealing to health and safety groups because it provides an easy methodology to identify how many workers may be experiencing musculoskeletal symptoms. It is general enough to apply in diverse occupational settings and can be administered to a large number of individuals in an efficient and affordable manner.[7] In addition to its simplicity, the SNQ as a tool is reliable and diagnostically valid.[7, 8] The repeatability of each item in the questionnaire has been tested in numerous studies, typically involving test-retest to assess the degree to which repeated measurements on the same individual provide similar results. For example, a modified version of the Standardized Nordic Questionnaire was administered to both patients who had a confirmed pathology by a rheumatologist and those who did not receive a diagnosis. Consistencies were observed by assessing replicate observations for pain over the past week and pain over the past year.[7] Cohen's kappa coefficient, which is a relevant measure of agreement, is normally calculated for replicate reports, with results showing good to excellent values (κ=0.73-0.82) in hospital outpatients and general-practice patients.[7]

Validity of the SNQ has also been assessed with sensitivity and specificity analyses, with clinical examination often used as the reference. The sensitivity is generally seen to be high, ranging between 80-100%; representing the proportion of true positives, these individuals are those whose clinical reports correctly matched their self-report.[7] This has practical importance as it implies this tool has a high utility when used in screening and surveillance. Specificity, however, is always found to be lower (50-80%), which is expected when the sensitivity is so high.[9,10] It doesn't necessarily mean that the SNQ is an inadequate tool for identification of musculoskeletal disorders; it does mean that studies based solely on the use of this measurement should be interpreted with caution, as cut-off values for diseased individuals may not correctly identify healthy persons free of the condition.[7]

The SNQ general questionnaire was chosen for the Saskatchewan Farm Injury Project survey based on space allotment and initial desire to capture the prevalence of musculoskeletal conditions in this specific population. There are, however, other time frames used in the original, long-form SNQ that are not included in the Saskatchewan Farm Injury Cohort survey.[4]

If further analysis on musculoskeletal disorders in follow-up were required in a future study, use of the SNQ special questionnaires for low back and shoulder may be valuable. These specific questionnaires probe more deeply into the analysis of prominent symptoms and contain questions on the direction and severity, coping mechanisms, and how the pain has interfered with a respondent's life.[5] If cumulative exposure and the nature of pain can be better assessed, longitudinal studies would be able to distinguish between acute/traumatic injuries and overuse/repetitive injuries leading to MSD. Information on work adaptation and the level of disability or dysfunction are required in order to inform ergonomics interventions. Identification of these remaining knowledge gaps will be important to guide future research.

6.2.4 Covariates

Potential covariates were identified based on studies describing musculoskeletal disorders and investigating the associated risk factors. A large set of variables found to contribute to development of musculoskeletal pain in farmers, other occupational groups, as well as the general adult population were tested for both confounding and effect modification. Many of the proposed variables were available in the survey, such as age, sex, BMI, smoking, acute injuries, farm size and tractor operation. Variables that were additionally explored due to suspected association were commodity type, seasonal hours worked, role on the farm, number of hired workers, and comorbidity status.

Possible confounders such as psychosocial factors were not available in the SFIC survey, which may have resulted in uncontrolled confounding. Measurement of confounding variables such as BMI (computed from height and weight) or comorbidity status, may have been incomplete or inaccurate, which may have contributed to residual confounding. Additional farm-level covariates that were not available were type of tools used and if they were a good ergonomic fit for the worker, the load-bearing stress while working with arms over head or shoveling, and the training procedures available and used purposely on the farm. Uncontrolled and also residual confounding may have therefore biased effect estimates towards or away from the null, leaving the true strength of association unknown.

6.2.5 Statistical Power

For the first manuscript, we were interested in the precision of estimates. These were estimated *a priori* using 95% confidence intervals calculated for proportions based on an estimated sample size of 2,400. The confidence intervals remained fairly tight at all proportions; typically plus or minus 2-3%, varying depending on the proportion size. Narrow confidence intervals are indicative of accuracy and that the results unlikely occurred due to chance. Please refer to Appendix A for calculations based on three different sample sizes.

The power of the study in the second manuscript refers to the ability to detect a true difference in musculoskeletal symptom frequency between farmers who have high levels of exposure to biomechanically-demanding work tasks and those who have little or no exposure. Power was calculated using the classical method for cross-sectional or cohort studies with a design effect of 1.2 that accounted for the clustered nature of the data. A minimum detectable risk of 1.5 was chosen, which is argued to be a meaningful increase in risk associated with the exposure of interest.[11] Proportions for both lower back pain and shoulder pain from previous studies were used to determine the power available to detect a difference between the highest and lowest exposure groups. Over 90% power was generated for both musculoskeletal outcomes. Refer to Appendix A for values used in each power calculation.

6.3 External Validity

External validity is the degree to which the results of an observation hold true in other settings. It is also referred to as generalizability, meaning the extent in which the target population can be represented by the findings, and how those findings can be generalized to other populations.[2]

As previously described, the representativeness of this sample is questionable due to a low response rate. Although the intention of the sampling approach was to recruit a heterogeneous sample that included information about farm practices, characteristics, and exposures, the descriptive findings should not be considered generalizable to the Saskatchewan farm population. Refer to Appendix B for farm operator comparisons.

However, the results from the etiological analysis in manuscript 2, despite misclassification, could (at least qualitatively) accurately represent the exposure-response relationship of musculoskeletal disorders in this target population. For the most part, there is a dose-dependent association between biomechanical work and the risk associated with musculoskeletal pain in the lower back and shoulders. As duration in days per year increases with respect to farm tasks, the relative risk of experiencing a musculoskeletal disorder increases as well. Although other factors play into the development of these conditions that may not have been accounted for, the biological plausibility of strenuous work activities instigating pain makes it reasonable to believe that this association would be observed in other populations. Quantitative associations may not be generalizable to other farming populations due to different commodity types, production demands, and therefore required tasks, but certainly apply in Saskatchewan where crop production is predominant. Qualitatively, however, the effects and their dose response could be generalized to farmers outside of Saskatchewan, as similar musculoskeletal strain or movements through physical work could have just as much associated risk for musculoskeletal disorders.

6.4 Other Strengths and Limitations of the Thesis

The greatest strength of this thesis is that it provides insight into an important occupational health problem that is only now starting to receive attention in the Canadian agricultural industry.[12] As studies of musculoskeletal disorders had never, to our knowledge, been published in Canadian farmers, the first manuscript contributed by describing the MSD prevalence in key groups, while the second manuscript determined the risks for MSDs associated with basic farming exposures. It was suspected that physical work contributed to or precipitated musculoskeletal disorders, based on studies performed on agricultural sectors and populations elsewhere.[13,14,15, 16,17,18] The current findings confirmed that musculoskeletal pain is prevalent in Saskatchewan farmers—especially in the lower back and shoulders—and that further attention is needed on occupational health and safety in Canadian farming. As exposures to several typical biomechanically-demanding work tasks were assessed, this foundational knowledge can help realistically define areas for prevention and awareness programs.

A strength specific to the second manuscript comes from the methodology chosen to obtain risk estimates. Although there are examples of alternative model structures in the literature[19], simple logistic is far more common in the area of farm musculoskeletal disorders. Etiological studies done on farmers in Iowa, Colorado, and Kansas all used odds ratios to estimate the risk of biomechanically-intensive work on the outcome of musculoskeletal disorders.[14,15,18] To our knowledge, the work presented in this thesis was among the first studies to investigate alternatives to logistic regression, which has been the standard method for modeling these relationships in studies of musculoskeletal disorders. This manuscript was able to advocate for, and make use of, a modified Poisson regression to compute interpretable relative risks, rather than odds ratios which are commonly misused to infer risk, inaccurately, when outcomes are common.[20] The comparisons of regression model outcomes are presented in Chapter 3.

As previously described, the studies presented here have some limitations that merit consideration. The etiological investigation in manuscript 2 had the classic limitation of temporality due to its cross-sectional design.[21] Although the analysis was able to detect associations between frequency of manual tasks and musculoskeletal disorders, many factors still need to be evaluated to ascertain any true relationships. The analysis provided preliminary information and answered the research questions, but better measurements that obtain detailed information on the nature of musculoskeletal pain as well as improved study design using prospective data are needed to appropriately respond to this issue. Temporality could be addressed through cohort studies to ensure that exposure does precede disease, and that the level and duration of exposure can be monitored precisely. Reverse causality (musculoskeletal disorders predict work patterns) could then be ruled out and a relationship where engagement in biomechanical tasks causes musculoskeletal pain in the lower back and shoulders may be established.

6.5 Future Research Directions

These results can serve as a baseline for future longitudinal studies and investigations of survey items that contribute to the understanding of these relationships. A prospective cohort study following farmers for an extended period of time and collecting data on incident cases would be ideal to establish temporality between specific tasks and musculoskeletal pain. Additional studies could look critically at both exposure and outcome measurement to ensure they are appropriate, or determine how they could be improved. As the development of MSDs is multifaceted, further research should incorporate psychosocial factors with the physical aspect of risk exposure.[22,23,24] Understanding independent components and how they contribute to musculoskeletal disorders is first needed, followed by a more comprehensive analysis of all potential predictors, and how they may coexist in the development of these conditions.

Although a result not stressed in the second manuscript, but an interesting observation worth mentioning as it may guide future research, is the finding that musculoskeletal pain was still experienced without engagement in the work tasks measured. Further research needs to determine if this is due to external exposures unrelated to farm work, personal factors such as overweight and obesity, or if the pain resulting from farm work has led to disability and low work participation. Identifying whether those disabled farmers have symptoms from agricultural work will help illustrate the severity of this occupational issue. In a similar respect, coping mechanisms employed by farmers to address symptoms also requires investigation, as the observed low report of work-interrupting pain may be related to the nature of farm work and cultural expectations.

6.6 Public Health and Policy Implications

Both manuscripts provide strong and compelling evidence that musculoskeletal disorders are a major occupational health concern in Saskatchewan, and possibly Canadian, farmers. Results of the first manuscript highlight that the vast majority of farm people suffer from musculoskeletal symptoms and therefore need to be equally targeted in prevention efforts. Results from the second manuscript show that involvement in manual labour at any exposure level is a risk factor for developing pain the lower back and shoulders. The exposure measurements may be specific to the Canadian plains, but the findings still contribute to the understanding of the mechanisms involved in the development of these conditions. Even though commodity-specific interventions may be needed, many agricultural tasks demand the same physical movements. If a firm set of risk factors can be established, ergonomic and engineering controls have the potential to be effectively designed.[25]

Until then, a public health response will have to work with the best information available. This means targeting all prairie farmers with awareness programs designed to integrate with the social and environmental context. Along with other agrarian values, independence and self-reliance are traditional and defining characteristics that make for a hard-working but change-resistant group of workers.[26] Recognizing that farmers can be resistant to external control and occupational intervention is crucial to communicating a respectful yet effective message. Inviting farmers to participate and have input in preventive actions will not only be useful in developing educational programs, but will likely improve reception by other farmers.[27]

Farmers do not need to be informed that pain is a common outcome in their line of work; what they should be reminded of are the consequences associated with unmanaged symptoms. It should be emphasized that reduced quality of life as well as economic burden to the farm operation can be serious and realistic effects.[17] Promoting a work environment that recognizes the need for physical labour but accepts recommendations for work modification and mechanistic change will hopefully reduce the occurrence of musculoskeletal disorders in all types of farmers.

Although heightened awareness is an important aspect of prevention in occupational settings, it is in most cases not independently sufficient to change the problem.[28] An evaluation done specifically on this population revealed the need for intervention efforts in agriculture to extend beyond education.[29] A full paradigm of prevention must be implemented to be effective in injury control and occupational outcomes. Introducing the public health model, composed of three pillars, including education, engineering, and regulation to help guide farm health and safety practices is necessary when more sound evidence on work-related musculoskeletal disorders becomes available.[29]

Collaboration with stakeholders and building on existing infrastructure will be key to addressing the needs of this, or any, farm population. Following the implementation of delivered programs and design controls will be more rigorous methods such as comparative studies and trials to determine their effectiveness and efficiency in reducing musculoskeletal pain as a result of farm work exposures.[30]

6.7 Conclusion

This thesis demonstrates that there is a substantial burden of musculoskeletal disorders in adults residing and working on Saskatchewan farms. The prevalence estimates provided in the first manuscript can be partly explained by the specific biomechanical work exposures that are common to farm people in this region. The associations between these physically demanding tasks and presence of musculoskeletal pain in the lower back and shoulders was found to be dose-dependent in nature. Future research should 1) investigate exposures common to other commodity types in Canada and how they predict musculoskeletal disorders; 2) use cohort data to evaluate in the correct temporal sequence how these work exposures contribute to prospective outcomes, i.e., incidence of musculoskeletal disorders; 3) use the extended version of the Standardized Nordic Questionnaire to better assess onset and characteristics of musculoskeletal pain; and 4) consider the methodological constraints and benefits of different regression methods and take caution when interpreting effect estimates.

Musculoskeletal disorders should be a priority for public health and occupational health and safety groups that cover rural and agricultural populations. Preventive efforts should adopt the public health model that incorporates education, engineering, and regulation to effectively control the occurrence and progression of these conditions in adult farmers and farm workers.

References

1. McMillan M, Trask C, Dosman J, Hagel L, Pickett W. Prevalence of musculoskeletal disorders among Saskatchewan farmers. *J. Rural Heal.* 2014;(C).

2. Rothman J, Greenland S, Lash T. Livro-131-Modern-Epidemiology.pdf.

3. Pickett W, Day L, Hagel L, et al. The Saskatchewan Farm Injury Cohort: rationale and methodology. *Public Health Rep.* 123(5):567-75. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2496929&tool=pmcentrez&rendertype=abstract.

4. Kuorinka I. Standardized Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl. Ergon.* 1987;(18.3):233-237.

5. Dickinson CE, Campion K, Foster a F, Newman SJ, O'Rourke a M, Thomas PG. Questionnaire development: an examination of the Nordic Musculoskeletal questionnaire. *Appl. Ergon.* 1992;23(3):197-201. Available at: http://www.ncbi.nlm.nih.gov/pubmed/15676868.

6. Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *J. Electromyogr. Kinesiol.* 2004;14(1):13-23. doi:10.1016/j.jelekin.2003.09.015.

7. Palmer K, Smith G, Kellingray S, Cooper C. Repeatability and validity of an upper limb and neck discomfort questionnaire: the utility of the standardized Nordic questionnaire.

Occup. Med. (Lond). 1999;49(3):171-5. Available at: http://www.ncbi.nlm.nih.gov/pubmed/10451598.

8. Franzblau A, Salerno D, Armstrong TJ, Werner R a. Test-retest reliability of an upper-extremity discomfort questionnaire in an industrial population. *Scand. J. Work. Environ. Health* 1997;23(4):299-307. doi:10.5271/sjweh.223.

9. Parot-Schinkel E, Descatha A, Ha C, Petit A, Leclerc A, Roquelaure Y. Prevalence of multisite musculoskeletal symptoms: a French cross-sectional working population-based study. *BMC Musculoskelet. Disord.* 2012;13(1):122. doi:10.1186/1471-2474-13-122.

10. Manniche C, Asmussen K, Lauritsen B, Vinterberg H, Kreiner S, Jordan a. Low Back Pain Rating scale: validation of a tool for assessment of low back pain. *Pain* 1994;57(3):317-26. Available at: http://www.ncbi.nlm.nih.gov/pubmed/7936710.

11. Lu N, Han Y, Chen T, et al. Power analysis for cross-sectional and longitudinal study designs. *Shanghai Arch. psychiatry* 2013;25(4):259-62. doi:10.3969/j.issn.1002-0829.2013.04.009.

12. Trask C, Bath B, McCrosky J, Lawson J. A profile of farmers and other employed canadians with chronic back pain: a population-based analysis of the 2009-2010 canadian community health surveys. *J. Rural Health* 2014;30(3):300-10. doi:10.1111/jrh.12062.

13. Park H, Sprince NL, Whitten ÃPS, Burmeister LF, Zwerling C. Risk Factors for Back Pain Among Male Farmers : Analysis of Iowa Farm Family Health and Hazard Surveillance Study. *Am. J. Ind. Med.* 2001;654:646-654. doi:10.1002/ajim.10025.

14. Nonnenmann MW, Anton D, Gerr F, Merlino L, Donham K. Musculoskeletal Symptoms of the Neck and Upper Extremities among Iowa Dairy Farmers. *Am. J. Ind. Med.* 2008;451:443-451. doi:10.1002/ajim.20582.

15. Rosecrance J, Rodgers G. Low Back Pain and Musculoskeletal Symptoms Among Kansas Farmers. *Am. J. Ind. Med.* 2006;556(49):547-556. doi:10.1002/ajim.20324.

16. Osborne A, Blake C, Meredith D, McNamara J, Phelan J, Cunningham C. The lived experience of low back pain among Irish farmers: case studies. *J. Agromedicine* 2014;19(2):181-90. doi:10.1080/1059924X.2014.884381.

17. Whelan S, Ruane DJ, McNamara J, Kinsella A, McNamara A. Disability on Irish farms--a real concern. *J. Agromedicine* 2009;14(2):157-63. doi:10.1080/10599240902813078.

18. Xiang H, Stallones L, Keefe TJ. Back pain and agricultural work among farmers: an analysis of the Colorado Farm Family Health and Hazard Surveillance Survey. *Am. J. Ind. Med.* 1999;35(3):310-6. Available at: http://www.ncbi.nlm.nih.gov/pubmed/9987565.

19. Boyer J, Galizzi ÃM, Cifuentes M, et al. Ergonomic and Socioeconomic Risk Factors for Hospital Workers ' Compensation Injury Claims. *Am. J. Ind. Med.* 2009;562(April):551-562. doi:10.1002/ajim.20702.

20. Zou G. A Modified Poisson Regression Approach to Prospective Studies with Binary Data. *Am. J. Epidemiol.* 2004;159(7):702-706. doi:10.1093/aje/kwh090.

21. Harris R, Tobias M, Jeff M, Waldegrave K, Karlsen S, Nazroo J. Effects of self-reported racial discrimination and deprivation on Māori health and inequalities in New Zealand : cross-sectional study. *Lancet* 2006;36:2005-2009.

22. Cieza A, Stucki G, Weigl M, et al. ICF Core Sets for low back pain. *J. Rehabil. Med.* 2004;(44 Suppl):69-74. doi:10.1080/16501960410016037.

23. Bergman S. Management of musculoskeletal pain. *Best Pract. Res. Clin. Rheumatol.* 2007;21(1):153-66. doi:10.1016/j.berh.2006.10.001.

24. Bergman S. Public health perspective--how to improve the musculoskeletal health of the population. *Best Pract. Res. Clin. Rheumatol.* 2007;21(1):191-204. doi:10.1016/j.berh.2006.08.012.

25. Kirkhorn SR, Earle-Richardson G, Banks RJ. Ergonomic risks and musculoskeletal disorders in production agriculture: recommendations for effective research to practice. *J. Agromedicine* 2010;15(3):281-99. doi:10.1080/1059924X.2010.488618.

26. Kelsey TW. The Agrarian Myth and Policy Responses to Farm Safety. *Public Heal. Then Now* 1988:1171-1177.

27. Chapman L, Meyers J. *Ergonomics and Musculoskeletal Injuries in Agriculture: Recognizing and Preventing the Industry's Most Widespread Health and Safety Problem.*; :13.

28. Vyas R. Mitigation of musculoskeletal problems and body discomfort of agricultural workers through educational intervention. *Work* 2012;41 Suppl 1:2398-404. doi:10.3233/WOR-2012-0473-2398.

29. Hagel LM, Pickett W, Pahwa P, et al. Prevention of agricultural injuries: an evaluation of an education-based intervention. *Inj. Prev.* 2008;14(5):290-5. doi:10.1136/ip.2008.018515.

30. Kim J, Arrandale VH, Kudla I, Mardell K, Lougheed D, Holness DL. Educational intervention among farmers in a community health care setting. *Occup. Med. (Lond).* 2012;62(6):458-61. doi:10.1093/occmed/kqs129.

Appendix A: Power Calculations

Manuscript 1

The following tables: Confidence intervals for population proportions of musculoskeletal disorders based on participant group size.

n=2407

Proportion (p)	**Lower 95% Confidence Interval**	**Upper 95% Confidence Interval**
10%	9%	12%
20%	18%	22%
30%	28%	32%
40%	38%	42%
50%	48%	52%
60%	58%	62%
70%	68%	72%
80%	78%	82%
90%	89%	92%

n=1204

Proportion (p)	Lower 95% Confidence Interval	Upper 95% Confidence Interval
10%	9%	12%
20%	18%	22%
30%	28%	33%
40%	37%	43%
50%	47%	53%
60%	57%	63%
70%	67%	73%
80%	78%	82%
90%	88%	92%

n=602

Proportion (p)	Lower 95% Confidence Interval	Upper 95% Confidence Interval
10%	8%	12%
20%	17%	23%
30%	26%	34%
40%	36%	44%
50%	46%	54%
60%	56%	64%
70%	66%	74%
80%	77%	83%
90%	87%	95%

Manuscript 2

N exposed and n unexposed have been deflated from the estimated sample size of 2,400 by a conservative design effect of 1.2 to account for clustering.

Z =1.96 α=0.05 Power = $Z\beta\ [n(d^*)^2r / (r+1)p(1-p)]^{½} - Z_{\alpha/2}$

Table 6. Power calculations to detect differences in the highest and lowest exposure groups for both low back and shoulder MSD outcomes.

Variable Outcome	Risk Exposure	% exposed	% non-exposed	n exposed	n un - exposed	r	RR	p	d*
Low Back MSD	Lowest exposure	0.25	0.25	500	500	1	1.5	0.35	0.14
								POWER	99 %
Shoulder MSD	Lowest exposure	0.25	0.25	500	500	1	1.5	0.25	0.10
								POWER	91 %

Appendix B: Population Comparison

Table 13. Comparison of Farm Operators between SFIC sample, province of Saskatchewan, and Canada[1]

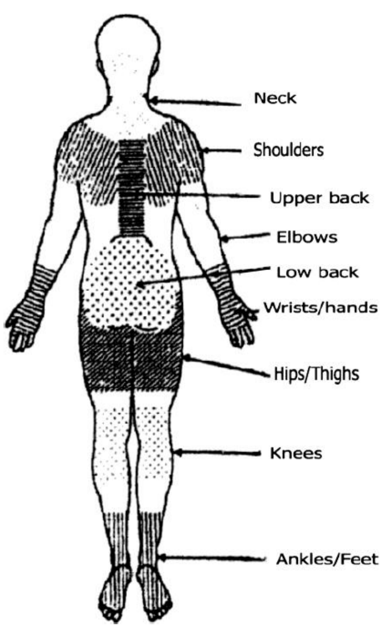
Farm Variable	SFIC sample	Saskatchewan	Canada[2]
Number of Operators	1,693	49,475	293,925
Total Male	1,227 (72%)	38,150 (77.1%)	213,265 (72.6%)
Total Female	466 (28%)	11,325 (22.9%)	80,665 (27.8%)
Age			
Average age	54.4	54.2	54.0
<35 years	327 (12.6%)	4,375 (8.8%)	24,120 (8.2%)
35-54 years	822 (31.68%)	20,700 (41.8%)	127,895 (43.5%)
≥55 years	1,446 (55.72%)	24,395 (49.3%)	141,920 (48.3%)
Total Number of Farms	1,193	36,953	205,730
Cattle Ranching	120 (10.1%)	7,455 (20.1%)	49,613 (24.1%)
Grain Farming	647 (54.2%)	22,195 (60.0%)	61,692 (29.9%)

[1] Data obtained from Canadian census 2011. [2] Excluding all territories.

Appendix C: Relevant Questionnaire Items

B-26	Lift, lower, or carry **heavy objects** (over 20lbs) more than 1 hour over the day?	_____
B-27	Use a **shovel or pitchfork** more than 1 hour over the day?	_____
B-28	Work with **hands over shoulder height** for more than 1 hour over the day?	_____
B-29	Operate **power tools** with the hands more than 1hour over the day?	_____

B-34



Have you at any time in the last 12 months had trouble (ache, pain, discomfort) in:		Have you at any time in the last 12 months been prevented from doing your normal work (at home or away from home) because of the trouble?
Neck	Yes 1☐ No 2☐	Yes 1☐ No 2☐
One or both shoulders	Yes 1☐ No 2☐	Yes 1☐ No 2☐
One or both elbows	Yes 1☐ No 2☐	Yes 1☐ No 2☐
One or both Hands	Yes 1☐ No 2☐	Yes 1☐ No 2☐
Upper Back	Yes 1☐ No 2☐	Yes 1☐ No 2☐
Lower Back	Yes 1☐ No 2☐	Yes 1☐ No 2☐
One or both hips/thighs	Yes 1☐ No 2☐	Yes 1☐ No 2☐
One or both knees	Yes 1☐ No 2☐	Yes 1☐ No 2☐
One or both ankles	Yes 1☐ No 2☐	Yes 1☐ No 2☐

Appendix D: Ethics Approval

QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD-DELEGATED REVIEW

August 20, 2013
Ms. Michelle McMillan
Department of Public Health Sciences
Queen's University
Dear Ms. McMillan
Study Title: EPID-438-13 Biomechanical exposures and work-related musculoskeletal disorders among Saskatchewan farmers
File # 6010669
Co-Investigators: Mrs. C. Trask, Dr. W. Pickett
I am writing to acknowledge receipt of your recent ethics submission. We have examined the protocol, SFIP Phase 2 questionnaire and the letter of information for your project (as stated above) and consider it to be ethically acceptable. This approval is valid for one year from the date of the Chair's signature below. This approval will be reported to the Research Ethics Board. Please attend carefully to the following listing of ethics requirements you must fulfill over the course of your study:
Reporting of Amendments: If there are any changes to your study (e.g. consent, protocol, study procedures, etc.), you must submit an amendment to the Research Ethics Board for approval. Please use event form: HSREB Multi-Use Amendment/Full Board Renewal Form associated with your post review file # **6010669** in your Researcher Portal (https://eservices.queensu.ca/romeo_researcher/)
Reporting of Serious Adverse Events: Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other serious adverse events must be reported within 15 days after becoming aware of the information. Serious Adverse Event forms are located with your postreview
file **6010669** in your Researcher Portal (https://eservices.queensu.ca/romeo_researcher/)
Reporting of Complaints: Any complaints made by participants or persons acting on behalf of participants must be reported to the Research Ethics Board within 7 days of becoming aware of the complaint. Note: All documents supplied to participants must have the contact information for the Research Ethics Board.
Annual Renewal: Prior to the expiration of your approval (which is one year from the date of the Chair's signature below), you will be reminded to submit your renewal form along with any new changes or amendments you wish to make to your study. If there have been no major changes to your protocol, your approval may be renewed for another year.
Yours sincerely,

Albert F. Clark

Chair, Health Sciences Research Ethics Board
August 20, 2013
Investigators please note that if your trial is registered by the sponsor, you must take responsibility to ensure that the registration information is accurate and complete

QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD

The membership of this Research Ethics Board complies with the membership requirements for Research Ethics Boards and operates in compliance with the Tri-Council Policy Statement; Part C Division 5 of the Food and Drug Regulations, OHRP, and U.S DHHS Code of Federal Regulations Title 45, Part 46 and carries out its functions in a manner consistent with Good Clinical Practices.

Federalwide Assurance Number: #FWA00004184, #IRB00001173

Current 2013 membership of the Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board:

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