MUSCULOSKELETAL SYMPTOMS AND EXPOSURE TO KNEE FLEXION AMONG DAIRY FARMERS

by

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PH.D. THESIS

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To my wife and kids; Jennifer, Jacob, Madeline and Maya

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ABSTRACT

Background: Dairy farmers have reported a high prevalence of musculoskeletal symptoms (MSS) and may have increased risk for knee osteoarthritis, according to Scandinavian studies. Work in stanchion milking facilities has been identified with excessive knee flexion, a risk factor for knee osteoarthritis. No study has investigated the prevalence of MSS or exposure to risk factors for knee osteoarthritis among U.S. dairy farmers. Dairy farmers in the U.S. work more hours than Scandinavian dairy farmers Hence, dairy farmers in the U.S. may have a greater risk for MSS compared to their Scandinavian counterparts.

Methods: Three studies were conducted. In study one and two, 813 dairy farmers were mailed questionnaires assessing demographic and farm exposure information, and complaints of MSS. Dairy farming practices such as type of milking facility (stanchion or parlor) and hours milking were examined for associations with reported MSS of the upper extremity in the first study, and the back and lower extremity in the second study. In the third study, knee flexion was recorded during both milking and feeding tasks for 23 dairy farmers who worked in stanchion or parlor milking facilities.

Results: For study one and two, the response rate was 44%. Low back and knee MSS were most prevalent at 67% and 60% respectively. Milking ≥1456 hrs per year was significantly associated with an increased risk for elbow MSS and a decreased risk for low back. In the third study, stanchion milking resulted in the most knee flexion exposure. Parlor feeding resulted in significantly more knee flexion exposure than parlor milking.

Conclusions: The results of these studies suggest that low back and knee MSS are highly prevalent among U.S. dairy farmers. Milking and cleaning animal stalls were identified as risk factors for MSS. Additionally, working in a stanchion milking facility resulted in more excessive knee flexion than parlor milking. The results of this study

could lead to future studies on interventions which may reduce MSS among dairy farmers.

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CHAPTER I

INTRODUCTION

Work-related musculoskeletal disorders (MSDs) have been identified as the leading cause of work disability, cost millions of dollars, and affect millions of people (NIAMS, 2000; NRC, 2001). Complaints of work-related musculoskeletal symptoms (MSS) and MSDs are common in the U.S. among workers in various industries, (NIOSH, 1997b; NRC, 2001) yet remain vastly understudied among U.S. agricultural workers (Anderson, Treuhaft, Pierce, & Horvath, 1989; Xiang, Stallones, & Keefe, 1999; Park, Sprince, Whitten, Burmeister, & Zwerling, 2001; Gomez et al., 2003).

Studies of agricultural workers in countries other than the U.S. have reported a high prevalence of MSS compared to workers in other industries (Croft, Coggon, Cruddas, & Cooper, 1992; Holmberg, Stiernstrom, Thelin, & Svardsudd, 2002; Holmberg, Thelin, Stiernstrom, & Svardsudd, 2003; Holmberg, Thelin, Stiernstrom, & Svardsudd, 2004; Stål, Moritz, Gustafsson, & Johnsson, 1996). Prevalence of MSS among dairy farmers in countries other than the U.S. has been reported as high as 80%, and milking and feeding tasks are among the most demanding tasks (Gustafsson, Pinzke, & Isbert, 1994; S. Pinzke, 2003). To our knowledge, no studies have evaluated prevalent MSS among U.S. dairy farmers. The lack of information is surprising considering dairy farmers in the U.S. work nearly 30% more hours per week compared to their Scandinavian counterparts (S. Pinzke, 2003; Pratt et al., 1992), and duration of exposure to physical risk factors associated with work tasks may increase the risk of developing MSS (NIOSH, 1997a). In addition, it is not known if associations exist between MSS of certain body sites and other dairy work factors such as type of milking operation (stanchion or parlor). Also, it is not known if dairy farmers suffering from MSS are restricted in their ability to perform activities of daily living (ADL).

Although information is lacking on prevalent MSS among U.S. dairy farmers, they have been identified as being at an increased risk of developing knee osteoarthritis (OA) compared to other farming groups and occupations (Anderson et al., 1989; Holmberg et al., 2002). Several physical risk factors associated with knee OA have been identified among agricultural work (Holmberg et al., 2003; N. Nevala-Puranen, Kallionpaa, & Ojanen, 1996). These factors include heavy lifting and frequent knee flexion exposures such as frequent knee bending, kneeling, squatting, and climbing (Anderson et al., 1989; Cooper, McAlindon, Coggon, Egger, & Dieppe, 1994; McAlindon, Wilson, Aliabadi, Weissman, & Felson, 1999; Vingård, Alfredsson, Goldie, & Hogstedt, 1991).

Activities that including knee bending, kneeling, squatting, and climbing are thought to generate peak knee torque forces (i.e. moment) and compressive forces which may contribute to the risk of knee OA (Dahlkvist, Mayo, & Seedhom, 1982; Escamilla, 2001; Felson, Goggins, Niu, Zhang, & Hunter, ; Felson et al., 1997; McAlindon et al., 1999; Nagura, Dyrby, Alexander, & Andriacchi, 2002; Reilly & Martens, 1972). Nevala-Puranen et al. (1996) identified physical risk factors for MSS such as awkward postures of the knee with cow milking. However, this study evaluated milking among Finnish farmers, and milking practices may differ substantially in the U.S. Additionally, Nevala-Puranen et al. (1996) used observation which is a less precise exposure assessment method than direct methods. Other exposure assessment methods such as direct methods, may more accurately estimate exposure to risk factors for lower extremity MSS among dairy farmers (Spielholz, Silverstein, Morgan, Checkoway, & Kaufman, 2001). Once risk factors for prevalent MSS among U.S. dairy farmers are identified, simple ergonomic interventions may reduce the prevalence and onset of MSS among dairy farmers.

The following is a review of the scientific literature related to the dairy farming process and to summarize current information related to musculoskeletal disorders research among dairy farming populations. The review will also provide the supporting background information for the research studies in this dissertation and allow for a more meaningful interpretation of the results related to MSS and knee flexion exposure among U.S. dairy farmers.

Specific topics that are reviewed include dairy farming, scope of the problem with MSDs, and costs associated with MSDs. Additionally, risk factors for MSDs, epidemiology of MSDs among agricultural workers, knee biomechanics, and methods for assessing exposure to physical risk factors for MSDs are reviewed.

Literature Review

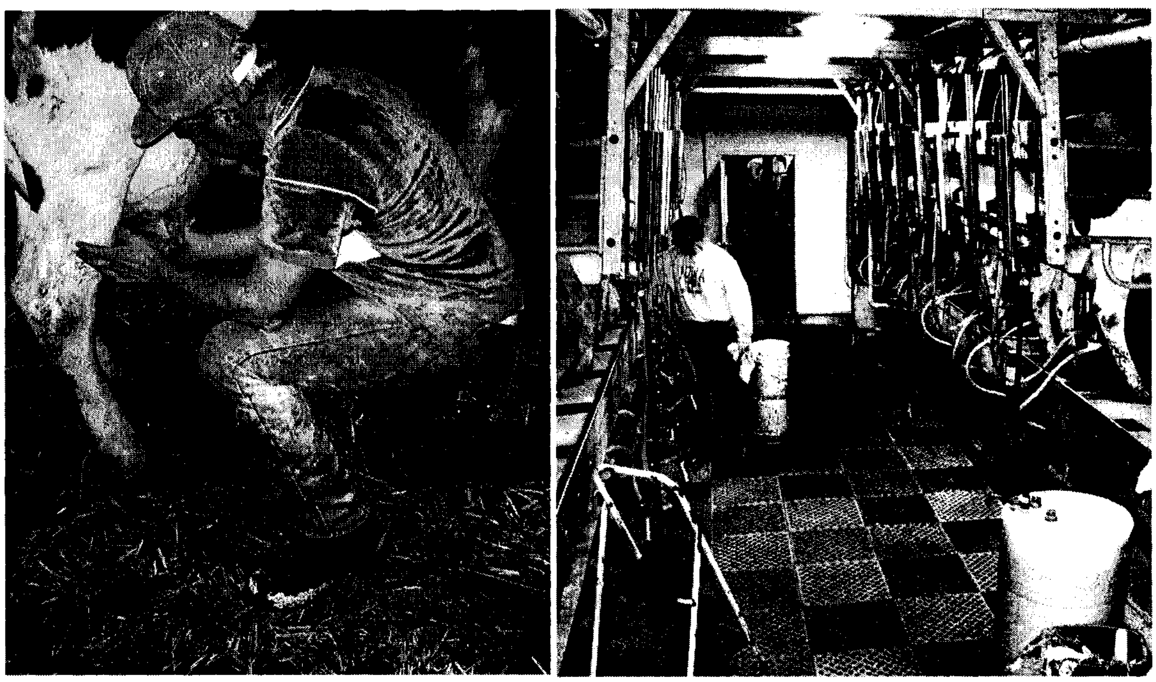
Dairy Farming

According to the United States Department of Agriculture (USDA), in 2004 there were 81,440 dairy farms in the United States (NASS, 2005). Milk production has increased 11% over the past ten years while the number of farms has decreased 45% (NASS, 2005). Thus, fewer dairy farmers are milking more cows, which may lead to more MSS. Dairy farming is common in Iowa and the state ranks 15th in U.S. dairy production (NASS, 2005).

Work on a dairy farm consists of seasonal work tasks (e.g. harvesting) and non-seasonal or daily work tasks. Two tasks that have been identified as non-seasonal or daily tasks are milking cows and feeding livestock (Tranel, L. 2004 personal communication). The time required to perform these daily tasks varies based on the number of milk cows (Tranel, L. 2004 personal communication). Dairy cows typically need to be milked two to three times per day, 365 days a year.

The feeding tasks on a dairy farm are highly variable, ranging from manually feeding cattle with hay bales and buckets, to using a conveyor system to deliver feed to the dairy cattle (Tranel, L. 2004 personal communication). The methods of feeding, (i.e. manual feeding or using a conveyor) are typically related to the type of milking facility on the farm. Two types of milking facilities are commonly used in dairy farms, the *stanchion* facility and the *parlor* facility. Typically, the more traditional stanchion milking facility requires more manual feeding techniques compared to a more modern parlor milking facility (Tranel, L. 2004 personal communication).

There are also differences in how the milking task is performed in stanchion and parlor milking facilities (Figure 1.1). Stanchion facilities require the cow and the milker to be at the same level, and the milking machine is carried from cow to cow. In most cases, the farmer must bend over and squat to milk the cow (Figure 1.1).



Stanchion Facility　　　　Parlor Facility

Figure 1.1 Milking in a Stanchion Facility and Milking in a Parlor Facility.

However, in a parlor facility, the cows are herded to fixed milking station, where the milker is in a pit below the cow (Figure 1.1). The parlor facility does not require the farmer to carry the milking machine and parlor work has been associated with fewer awkward postures compared to stanchion facilities (Nevala-Puranen et al., 1996). Although the parlor system is efficient and productive with lower labor costs, these systems are expensive to purchase. It may be the case that the expense precludes smaller farms from installing a parlor facility. Approximately 75% of the farms in Northeast Iowa have stanchion facilities (Tranel, L. 2004 personal communication). Hence, since awkward postures and more manual labor is associated with stanchion milking facilities, dairy farmers who utilize a stanchion milking facility may suffer from more MSS compared to farmers who use a parlor facility.

Work Related Musculoskeletal Disorders

Scope and Costs of Work Related MSDs

Work-related MSDs are prevalent among workers from various industries (NIOSH, 1997b; NRC, 2001). MSDs affect nearly 1 million people and account for approximately 130 million health care visits annually in the U.S. (NRC, 2001). The estimated workers compensation costs range from $13 – 20 billion annually (NRC, 2001). Conservative estimates of the direct costs of MSDs range from $45 – 54 billion annually, and the total economic burden of MSDs has been estimated at more than 3 times the direct cost (Baldwin, 2004; Coyte, Asche, Croxford, & Chan, 1998; NRC, 2001). These cost estimates are substantial, and preventing MSDs would reduce the cost of doing business in the U.S.

Farmers would benefit uniquely by preventing MSDs. For example, the prevention of debilitating MSS and MSDs such as low back or knee pain may allow self employed farmers to continue farming. If a farmer performs the majority of the tasks on the farm and experiences debilitating MSDs, the farmer may not be able to continue to work. Consequently, the farmer may have to stop farming altogether. Onset of debilitating MSS may force farmers to change work practices, by making a substantial investment in upgraded facilities (e.g. changing from a stanchion to a parlor milking facility) in order to continue farming.

Association Between Risk Factors and Musculoskeletal Disorders

There are three basic categories of risk factors for MSDs: 1) physical risk factors, 2) psychosocial risk factors and 3) individual risk factors. All of these factors are considered by researchers, ergonomists, and occupational safety and health professionals when evaluating work that may be hazardous to the musculoskeletal system.

Physical Risk Factors

The magnitude and duration of exposure to physical risk factors such as forceful exertions, awkward postures, repetition and vibration are considered when evaluating work that may be hazardous to the musculoskeletal system (NIOSH, 1997b). Some examples of physical risk factors include awkward postures, forceful exertions, repetition, static work and vibration exposure (NIOSH, 1997b). Motions requiring maximum upper extremity strength may be considered a forceful exertion, or jobs requiring similar body movements for prolonged period may be considered repetitive (NIOSH, 1997b). Additionally, holding an object over head for a period of time may be considered static work. Finally, an example of vibration exposure could be using a power tool for hand/arm vibration exposure or driving a tractor for whole body vibration exposure (NIOSH, 1997b).

Multiple physical risk factors have been identified for different body sites. For example, physical risk factors that have been associated with neck and shoulder MSDs include awkward postures, forceful exertions, static work, and vibration (Ariens, Bongers, Hoogendoorn, van der Wal, & van Mechelen, 2002; Ariens, van Mechelen, Bongers, Bouter, & van der Wal, 2000; NIOSH, 1997b). Additionally, physical risk factors such as static work (e.g. arm postures above shoulder level) have been identified with neck and shoulder MSS (Ekberg et al., 1994; Svendsen et al., 2004). Repetition, forceful exertions, and vibration have been associated with hand and arm MSS (NIOSH, 1997b).

Several physical risk factors have been associated with low back MSS and MSDs (Ferguson, Marras, & Burr, 2004; Guo, 2002; Marras et al., 1995; NIOSH, 1997b). Some physical risk factors for low back MSS include awkward postures (Guo, 2002), heavy lifting (Marras et al., 1995), and whole body vibration (Torèn, Öberg, Lembke, Enlund, & Rask-Andersen, 2002). Vibration and heavy lifting exposure have been identified as physical risk factors for hip MSS and hip OA (Bovenzi, 1996; Croft et al., 1992; Thelin, Jansson, Jacobsson, & Strom, 1997; Thelin, Vingård, & Holmberg, 2004).

Physical risk factors that have been identified for knee MSS include heavy lifting and awkward knee postures (Holmberg et al., 2003; McAlindon et al., 1999). Additionally, knee flexion exposures such as bending, kneeling, squatting, and climbing were identified as physical risk factors for knee OA (Anderson et al., 1989; Cooper et al., 1994; McAlindon et al., 1999; Vingård et al., 1991).

Physical risk factors for MSS and MSDs such as heavy lifting, awkward postures, repetition, and vibration have been identified among agricultural work (Allread, Wilkins, Waters, & Marras, 2004; Bovenzi, 1996; Croft et al., 1992; Holmberg et al., 2003; Holmberg et al., 2004; Stål, Hansson, & Moritz, 1999; Torèn et al., 2002; Xiang et al., 1999).

Psychosocial Risk Factors

Psychosocial risk factors such as depression and individual risk factors such as age and gender should be considered when evaluating associations between exposure to physical risk factors and MSDs (NIOSH, 1997b). Psychosocial risk factors that have been identified for upper extremity neck and low back MSS include depression, high job demands, low level of job stimulus and worry (Linton, 2005; NIOSH, 1997b; NRC, 2001). Little data is available on psychosocial risk factors for hip, knee or feet MSS. Limited information is available on psychosocial risk factors for MSDs among farmers. However, depression has been identified among farmers with back MSS (Xiang et al., 1999).

Individual Risk Factors

Individual risk factors that should be considered when evaluating associations between exposure to physical risk factors and MSS include age, gender, obesity, smoking and previous injury (Geoghegan, Clark, Bainbridge, Smith, & Hubbard, 2004; Manninen, Riihimaki, Heliovaara, & Makela, 1996; NIOSH, 1997b; NRC, 2001). Individual risk factors such as obesity and previous injury may also be present among farmers. Hence, all of these physical, psychosocial, and individual risk factors should be considered by occupational health and safety professionals when assessing risk for MSS and MSDs among farmers.

Epidemiology of Work Related Musculoskeletal Disorders and Musculoskeletal Symptoms Among Agricultural Workers

Work related MSDs and MSS are common in many industries, and are highly prevalent among agricultural workers in countries other than the U.S. (Table 1.1) (Anderson et al., 1989; Bovenzi, 1996; Croft et al., 1992; Gomez et al., 2003; Gustafsson et al., 1994; Holmberg et al., 2002; Holmberg et al., 2003; Holmberg et al., 2004; Lower, Fuller, & Tonge, 1996; NRC, 2001; Park et al., 2001; S. Pinzke, 2003; Stål et al., 1996; Thelin, 1990; Thelin et al., 1997; Thelin et al., 2004; Torèn et al., 2002; Xiang et al., 1999). However, few studies are available that examine MSDs and MSS among U.S. agricultural workers (Anderson et al., 1989; Gomez et al., 2003; Park et al., 2001; Xiang et al., 1999). Consequently, the National Institute for Occupational Safety and Health (NIOSH) has designated research of MSDs among agricultural workers a priority of the

National Occupational Research Agenda (NIOSH, 2005). MSS may be prevalent among U.S. agricultural considering farm work involves exposure to physical risk factors that are known to be associated with MSDs, such as awkward postures, repetition, forceful exertions, and vibration exposure from tractors and power tools (Allread et al., 2004; Bovenzi, 1996; Gomez et al., 2003; Lower et al., 1996; Lundqvist, Stål, & Pinzke, 1997; Nevala-Puranen et al., 1996; Perkiö-Mäkelä & H, 2005; S. Pinzke, Stal, & Hansson, 2001; Stål, Pinzke, Hansson, & Kolstrup, 2003; Thelin et al., 2004).

Table 1.1 Reported 12 Month Period Prevalence of MSS Among Workers From Various Industries.

	Anton et al. 2002	Gustafsson et al. 1994	Merlino et al. 2003	Pinzke et al. 2003	Stål et al. 1996
Industry	Dental Hygienists	Male Dairy Farmers	Construction	Male Dairy Farmers	Female Cow Milkers
Wrist /Hand (%)	70	18	42	24	58*
Elbow (%)	21	18	16	20	–
Shoulder (%)	60	37	28	44	50
Neck (%)	69	25	32	31	57
Upper Back (%)	67	12	27	12	–
Low Back (%)	57	55	54	54	–
Hip (%)	19	23	9	28	–
Knee (%)	14	41	38	38	–
Feet (%)	16	13	23	14	–

* included elbow MSS

Among agricultural workers, dairy farmers have been identified as having a high prevalence of low back and knee MSS, and having a higher risk of developing knee OA compared to other occupations (Anderson et al., 1989; Gomez et al., 2003; Gustafsson et al., 1994; Holmberg et al., 2002). Additionally, dairy farmers have been reported to have the second highest prevalence of work-related injuries, with involvement of the musculoskeletal system reported most common (Boyle et al., 1997; Crawford et al., 1998; NIOSH, 1993). Although previous studies have not specifically focused on MSDs, the majority of injuries occurred while working closely with dairy cattle (i.e. milking) (Boyle et al., 1997; Pratt et al., 1992; Waller, 1992). Several studies have reported a high prevalence of MSS and MSDs among dairy farmers in Scandinavia and Australia (Gustafsson et al., 1994; Lower et al., 1996; S. Pinzke, 2003; Stål et al., 1996), but research on MSS and MSDs among U.S. dairy farmers is limited.

Although U.S. dairy farmers may have comparable frequencies of MSS, the results from Scandinavia cannot be extrapolated directly to the U.S. dairy industry. Dairy farmers in the U.S. work more hours per week compared to their Scandinavian dairy farmers (S. Pinzke, 2003; Pratt et al., 1992), and duration of exposure to tasks such as milking or feeding may increase the risk of developing MSS (NIOSH, 1997a). Considerably more cattle are milked in the U.S. than in Scandinavian countries. For example, the number of dairy cattle in the State of Iowa alone is more than half of the number milked in all of Sweden (Sweden, 2003). Many dairy farms are much larger in the U.S. as well, and previous studies have indicated that larger farms are associated with increased risk of injury (Crawford et al., 1998; Pratt et al., 1992; Stallones, Pratt, & May, 1986). Additionally, the milking processes used in the U.S. may not be equivalent to methods used in other countries. The cultural differences, greater number of cattle, larger farms, and different milking methods in the U.S. make comparisons to previous literature difficult.

To date, there have been only four published studies of MSDs among U.S. agricultural workers (Gomez et al., 2003; Park et al., 2001; Xiang et al., 1999), and only one study has focused specifically on knee OA among farmers (Anderson et al., 1989). Anderson et al. (1989) found a more cases of knee OA among farmers compared to blue and white collar workers. Farmers were identified as having and increased risk of knee OA compared to non-farmers (OR= 4.30; $p = 0.0001$). A large proportion of farmers in this study were identified as dairy farmers (74%). The results of this study suggest that dairy farmers may be at an increased risk for knee OA compared to white and blue collar workers. However, dairy farming may be the dominant type of farm production in the area, so it is unclear if the increased in risk for knee OA is a result of dairy farming practices.

Gomez et al. (2003) assessed prevalent MSS among farmers and found low back MSS to be most prevalent at 41%, closely followed by knee MSS at 29%. Risk factors that were identified as being statistically significant for low back MSS were being an owner/operator ($OR_{Adj} = 1.37$; 95% CI = 1.08–1.74), and tractor work ($OR_{Adj} = 1.51$; 95% CI = 1.20–1.89) (Gomez et al., 2003). Additionally, Gomez et al. identified milking ($OR_{Adj} = 1.38$; 95% CI = 1.09–1.74), and tractor work ($OR_{Adj} = 1.52$; 95% CI = 1.21–1.91) as being statistically associated with knee MSS. Gomez et al. did not specifically focus on dairy farmers, but farmers who specialized in dairy production were the largest proportion of the study sample (56%). Also, the investigators found tractor use to be significantly associated with an increased risk of MSS for all body sites (hand/wrist, neck/shoulder, low back, hip and knee). Association of MSS in any body site with tractor use indicates there may be exposure to a particular physical risk factor (e.g. vibration) during tractor use. However, tractor use may also be a variable that represents some other exposure that has an impact on musculoskeletal health, but was not considered (e.g. hours baling hay).

The two remaining studies evaluated back MSS among U.S. agricultural workers (Park et al., 2001; Xiang et al., 1999). Both of these studies reported fairly low level of prevalent back MSS compared to previously published studies among agricultural workers (26-31%). This is not surprising considering the definition of back pain used in these studies was more conservative than has been previously used on studies of low back MSS among agricultural workers. Park et al. (2001) reported no statistically significant risk factors associated with LBP. However Xiang et al. (1999) reported depression (OR_{Adj} = 3.68; 95% CI = 2.23–6.09), farming activities (OR_{Adj} = 1.66; 95% CI = 1.17–2.36) and working in agriculture for 10 – 29 years (OR_{Adj} = 1.62; 95% CI = 1.14–2.30) as statistically significant risk factors for back MSS.

The current lack of information on risk factors for prevalent MSS and MSDs among U.S. dairy farmers is surprising considering the reported high prevalence of MSS and MSDs among dairy farmers in other countries. Several studies have identified dairy farmers as being at an increased risk for knee OA, but these studies are based on self report exposure data (Manninen, Heliovaara, Riihimaki, & Suoma-Iainen, 2002; Sandmark, Hogstedt, & Vingard, 2000; Vingård et al., 1991). Other exposure assessment techniques such as direct methods may provide more accurate estimate of exposure to physical risk factors for knee OA (Spielholz et al., 2001). Limited information exists on exposure to physical risk factors for knee MSS and knee OA among dairy farmers, and no study of which the authors are aware has assessed exposure to physical risk factors for knee MSS among U.S. dairy farmers.

Knee Biomechanics

Mechanical forces such as knee moment and patellofemoral compressive forces are thought to contribute to the development of knee OA (Felson et al., 1997). Existing literature on knee moment and patellofemoral compressive forces generated during the squatting and the sit-to-stand motion were reviewed. Squatting was thought to represent occupational activities that occur on a dairy farm, such as milking and feeding. The sit-to-stand activity was chosen as a benchmark for exposure to knee forces because rising from a chair is a normal activity and is performed daily.

Maximum knee moments calculated by Nagura et al. (2002) for a double leg descend revealed that the minimum knee flexion posture from which a maximum knee moment was observed was approximately 110°. The maximum flexion posture from which a maximum knee moment was observed was approximately 155°. Additionally, peak patellofemoral compressive forces have been estimated at about 120° knee flexion during squatting (Dahlkvist et al., 1982; Reilly & Martens, 1972).

Another investigator has reported a decreased patellofemoral contact area for postures of near maximum knee flexion compared to 90° knee flexion (Nakagawa et al., 2003). This decreased contact area may result in the mechanical forces on the knee being focused on a small area in the knee joint, which could result in knee pathology. Currently, it is unknown what magnitude of exposure to knee moment and/or patellofemoral compressive forces result in knee pathology (Escamilla, 2001). However, knee flexion beyond 110° appears to represent peak moments and compressive forces on the knee, which may be a physical risk factor for the initiation and progression of knee OA.

A review of the estimated the peak knee moments generated during the sit-to-stand activity revealed that knee postures beyond 70° should represent knee moments that are above what occurs from normal daily activities such as the sit-to-stand motion (Rodosky, Andriacchi, & Andersson, 1989). Rodosky et al. (1989) used the exact same method to determine knee moment as Nagura et al. (2002). Comparing the results of Rodosky et al. (1989) to Nagura et al. (2002), the equivalent peak knee moment for the sit-to-stand activity was generated at a knee posture of approximately 70° flexion during a squatting.

Methods of Assessing Exposure to Physical Risk Factors for Work Related Musculoskeletal Disorders and Musculoskeletal Symptoms

It is difficult to determine the association of risk factors for developing MSS and MSDs among workers without having an accurate, and valid, measure of those risk factors (Spielholz et al., 2001). There are three methods commonly used to assess exposure to risk factors for MSDs self-report, observational, and direct methods (Burdorf & van der Beek, 1999; Riihimaki, 1999; Spielholz et al., 2001).

Self Report

As self report implies, this method uses information about exposure that is provided by the individual (Burdorf & van der Beek, 1999; Zhang et al., 2004). This self report method is commonly used in epidemiological studies of MSDs (Burdorf & van der Beek, 1999; Sahlstrom & Montgomery, 1997; Zhang et al., 2004). Self report exposure data is easily collected on a large number of subjects, and is relatively inexpensive to collect compared to other methods (Kilbom, 1994). An example of data that can be collected using self report methods may be hours spent milking cows per day.

Data collected using self report varies in precision and accuracy. A major weakness of self report data is the potential for systematic bias and lack of precision (Burdorf, 1995; Burdorf & van der Beek, 1999; Riihimaki, 1999). Self report has been the primary exposure assessment technique used for research of MSS and MSDs among agricultural workers (Anderson et al., 1989; Bovenzi, 1996; Gustafsson et al., 1994; Holmberg et al., 2003; Lower et al., 1996; Park et al., 2001; S. Pinzke, 2003; Stål & Englund, 2005; Stål et al., 1996; Torèn et al., 2002; Xiang et al., 1999).

Observational Methods

Compared to self report, observational methods provide better information about exposure to risk factors for MSDs among workers (Burdorf & van der Beek, 1999;

Riihimaki, 1999; Spielholz et al., 2001). An example of an observational method would be a researcher observing a farmer performing work, and periodically recording some element of posture. This series of observations may then be evaluated to identify common postures that occur while performing a specific task. Observational methods range from a simple posture checklist such as the Ovako Working posture Analysis System (OWAS) (Karhu, Kansi, & Kuorinka, 1977) to a more technical video-based observation (VBO) method (Yen & Radwin, 2002).

OWAS has been used to assess awkward postures in agricultural populations (Karhu et al., 1977; Lundqvist et al., 1997; Nevala-Puranen et al., 1996; N. Nevala-Puranen, Taattola, & Venäläinen, 1993; Perkiö-Mäkelä & H, 2005). Specifically, OWAS allows the observer to categorize work postures of the upper extremities, back, and lower extremities into categories of urgency. For example, postures observed may be categorized as "needs attention immediately" or "no change required (Karhu et al., 1977)." The result is a form of postural triage, which allows the identification of the most urgent ergonomic problems.

OWAS is simple and easy to use, however the method lacks several key components of exposure assessment that are necessary to accurately determine exposure to risk factors for MSDs (Kilbom, 1994). For example, OWAS does not allow for evaluation of the intensity or duration of the exposure, which are important in determining risk for MSDs (NIOSH, 1997a, , 1997b; NRC, 2001).

Video-based observation methods (VBO) provide more detailed information such as frequency, intensity, and duration of awkward postures, compared to observational methods (Spielholz et al., 2001). VBO provides a more accurate measures estimate of exposure to risk factors for MSDs compared to postural checklists, and self report data (Spielholz et al., 2001). VBO methods are simple, easy to use, and exposure information can be collected inexpensively compared to direct methods (Kilbom, 1994). However, lack of precision exists when using VBO methods and the quality of data generated is in many cases dependent on the camera angle. Error may be introduced by estimating exposure using a camera angle that does not capture the joint motion (Kilbom, 1994; Spielholz et al., 2001). To eliminate this error in observation, direct methods such as electrogoniometry can be used which constantly record joint position when observational methods may not be possible.

Direct Methods

Direct methods are considered the most accurate measure for assessing exposure to risk factors for MSDs (Kilbom, 1994). Direct methods are usually methodologically complex highly technical, and involve considerable expense and expertise when used to measure exposure to physical risk factors (Burdorf & van der Beek, 1999; Kilbom, 1994). Additionally, direct methods are often more accurate and precise than self report and observational methods (Juul-Kristensen, Hansson, Fallentin, Andersen, & Ekdahl, 2001; Kilbom, 1994).

Several studies have compared the accuracy and validity of self report and observational exposure assessment methods to direct ergonomic exposure assessment methods (Burdorf, 1992; Juul-Kristensen et al., 2001; Ketola, Toivonen, & Viikari-Juntura, 2001; Lowe, 2004a, , 2004b; Spielholz et al., 2001). These studies have established that uncertainty exists about the accuracy and validity of using observational methods for exposure assessment to risk factors for MSDs of the upper extremities, neck, and trunk. Consequently, exposure assessment methods must be chosen carefully, taking into account the required accuracy of the data, the validity of results, and resources available (Kilbom, 1994). To date, few studies have evaluated exposure to physical risk factors for MSS and MSDs among agricultural workers using direct methods (Allread et al., 2004; Arborelius, Ekholm, Nisell, Nemeth, & Svensson, 1986; Nemeth, Arborelius, Svendsen, & Nisell, 1990; S. Pinzke et al., 2001; Stål et al., 1999; Stål et al., 2003; Svensson, Ekholm, Arborelius, Nisell, & Nemeth, 1985).

Self Report Methods for Assessing Work Related

Musculoskeletal and Disability

Accurately and inexpensively assessing MSS can be challenging. Self report standardized questionnaires that are commonly used in research of MSS and MSDs include generic measures of MSS (e.g. Modified Nordic), regional measures of MSS (e.g. Disorders of the Arm Shoulder and Hand (DASH)), and joint specific measures of MSS (e.g. Oswestry) (Beaton et al., 2001). Self report postal questionnaires are easy to use and allow researchers to collect a large amount of data with , but often result in systematic bias and lack precision (Burdorf, 1995; Burdorf & van der Beek, 1999; Riihimaki, 1999).

Modified Nordic questionnaire

The Modified Nordic questionnaire has been commonly used to assess MSS among various working populations (Anton, Rosecrance, Merlino, & Cook, 2002; Gustafsson et al., 1994; Holmström & Engholm, 2003; Kuorinka et al., 1987; Merlino, Rosecrance, Anton, & Cook, 2003; Morken et al., 2003; J. C. Rosecrance, Ketchen, Merlino, Anton, & Cook, 2002), and has good test-retest reliability (Kuorinka et al., 1987). The Modified Nordic Questionnaire is used to assess the reported 12-month period prevalence of MSS in the: 1) wrist/hand, 2) elbow, 3) shoulder, 4) neck, 5) upper back, 6) low back, 7) hip, 8) knee, and 9) feet. Respondents are also asked if the MSS they experience resulted in a loss of work time or from a previous injury and if health care was obtained as a result of the MSS. All responses are a dichotomous format (yes or no) (Appendix A).

Disorders of the Arm, Shoulder and Hand (DASH)

The DASH is a region specific questionnaire which consists of 30 questions addressing the impact of the upper extremity MSS on activities of daily living (Hudak, Amadio, & Bombardier, 1996) (Appendix A). The DASH questionnaire has been validated in several studies for use to evaluate complaints of upper extremity pain (Beaton et al., 2001; Hunsaker, Cioffi, Amadio, Wright, & Caughlin, 2002; SooHoo, McDonald, Seiler, & McGillivary, 2002).

The DASH is used to obtain information about the participant's ability to perform specific tasks such as writing or pushing open a heavy door, as well as the severity of upper-extremity symptoms experienced during the week prior to completing the questionnaire. Each question has five possible responses, which are scored from one to five. The score of five indicates the worst outcome for each question. For example, a dairy farmer who had extreme shoulder pain in the past week may indicate a five for that question. There are 30 questions on the DASH, and the possible range of a DASH score is 0 – 100.

There are no recommendations for what DASH score constitutes disability, although several studies have reported mean scores ranging from 30 – 50 for patients undergoing medical treatment for upper-extremity disorders (Beaton et al., 2001; Gummesson, Atroshi, & Ekdahl, 2003; Navsarikar, Gladman, Husted, & Cook, 1999; SooHoo et al., 2002).

Oswestry Disability Index

The Oswestry Disability Index questionnaire was developed to assess the impact of low back pain on the subject's daily activities (Fairbank, Couper, Davies, & O'Brien, 1980) (Appendix A). The Oswestry is a one-page questionnaire that consists of 10 questions about daily living that may be affected by low back pain, such as lifting ability, sitting, and social activities. Each question has six possible responses ranked 0 – 5, with 0 indicating no difficulty performing activity, and 5 indicating the low back symptoms are preventing the participant from doing the activity. The Oswestry Disability Index has a range of scores from 0 – 100, with an increasing score indicating increasing disability.

The Oswestry Disability Index score indicates the extent to which the subject's functional ability is restricted by low back symptoms. A score of 0 – 20 indicates minimal disability, 20 – 40 modest disability, 40 – 60 severe disability, and > 60 severe disability by low back symptoms in several aspects of life (Fairbank et al., 1980). The Oswestry questionnaire has been used extensively over the last 20 years, and has been reported as an accurate and valid measure of a participant's functional ability in many studies (Davidson & Keating, 2002; Deyo et al., 1994; Suarez-Almazor, Kendall, Johnson, Skeith, & Vincent, 2000). The Oswestry has been reported to have good test-retest reliability, and has been used by previous researchers as a self report postal questionnaire (Holm, Friis, Storheim, & Brox, 2003).

Western Ontario and McMaster Universities Osteoarthritis Index

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC VA 3.0) has been used to assess impact of knee MSS on daily activities and is commonly used to determine if knee MSS has improved after medical treatment (Appendix A). For example, a patient undergoing a knee replacement may complete the WOMAC before and after knee surgery. Pre and post surgical scores would then be compared for differences as and indication of the effectiveness (i.e. decreased knee MSS) of the treatment. The WOMAC consists of three sections addressing pain (questions 0 – 5), stiffness (questions 6 – 7), and physical function (questions 8 – 24) of the knee, for a total of 24 questions (Bellamy, Buchanan, Goldsmith, Campbell, & Stitt, 1988). Participants mark a visual analog scale of 10 cm in length with terminal descriptors of "*None*" and "*Extreme.*" The subject is asked to place an "*x*" on the line to indicate the amount pain, stiffness or difficulty they have performing a specific task. The total WOMAC score is calculated by summing the scores from each section for a section score, and combining all the scores for an aggregate score (0 – 2400). An increasing WOMAC score indicates increasing disability due to knee MSS.

The WOMAC has been used in population studies to assess the impact of knee osteoarthritis and disability (Jinks, Jordan, & Croft, 2002). There are no recommendations for what score constitutes disability. Previous researchers have used the median aggregate score as an arbitrary boundary for disability (O'Reilly, Muir, & Doherty, 1998), or classified anyone who scored "Extreme" or "Severe" on any question using a Likert version of the WOMAC as having disability (Jinks et al., 2002).

Physical Risk Factors Associated With Dairy Farm Work

Some information exists on the biomechanics, muscle activity, physical load, and awkward postures of workers during dairy farm tasks (Ahonen, Venalainen, Kononen, & Klen, 1990; Arborelius et al., 1986; Ekholm, Nisell, Arborelius, Svensson, & Nemeth, 1985; Lundqvist et al., 1997; Nemeth et al., 1990; Nevala-Puranen et al., 1996; Nevala-Puranen et al., 1993; Perkiö-Mäkelä & H, 2005; Stål et al., 1999; Stål et al., 1996; Stål et al., 2003; Svensson et al., 1985). However, information on exposure to physical risk factors for lower extremity MSS and MSDs is limited. Ekholm et al. (1985) evaluated the load on the knee joint for various postures during simulated milking, and found that a knee posture with a 108° knee flexion produced the highest knee loading moment. Nevala-Puranen et al. (1996) reported that stanchion milkers were in flexed knee postures for 32% of the working time. However, parlor milkers spend about 2% of the time in flexed knee postures (Nevala-Puranen et al., 1996; Perkiö-Mäkelä & H, 2005). Clearly, workers who use stanchion milking facilities utilize different postures for the lower extremity to complete the work. Again, these studies were done on Scandinavian dairy farmers, and dairy farm tasks may be quite different than the tasks performed by U.S. dairy farmers. Hence, evaluating exposure to physical risk factors for lower extremity MSS among U.S. dairy farmers is important so that methods can be developed to reduce exposure to physical risk factors for lower extremity MSS.

Conclusion

This dissertation is aimed to provide background information on associations between exposures and prevalent MSS among dairy farmers. Additionally, this dissertation is aimed to provide estimates of exposure to physical risk factors for knee MSS. Preventing MSDs occurs by identifying potential risk factors for prevalent MSDs, determining exposure to these risk factors, and finally developing interventions to prevent exposure to risk factors for MSDs.

There are three research projects contained in this dissertation: 1) determining risk factors for prevalent MSS of the neck and upper extremity among dairy farmers, 2) determining risk factors for prevalent MSS of the back and lower extremity among dairy farmers, and 3) assessing knee flexion exposure among dairy farmers. These studies are contained in Chapters 2, 3, and 4. Chapter 5 is a discussion of how the conclusions of each paper add to the scientific knowledge about exposure to risk factors for prevalent MSS among U.S. dairy farmers. The final Chapter will also discuss the potential for future research.

The specific aims of Chapters 2, 3, and 4 are:

1) Evaluate the association between work-related factors and personal factors with prevalent musculoskeletal symptoms of the neck, shoulder, elbow and wrist/hand among U.S. dairy farmers.
2) Evaluate the association between work-related factors and personal factors with prevalent musculoskeletal symptoms of the neck, shoulder, elbow and wrist/hand among U.S. dairy farmers.
3) Compare the knee flexion exposure among dairy farmers who work in stanchion and parlor milking facilities while performing milking and feeding tasks.

CHAPTER II

RISK FACTORS FOR PREVALENT MUSCULOSKELETAL SYMPTOMS OF THE NECK AND UPPER EXTREMITIES AMONG IOWA DAIRY FARMERS

Abstract

Background: Several studies have estimated the prevalence of musculoskeletal symptoms among Scandinavian dairy farmers. No study has investigated the prevalence of musculoskeletal symptoms among U.S. dairy farmers. The purpose of this study is to evaluate the association between work-related factors and personal factors with prevalent musculoskeletal symptoms of the neck, shoulder, elbow and wrist/hand among U.S. dairy farmers.

Methods: 813 randomly selected Iowa dairy farms were mailed questionnaires assessing demographic and farm exposure information, in addition to information on musculoskeletal symptoms (neck, shoulder, elbow, and wrist/hand) and musculoskeletal disability. In an enclosed letter, the investigators asked that the individual who performs the majority of the milking, complete the questionnaires. Exposures specific to dairy farming such as type of milking facility (stanchion or parlor) and hours milking per year were examined for associations with prevalent MSS before and after adjusting for relevant covariates.

Results: Three hundred and forty one (44%) dairy farmers responded to the questionnaire. Shoulder musculoskeletal symptoms were most prevalent at 54%. Hours milking per year was significantly associated with an increased risk of elbow musculoskeletal symptoms (OR_{Adj}=2.24; 95% CI = 1.00–5.02). Additionally, manually cleaning animal stall (hours per year) was significantly associated with wrist/hand musculoskeletal symptoms (OR_{Adj}=1.96; 95% CI = 1.05–3.68).

Conclusions: Musculoskeletal symptoms of the neck and upper extremity were common among Iowa dairy farmers. Some of these symptoms were associated with common dairy farming practices. Future studies need to more accurately assess exposures to physical risk factors for neck and upper extremity musculoskeletal symptoms so that ergonomic interventions can be developed.

Background and Significance

Work-related musculoskeletal disorders (MSDs) afflict millions, cause substantial pain and disability, and cost the U.S. economy billions of dollars (NIAMS). Musculoskeletal disorders are prevalent among workers from many industries, nationally and internationally (NIOSH, 1997b; NRC, 2001).

Work related MSDs and musculoskeletal symptoms (MSS) have been reported widely among agricultural workers worldwide (Bovenzi, 1996; Croft et al., 1992; Gustafsson et al., 1994; Holmberg et al., 2002; Holmberg et al., 2003; Holmberg et al., 2004; Lower et al., 1996; S. Pinzke, 2003; Stål & Englund, ; Stål et al., 1996; Torèn et al., 2002). However, few studies are available that examine MSDs and MSS among U.S. agricultural workers (Anderson et al., 1989; Gomez et al., 2003; Park et al., 2001; Xiang et al., 1999). Consequently, the National Institute for Occupational Safety and Health has designated research of MSDs among agricultural workers a priority of the National Occupational Research Agenda (NIOSH, 2005). The lack of study of U.S. farm workers is surprising considering farm work involves exposure to physical risk factors that are known to be associated with MSDs, such as heavy lifting, bending, squatting, twisting posture, repetition, forceful exertions, and vibration exposure. (Allread et al., 2004; Bovenzi, 1996; Gomez et al., 2003; Lower et al., 1996; Lundqvist et al., 1997; Nevala-Puranen et al., 1996; Perkiö-Mäkelä & H, 2005; S. Pinzke et al., 2001; Stål et al., 2003; Thelin et al., 2004).

Of all agricultural work groups, dairy farmers have been reported to have the second highest prevalence of work-related injuries with involvement of the musculoskeletal system reported most frequently (Boyle et al., 1997; Crawford et al., 1998; NIOSH, 1993). Although previous studies have not specifically focused on MSDs, the majority of these injuries occurred while working closely with dairy cattle (e.g. milking) (Boyle et al., 1997; Pratt et al., 1992; Waller, 1992). Several studies have reported prevalent MSS and MSDs among dairy farmers in Scandinavia and Australia (Gustafsson et al., 1994; Lower et al., 1996; S. Pinzke, 2003; Stål et al., 1996). Scandinavian studies estimate that over 80% of dairy farmers have MSS, with milking and feeding tasks being the most physically demanding (Gustafsson et al., 1994; S. Pinzke, ; Stål et al., 1996). However, research on MSS and MSDs among U.S. dairy farmers is limited.

Only one study has evaluated MSS of the neck and upper extremity among farmers in the U.S. (Gomez et al., 2003). Using telephone interviews, Gomez et al. (2003) evaluated MSS in five body locations (low back, neck/shoulders, hips, knees and wrist/hands). Low back MSS was the most prevalent symptom (41%) followed by neck/shoulder symptoms (35%). The study did not focus solely on dairy farmers, although dairy farmers were the largest proportion of the study sample (56%). The investigators found an increased risk for MSS in all five body sites among participants who did tractor work and an increased risk for knee MSS (OR=1.38; 95% CI 1.1-1.7) among those who milked cows.

In the U.S., fewer dairy farmers are producing more milk which may adversely affect their musculoskeletal health. Milk production in the U.S. has increased 11% over the past ten years while the number of farms has decreased 45% (NASS, 2005).

Dairy farming is common in Iowa and the state ranks 15th in U.S. dairy production (NASS, 2005). Approximately 2600 dairy farms are found in Iowa with herd sizes varying from one cow to several hundred. A majority of Iowa dairy farms have small to moderate herd sizes of less than 100 head, with an average of 75 cows (NASS, 2005). In comparison, the average herd size in Sweden is about 30 head (MDC, 2003). Dairy cows are milked two to three times a day, 365 days a year.

Two types of milking facilities are commonly used in dairy farms: the stanchion facility and the parlor facility. Stanchion facility requires the milking machine to be carried from cow to cow, with the cow and the milker standing at the same level. Typically, the farmer must bend over and squat to milk the cow. In a parlor facility, the cows are herded to fixed milking station, where the milker is in a pit below the cow. The parlor facility does not require the farmer to carry the milking machine and parlor work has been associated with fewer awkward postures compared to stanchion facilities (Nevala-Puranen et al., 1996). Although the parlor system is efficient and productive with lower labor costs, these systems are expensive to purchase. Approximately 75% of the farms in Northeast Iowa have stanchion facilities (Tranel, L. 2004 personal communication).

Identifying risk factors for prevalent MSS and MSDs among the dairy farming population is important so that interventions designed to reduce risk can be developed and implemented. Therefore, the *purpose of this study* is to examine associations between exposure to dairy farming tasks and prevalent MSS of the neck and upper extremity.

Methods

Study Sample

Dairy farmers from five counties in Northeast Iowa (Dubuque, Clayton, Winneshiek, Delaware, and Allamakee) were recruited to participate in this cross-sectional study. These five counties represent about half of the total dairy farms in the state of Iowa (1,706 farms) (NASS, 2005). Potential participants were identified from a list of dairy farm owner/operators provided by the Iowa Department of Agriculture and

Land Stewardship (IDALS) (IDALS, 2003). From this list, 813 dairy farms comprising approximately 50% of the total dairy farms in the five counties were randomly sampled in proportion to the number of farms of each county. Letters were addressed to the selected dairy farms or dairy farmers who were present on the IDLS list asking that the individual who performed the majority of the milking tasks participate in the study. The investigators obtained University of Iowa Institutional Review Board approval prior to all contact.

Data Collection Instruments

Four self administered questionnaires were used in this study: 1) a demographic questionnaire, 2) a farm exposure questionnaire, 3) the Modified Nordic questionnaire, and 4) the Disorders of the Arm, Shoulder, and Hand (DASH) (Hudak et al., 1996; Kuorinka et al., 1987).

Demographic questionnaire. The demographic questionnaire was used to collect information on covariates including: age, gender, body mass index (BMI), and smoking status.

Farm questionnaire. The farm questionnaire was used to assess farm exposure information (Appendix A). Farm exposure information that was obtained included years working in a dairy facility, hours worked per day, days worked per week, weeks worked per year and type of milking facility used (i.e., stanchion or parlor). Participants were asked to report the amount of time they spent performing specific tasks such as milking, tractor driving, manual feeding, carrying/lifting ≥23 kg, and artificial insemination.

Participants were also asked to report the commodities produced on their farms as a percentage of their total farm production (e.g., 90% milk, 10% grain). The distribution of commodities produced was used as an indicator of the major farming activity that occurred on each farm. Additionally, information was collected on any current employment which included occupations other than dairy farming. Participants were asked how much they worked at their other occupation (hours per week and weeks per year), and what activities they performed at their other occupation (e.g. operate heavy equipment, lift boxes, computer work).

Modified Nordic Questionnaire. Musculoskeletal symptoms were assessed using the Modified Nordic Questionnaire (Kuorinka et al., 1987) (Appendix A). This questionnaire has been widely used by previous investigators and has good test-retest reliability (Anton et al., 2002; Gustafsson et al., 1994; Holmström & Engholm, 2003; Merlino et al., 2003; Morken et al., 2003; J. C. Rosecrance et al., 2002). In this study, the Modified Nordic Questionnaire was used to collect the 12-month period prevalence of MSS in the following areas: 1) neck, 2) shoulder, 3) elbow, and 4) wrist/hand. Each of the four outcome variables were obtained in a dichotomous response format (yes or no).

Disorders of the Arm, Shoulder and Hand. The Disorders of the Arm, Shoulder and Hand (DASH) is a region specific questionnaire of 30 questions addressing the impact on daily living of the upper extremity condition (Hudak et al., 1996). Participants who reported upper extremity MSS on the Modified Nordic questionnaire completed DASH (Appendix A). The DASH questionnaire has been validated in several studies among individuals with upper extremity MSS (Beaton et al., 2001; Hunsaker et al., 2002; SooHoo et al., 2002).

The information that was obtained included participant's ability to perform specific tasks such as writing or pushing open a heavy door as well as the severity of upper-extremity symptoms experienced during the week prior to completing the questionnaire. The range for a DASH score in 0 – 100, with 100 indicating the most disabled.

Procedures

The four self-administered questionnaires were mailed to each of the 813 farms with a self-addressed stamped envelope. Reminder postcards were sent to non-responders two weeks after the initial mailing. A second mailing of the original letter, questionnaire, and envelope was sent to the non-respondents four weeks after the initial mailing. In order to enhance participation, the participants were entered into a drawing for five (5) $100 prizes (one prize for each county).

Statistical Analysis

Summary statistics were calculated for the demographic and farm work variables. Prevalences of MSS were determined for the separate body sites by dividing the number of "yes" responses for each body site by the total number of participants. All questionnaire responses were examined for unlikely values and reconciled with original questionnaire forms. Prior to all analysis, a Pearson correlation matrix was performed to examine for colinearity between independent variables.

Most continuous independent exposure variables were categorized into quartiles, but some were categorized into three categories (unexposed, "low exposure," "high exposure") due to a skewed distribution of exposure among the study sample. In these cases, nearly a third or more of the study sample was unexposed. Consequently, a referent category was created from the unexposed group, and the "low exposure," and "high exposure" groups were created by dividing the exposed participants by the median of their exposure. In the case of artificial insemination, more than half of the study sample was unexposed, so exposure status was dichotomized into exposed (participants who had any exposure) and unexposed.

Bivariate logistic regression examining associations between the exposure variables and the symptom variables were performed. The potential confounders, age and gender, were included in all bivariate analyses. The bivariate analysis was used to screen independent variables for inclusion in multivariable logistic regression models for the four outcome variables (neck, shoulder, elbow, and wrist/hand MSS). The inclusion criteria for variables to be entered into the subsequent multivariable model were a significance level of $p \leq 0.15$ while controlling for age and gender.

The following independent variables were screened for inclusion in multivariable logistic regression model: BMI, smoking status, working on a dairy farm (standardized years), manual feeding (hrs per yr), tractor use (hrs per yr), carrying or lifting ≥23 kg (hrs per yr), artificial insemination (hrs per yr). These independent variables were included because they have been identified as potential confounders for MSS and MSDs, or represent tasks which may confound the association between the primary exposure variables (type of milking facility (stanchion or parlor) and milking (hrs per yr)) and prevalent MSS. All variables significantly associated with the MSS outcomes were entered into a "final" multivariable model. Associations were considered statistically significant at $p \leq 0.05$.

To minimize problems with multiple comparisons, the primary exposures of interest for this study were type of milking facility (stanchion or parlor) and time milking. All final multivariable models included the independent variables of age, gender, type of milking facility (stanchion or parlor), and milking (hrs per yr), in addition to the other screened variables. Finally, effect measure modification (i.e. interaction) of the association between type of milking facility (stanchion or parlor) and MSS outcomes by hours milking per year were examined. For all analyses, odds ratios (OR) and 95% confidence intervals (CIs) were estimated. All statistical analyses were performed using Proc Logistic in SAS statistical software (SAS Institute, Cary, NC).

Results

Description of the Response

A total of 813 questionnaire packets were mailed to dairy farms in early February, 2004. Information about the response of this cohort is detailed in Figure 2.1. Of the 813 questionnaires that were mailed, 341 dairy farmers participated, 85 chose not to participate, 344 did not respond, 31 no longer worked on a dairy farm, and 12 were addressed incorrectly. After the non-farmers and incorrectly addressed questionnaires were removed, the study sample was 341. The response rate was 44% (341/ (813-31-12))

Demographic and Exposure Characteristics

The demographic, and exposure characteristics of the study sample are detailed in Table 2.1. The mean age of the dairy farmers was 50 years (SD = 10) and 90% were male. Redgarding the two primary exposures of interest, approximately 70% of farms used the "traditional" stanchion milking facility, with the remaining 30% using the "modern" parlor milking facility. On average, each farmer milked cows about 1203 hrs per yr (SD = 625). The mean years working on a dairy farm had was 32.4 years (SD = 11.5). However, because many participants reported working more than 2000 hours per year, when years working was standardized to 2000 hours worked per year, the mean standardized years working on a dairy farm was 65.5 (SD = 31.3). The percentage of participants who worked at another occupation was low (10%). Of all the agricultural products produced by these farms, 83% were dairy farm products, indicating that dairy farming was the major farming activity that occurred with this study sample.

Prevalence of MSS and Indicators of MSS Severity

The body site with the highest 12 month prevalence of MSS was the shoulder (54%), with nearly half (45%) of the participants experiencing MSS in multiple sites (Table 2.2). There was a large difference between the percentage of participants who were unable to work and the percentage who sought health care due to MSS in the last 12 months. The greatest percentage of participants (48%) who sought health care due to their MSS was among those who experienced neck MSS (Table 2.3). However, only 3% of the participants who experienced neck MSS were unable to work due to neck MSS. In all body sites (neck, shoulder, elbow, and wrist/hand) the presence of MSS due to a previous injury ranged from 23 - 28%, with elbow MSS being the most frequent. The mean

DASH score for participants who experience upper extremity MSS was low at 12.5 (SD = 10.8) (Gummesson et al., 2003).

Risk Factors

Neck: The primary exposures of interest were type of milking facility and hours milking per year. No Pearson Correlation coefficient was above 0.3, so collinearity was not a problem among the independent variables (Table 2.4). The independent variables that were associated with neck MSS in the bivariate analyses included manually feeding ($p \leq 0.03$), tractor use ($p \leq 0.03$) and carrying or lifting ≥23kg ($p \leq 0.03$) (Table 2.5). In the multivariable model, there was no statistically significant difference in risk across exposure strata of hours milking per year or type of milking facility (stanchion or parlor) for neck MSS (Table 2.6).

Shoulder: Shoulder MSS were associated with milking ($p \leq 0.11$) and manually feeding ($p \leq 0.01$) in the bivariate analyses (Table 2.7). The multivariable analysis revealed no significant difference in risk across exposure strata for type of milking facility or hours per year of milking (Table 2.8).

Elbow: Significant bivariate associations were observed between elbow MSS and milking ($p \leq 0.02$), years working on a dairy farm (standardized) ($p \leq 0.06$), manually feeding ($p \leq 0.08$), and carrying or lifting ≥23 kg ($p \leq 0.06$) (Table 2.9). The multivariable analysis revealed a significantly increased risk for elbow MSS for milking ≥1456 hours year (OR_{Adj}=2.24; 95% CI = 1.00–5.02), although no significant increase in risk was observed for type of milking facility (Table 2.10).

Wrist/hand: In the unadjusted analyses, only carrying or lifting ≥23 kg ($p \leq 0.06$) was significantly associated with wrist/hand MSS (Table 2.11). The multivariable analysis revealed no significant difference in risk by milking facility type or hours milking per year (Table 2.12).

Discussion

Shoulder MSS was reported as most prevalent (54%) among the dairy farmers who participated in this study. Milking ≥1456 hrs per yr was associated with elbow MSS (OR_{Adj}=2.24; 95% CI = 1.00–5.02). Additionally, participants who carried or lifted ≥23 kg between 0.5 – 363 hrs per yr, had an increased risk for elbow MSS (OR_{Adj} = 1.77; 95% CI = 0.89–3.52). Finally, the association between wrist/hand MSS and manually cleaning animal stalls (hrs per yr) was statistically significant (OR_{Adj}=1.96; 95% CI = 1.05–3.68).

Prevalence

To our knowledge, the current cross-sectional study is the first study of risk factors for prevalent neck, shoulder, elbow, and wrist/hand MSS among U.S. dairy farmers. Neck and upper extremity MSS among dairy farmers appears to be common with shoulder MSS being the most prevalent (54%). Prevalence rates for MSS for all body sites among members of this study sample were much higher than what has been observed among dairy farmers by previous investigators (Gustafsson et al., 1994; S. Pinzke, 2003). The previous studies were performed among Swedish dairy farmers, indicating that Iowa dairy farmers report more MSS. The greater prevalence among U.S. dairy farmers may be due to the greater number of hours worked and number of cows milked per day in comparison to Swedish dairy farmers. U.S. dairy farmers work twice as many hours (80 hr per week; Table 2.1) and milk more than twice as many cows (75 cows) per day compared to their Swedish counterparts (MDC, 2003, ; S. Pinzke, 2003).

To date, only one study focused on prevalent MSDs and MSS of the neck and upper extremities among any U.S. farmers (Gomez et al., 2003). Gomez et al. (2003) observed lower prevalent neck and shoulder MSS among farmers compared to previous research on dairy farmers in countries other than the U.S. (Gustafsson et al., 1994; S. Pinzke, 2003). It may be the case that the effect of dairy farming on the musculoskeletal system was attenuated by combining both dairy and non-dairy farmers in that study. Additionally, dairy farmers may not have as much variability in their daily tasks compared to crop or livestock farmers, resulting in increased daily musculoskeletal load on specific body sites. This stress may be in the form of forceful exertions, awkward postures and repetition which been identified with dairy farm work (Ahonen et al., 1990; Arborelius et al., 1986; Lundqvist et al., 1997; Nevala-Puranen et al., 1996; Stål et al., 1999; Stål et al., 2003).

Risk Factors

One of the primary objectives of this study was to examine the associations between milking exposures, such as type of milking facility (stanchion or parlor) and hours milking per year, and prevalent MSS of the neck, shoulder, elbow, and wrist/hand. The only statistically significant association was found between milking and elbow MSS. Milking ≥1456 hrs per yr was associated with elbow MSS (OR_{Adj}=2.24; 95% CI = 1.00–5.02). Additionally, adjusted odds ratios for elbow MSS across the exposure strata for time milking (hrs per yr) showed a significantly increasing linear trend (p-trend = 0.02), indicating a linear dose-response relationship. Elbow MSS may result from static loading of the upper extremity which has been associated with milking (Stål et al., 1996).

Participants who carried or lifted ≥23 kg between 0.5 – 363 hrs per yr, had an increased risk for elbow MSS (OR_{Adj} = 1.77; 95% CI = 0.89–3.52). Pinzke et al. (2003) found an association between elbow MSS among female milkers and number of cows milked (OR_{Adj} = 4.0; 95% CI = 1.1–15.2). They also found that the number of milking units was associated with elbow MSS among female milkers (OR_{Adj} = 4.3; 95% CI = 1.1–187.4). Both exposure variables used by Pinzke et al. (number of cows milked and number of milking machines) could be indirect indicators of hours milking, which this investigation found to be significantly associated with elbow MSS.

The only other significant observation in the multivariable analysis was the association between wrist/hand MSS and manually cleaning animal stalls (hrs per yr) (OR_{Adj}=1.96; 95% CI = 1.05–3.68). Manually cleaning animal stalls may include exposure to physical risk factors such as forceful exertions, as being associated with an increased risk wrist/hand MSDs (Malchaire, Cock, & Robert, 1996). A more detailed investigation of this task with more precise exposure assessment techniques may reveal physical risk factors for wrist/hand MSS.

It is unclear why other associations between workplace exposure and symptoms were not observed. Imprecision in exposure estimation may have attenuated observed associations with neck and upper extremity MSS. Other studies have shown associations between exposure to physical load, forceful exertions, awkward postures, repetition and vibration and upper extremity outcomes (Malchaire et al., 1996; NIOSH, 1997b; Werner et al., 2005). In the current study, these physical risk factors were thought to be represented in exposure variables such as milking facility type (stanchion or parlor), hours per year of milking, manual feeding, tractor use, lifting, manually cleaning animal stalls, and artificial insemination. Years working on a dairy farm (standardized) was an indicator of exposure duration, which is also a factor when estimating risk for MSDs (NIOSH, 1997a). Perhaps more precise exposure assessment methods such as electromyography and electrogoniometry are needed to accurately assess exposure to physical risk factors for MSS among dairy farmers (Spielholz et al., 2001).

The association between neck MSS and the following variables approached significance: manual feeding between 446 -727 hrs per yr, tractor use between 1160 – 1637 hrs per yr, and carrying or lifting ≥23 kg between 0.5 – 363 hrs per yr. Results of the current study were similar to those of Gustafsson et al. (1994), who observed an association between hours worked per week and neck MSS among male dairy farmers (OR_{Adj} = 1.58; 95% CI = 1.15–2.180. Manninen et al. (1995) observed an association between farm size and neck MSS, but noted no association between neck MSS and owning a tractor. Farm size was not an exposure variable in the current study, and tractor use (hrs per yr) should have captured any association between tractor use and neck MSS.

Our expectation was that milking in a parlor would increase the risk of shoulder MSS when compared to stanchion work. This expectation was due to the frequent shoulder musculoskeletal load observed during parlor milking (Stål et al., 1999). However, Gustafsson et al. (1994) also found no association between type of milking facility (stanchion or parlor) and prevalent musculoskeletal symptoms. Additionally, Stål et al. (1999) evaluated the bicep muscle activity of both stanchion and parlor milkers, and found minimal differences between the groups. It may be that there is no difference in shoulder load between stanchion and parlor milkers. The interaction between milking facility type (stanchion or parlor) and hours milking per year was not significant ($p \geq 0.10$) for any body site.

Limitations

This study has several limitations that may have influenced the results. The primary limitation of this study was the inability to determine the temporal relationship between the exposure variables and neck and upper extremity MSS resulting in cause effect reversal bias. If stanchion milking resulted in MSS, then many of the highly symptomatic individuals may change to parlor milking. This bias would attenuate the association of MSS with either type of milking facility, and could produce the results observed by this study. Selective survival may also have affected the study sample, which may explain why participants who were in the highest exposure were not at the highest risk for having MSS. Highly exposed and symptomatic individuals may have left the workforce prior to the study. Prior to the study individuals may have decreased their exposure (e.g. milked fewer hours) to reduce their symptoms and thereby being classified as having lower exposure. Additionally, individuals may report exposures differentially based on the presence or absence of MSS. It is possible that exposure was misclassified in this study since self report methods were used. It is well known that self report of exposure is less precise and accurate compared to direct methods (Spielholz et al., 2001).

The study sample appeared to be fairly representative of dairy farmers and the exposures they experience. Although, previous injury was a common cause (23-28%) of MSS among the participants, only 10% of the participants had another occupation where they worked at least part time. Dairy farm products accounted for on average 83% of total production for the farms that participated. The amount of dairy farm products generated is of interest because it is an overall indication of a farm's dominant type of production. Some farms are considered dairy farms, but swine may be the largest proportion of commodities sold from the farm. With this study sample, dairy farming appeared to be the dominant type of production, and the results were not like to be strongly confounded by the presence of another type of production.

Another concern was the modest response rate (44%). It is possible that the symptomatic individuals responded at a different rate than the non-symptomatic individuals resulting in an over or under estimation of the prevalence of MSS.

Information about the presence of co-morbidities that may cause MSS, but are not related to the exposures of interest, was not collected. The probability that these diseases, like rheumatoid arthritis, are distributed differentially across exposure strata is small. Additionally, the population studied was a working population and the investigators felt that the confounding due to the presence of other disease which may cause MSS was small (i.e. due to the healthy worker effect). The presence of the healthy worker effect may be substantiated by the low mean disability score for the DASH (12.5). There are no recommendations for what DASH score constitutes disability, although several studies have reported mean scores ranging from 30 – 50 for patients undergoing medical treatment for upper-extremity disorders (Beaton et al., 2001; Gummesson et al., 2003; Navsarikar et al., 1999; SooHoo et al., 2002).

Care should be taken when generalizing these results to other agricultural or non-agricultural workers who have a standard 40-hr work week. The majority of dairy farms in this study consisted of smaller "family" farms, where the owner, operator, and milker are the same individual, resulting in long work days (11.4 hrs per day, 7 days per week, and 51 weeks per yr). The reported duration of work in the current study was nearly twice what has been previously reported among dairy farmers from countries other than the U.S. (S. Pinzke, 2003). Consequently, exposures that were statistically significant in this study (e.g. hours milking) may not be significant among workers who milk fewer hours.

Conclusion

In this study, a higher prevalence of MSS of the neck and upper extremity was observed among U.S. dairy farmers compared to previous studies (Gomez et al., 2003; Gustafsson et al., 1994; S. Pinzke, 2003). Dairy farmers may be especially affected by MSS of the neck and upper extremity, compared to farmers who specialize in other types of production.

Similar to other studies, few associations were found between workplace exposure and prevalent MSS among these dairy farmers (Gustafsson et al., 1994; S. Pinzke, 2003). In this study, milking ≥1456 hrs per year was associated with elbow MSS and indicated a significantly increasing linear trend was observed across increasing categories of hours milking per year. The results of this study suggest that by simply reducing the hours an individual milks, risk of developing elbow MSS will be reduced.

Determining exposures associated with MSS of the neck and upper extremity is important so that the interventions can be implemented to reduce MSS and MSDs among dairy farmers. Future studies should focus on accurate and precise exposure assessment methods in order to identify exposures that contribute to risk of MSS of the neck and upper extremity among dairy farmers. The role of physical risk factors on MSS and

MSDs is clearly understood, intervention research should be performed to identify ways to reduce exposures to these risk factors for MSS and MSDs.

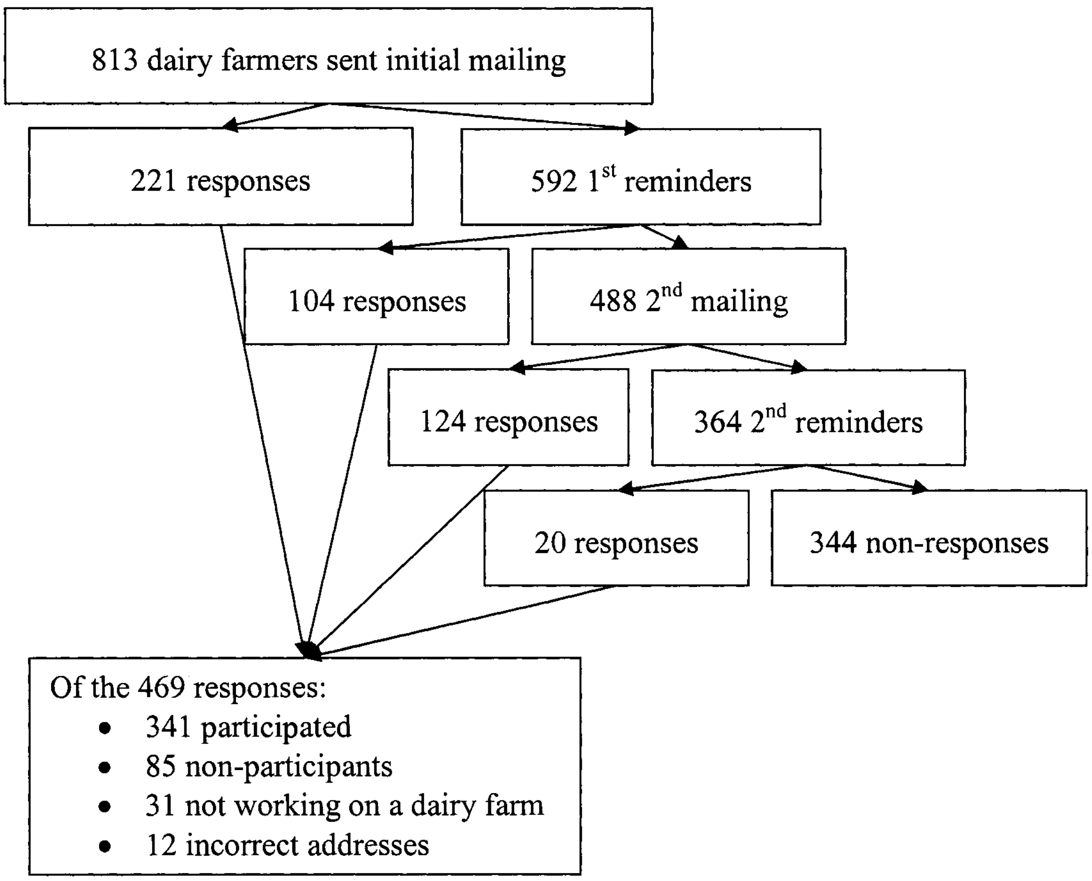


Figure 2.1 Participation Characteristics of the Study Sample

Table 2.1 Demographic and Exposure Characteristics of the Study Sample (N = 341).

Characteristic	Mean (SD), Number (%)
Demographic Characteristics	
Age (years)	49.6 (9.9)
Gender (male)	305 (90%)
Body Mass Index (kg/m^2) (N=300)	27.8 (4.5)
Non Smokers (N=307)	260 (85%)
Current and ever smokers (N=307)	47 (15%)
Farm characteristics	
Type of milking facility (stanchion) (N=338)	238 (70%)
Milking (hrs/yr)	1202.9 (624.9)
Worked on a dairy farm (hrs/day)	11.4 (3.3)
Worked on a dairy farm (days/week)	7.0 (0.4)
Worked on a dairy farm (weeks/yr)	51.1 (4.2)
Working on a dairy farm (years)	32.4 (11.5)
Worked on a dairy farm (standardized years)	65.5 (31.3)
Manual feeding (hrs/yr)	553.9 (430.9)

Table 2.1 Continued.

Tractor use (hrs/yr)	1148.9 (777.4)
Carrying or lifting ≥23 kg (hrs/yr)	298.1 (320.4)
Manually cleaning stalls (hrs/yr)	214.6 (205.4)
Artificial insemination (hrs/yr)	56.4 (110.7)
Herd size (milk cows/farm)	73.7 (64.2)
Sales from dairy farm products (%) (i.e. milk, heifers, bulls, etc) (N = 317)	83 (19)
Primary occupation other than farming	34 (10)

Table 2.2 12-Month Prevalence of Musculoskeletal Symptoms (MSS) Among Dairy Farmers in Northeast Iowa.

Body Site (N=341)	Frequency	% (95% CI)
Neck	148	43 (38 – 48)
Shoulder	183	54 (48 – 59)
Elbow	82	24 (19 – 28)
Wrist/hand	137	40 (35 – 45)
MSS Any Site	255	75 (70 – 79)
MSS Multiple Sites	155	45 (40 – 50)

Table 2.3 Lost Work, Health Care Use, Previous Injury, and Disability Characteristics of the Study Sample (N = 341).

	Number (%) or Mean (SD)
Neck Symptoms (N=148)	
Lost work due to MSS	5 (3)
Accessed health care due to MSS	71 (48)
MSS was due to previous injury	36 (24)
Shoulder Symptoms (N=183)	
Lost work due to MSS	8 (4)
Accessed health care due to MSS	65 (36)
MSS was due to previous injury	47 (26)
Elbow Symptoms (N=82)	
Lost work due to MSS	3 (4)
Accessed health care due to MSS	17 (21)
MSS was due to previous injury	23 (28)
Wrist/hand/hand Symptoms (N=137)	
Lost work due to MSS	8 (6)
Accessed health care due to MSS	28 (20)

Table 2.3 Continued

MSS was due to previous injury	32 (23)
Disability Characteristics	
DASH Score (N=211)	12.5 (10.8)

Table 2.4 Pearson Correlation Matrix of Continuous Independent Variables

	Body Mass Index (kg/m^2)	Age	Working on a dairy farm (standardized years)	Manually feeding (hrs/yr)	Tractor use (hrs/yr)	Carrying or lifting $\geq$23 kg (hrs/yr)	Milking (hrs/yr)	Manually cleaning animal stalls (hrs/yr)	Artificial Insemination (hrs/yr)
Body Mass Index (kg/m^2)	1.000								
Age	0.042	1.000							
Working on a dairy farm (standardized years)	0.032	0.298	1.000						
Manually feeding (hrs/yr)	0.033	0.043	0.172	1.000					
Tractor use (hrs/yr)	-0.015	0.163	0.021	0.166	1.000				
Carrying or lifting $\geq$23 kg (hrs/yr)	-0.049	0.090	0.128	0.138	0.146	1.000			
Milking (hrs/yr)	-0.041	0.175	0.130	0.159	0.099	0.108	1.000		
Manually cleaning animal stalls (hrs/yr)	-0.044	0.129	0.140	0.269	0.131	0.247	0.119	1.000	
Artificial Insemination (hrs/yr)	0.276	0.164	0.077	0.193	0.156	0.162	0.041	0.033	1.000

Table 2.5 Bivariate Neck MSS Odd Ratios for Dairy Farming Exposures

	Bivariate OR[A]	95% CI	*p*-value
Type of Milking Facility			
Parlor	1.00	-	-
Stanchion	0.91	0.57 – 1.47	0.710
Milking (hrs/yr)			
≤727	1.00	-	-
728 – 1137	1.33	0.69 – 2.55	0.392
1138 – 1455	1.48	0.65 – 3.34	0.348
≥1456	1.34	0.71 – 2.52	0.361
Worked on a dairy farm (standardized yrs)			
≤42	1.00	-	-
43 – 62	0.81	0.43 – 1.51	0.502
63 – 86	0.87	0.45 – 1.69	0.671
≥87	1.18	0.60 – 2.32	0.624
Manually feeding (hrs/yr)			
≤317	1.00	-	-
318 – 445	1.16	0.62 – 2.16	0.653
446 – 727	2.16	1.08 – 4.33	0.030*
≥728	1.13	0.63 – 2.04	0.686
Tractor use (hrs/yr)			
≤545	1.00	-	-
546 – 1159	1.22	0.61 – 2.42	0.575
1160 – 1637	2.21	1.11 – 4.41	0.025*
≥1638	1.32	0.66 – 2.62	0.434
Carrying or lifting ≥23 kg (hrs/yr)			
Zero	1.00	-	-
0.5 – 363	1.89	1.05 – 3.40	0.033*
≥364	1.41	0.80 – 2.51	0.238

Table 2.5 Continued

Manually cleaning animal stalls (hrs/yr)			
Zero	1.00	-	-
0.4 – 273	1.83	1.03 – 3.25	0.040*
≥1275	1.18	0.68 – 2.04	0.568
Artificial Insemination (hrs/yr)			
Zero	1.00	-	-
3.5 – 728	1.23	0.63 – 1.67	0.928
Smoking			
Never Smoker	1.00	-	-
Ever Smoker	1.72	0.85 – 3.48	0.129*
Body Mass Index (kg/m^2)	1.00	0.95 – 1.05	0.944

[A] Age and gender adjusted

* Significant at $p \leq 0.15$

Table 2.6 Adjusted Neck MSS Odds Ratios for Dairy Farming Exposures

	Symptoms		Adjusted[A]		Adjusted[A]
	Yes	No	Odds Ratio	95% CI	Trend Test
Type of Milking Facility					
Parlor	47	101	1.00	-	
Stanchion	56	134	0.75	0.43 – 1.30	-
Milking (hrs/yr)					
≤727	23	43	1.00	-	
728 – 1137	46	58	0.94	0.45 – 1.96	
1138 – 1455	20	21	1.19	0.47 – 3.01	
≥1456	59	71	1.00	0.48 – 2.05	$p = 0.587$
Manually feeding (hrs/yr)					
≤317	32	53	1.00	-	
318 – 445	36	49	1.27	0.63 – 2.59	
446 – 727	34	24	2.03	0.90 – 4.61	
≥728	46	67	1.20	0.58 – 2.49	$p = 0.489$
Tractor use (hrs/yr)					
≤545	32	52	1.00	-	
546 – 1159	34	50	1.14	0.52 – 2.50	
1160 – 1637	46	39	1.84	0.84 – 4.05	
≥1638	36	52	1.11	0.51 – 2.45	$p = 0.391$
Carrying or lifting ≥23 kg (hrs/yr)					
Zero	30	59	1.00	-	
≤0.5 – 363	59	57	1.75	0.89 – 3.41	
≥364	59	77	1.26	0.63 – 2.52	$p = 0.489$
Manually cleaning animal stalls (hrs/yr)					
Zero	37	64	1.00	-	
0.4 – 273	57	52	1.60	0.82 – 3.12	
≥1275	54	77	0.85	0.43 – 1.66	$p = 0.698$

[A] Age, gender and smoking adjusted

Table 2.7 Bivariate Shoulder MSS Odd Ratios for Dairy Farming Exposures

	Bivariate OR[A]	95% CI	*p*-value
Type of Milking Facility			
Parlor	1.00	-	-
Stanchion	1.09	0.69 – 1.74	0.712
Milking (hrs/yr)			
≤727	1.00	-	-
728 – 1137	1.03	0.53 – 1.92	0.928
1138 – 1455	1.94	0.86 – 4.39	0.111*
≥1456	1.27	0.69 – 2.32	0.444
Worked on a dairy farm (standardized yrs)			
≤42	1.00	-	-
43 – 62	0.69	0.37 – 1.27	0.234
63 – 86	1.04	0.54 – 1.99	0.906
≥87	1.12	0.58 – 2.16	0.732
Manually feeding (hrs/yr)			
≤317	1.00	-	-
318 – 445	1.25	0.68 – 2.29	0.472
446 – 727	1.81	0.90 – 3.62	0.095*
≥728	0.89	0.51 – 1.58	0.696
Tractor use (hrs/yr)			
≤545	1.00	-	-
546 – 1159	1.14	0.59 – 2.18	0.698
1160 – 1637	1.365	0.70 – 2.64	0.366
≥1638	0.91	0.48 – 1.75	0.787
Carrying or lifting ≥23 kg (hrs/yr)			
Zero	1.00	-	-
0.5 – 363	1.13	0.65 – 1.99	0.664
≥364	1.18	0.68 – 2.04	0.550

Table 2.7 Continued

Manually cleaning animal stalls (hrs/yr)			
Zero	1.00	-	-
0.4 – 273	1.40	0.80 – 2.44	0.238
≥1275	1.30	0.76 – 2.20	0.338
Artificial Insemination (hrs/yr)			
Zero	1.00	-	-
3.5 – 728	1.00	0.62 – 1.61	0.991
Smoking			
Never Smoker	1.00	-	-
Ever Smoker	0.64	0.33 – 1.22	0.175
Body Mass Index (kg/m^2)	0.99	0.94 – 1.04	0.759

[A] Age and gender adjusted

* Significant at $p \leq 0.15$

Table 2.8 Adjusted Shoulder MSS Odds Ratios for Dairy Farming Exposures

	Symptoms		Adjusted[A]		Adjusted[A]
	Yes	No	Odds Ratio	95% CI	Trend Test
Type of Milking Facility					
Parlor	54	49	1.00	-	
Stanchion	128	107	1.11	0.68 – 1.82	-
Milking (hrs/yr)					
≤727	32	34	1.00	-	
728 – 1137	52	52	0.96	0.50 – 1.84	
1138 – 1455	27	14	1.86	0.81 – 4.29	
≥1456	72	58	1.35	0.71 – 2.54	$p = 0.182$
Manually feeding (hrs/yr)					
≤317	43	42	1.00	-	
318 – 445	48	37	1.27	0.67 – 2.38	
446 – 727	38	20	1.69	0.82 – 3.48	
≥728	54	59	0.82	0.45 – 1.50	$p = 0.469$

[A] Age and gender adjusted

Table 2.9 Bivariate Elbow MSS Odd Ratios for Dairy Farming Exposures

	Bivariate OR[A]	95% CI	p-value
Type of Milking Facility			
Parlor	1.00	-	-
Stanchion	0.91	0.53 – 1.56	0.735
Milking (hrs/yr)			
≤727	1.00	-	-
728 – 1137	1.38	0.61 – 3.31	0.440
1138 – 1455	1.59	0.58 – 4.33	0.366
≥1456	2.57	1.19 – 5.53	0.016*
Worked on a dairy farm (standardized yrs)			
≤42	1.00	-	-
43 – 62	1.39	0.64 – 3.02	0.405
63 – 86	2.11	0.96 – 4.63	0.064*
≥87	1.82	0.82 – 4.06	0.145*
Manually feeding (hrs/yr)			
≤317	1.00	-	-
318 – 445	1.92	0.92 – 4.01	0.083*
446 – 727	1.91	0.85 – 4.31	0.118*
≥728	1.52	0.75 – 3.11	0.248
Tractor use (hrs/yr)			
≤545	1.00	-	-
546 – 1159	0.90	0.41 – 2.00	0.797
1160 – 1637	1.44	0.67 – 3.11	0.352
≥1638	1.44	0.67 – 3.07	0.350
Carrying or lifting ≥23 kg (hrs/yr)			
Zero	1.00	-	-
0.5 – 363	1.05	0.52 – 2.11	0.894
≥364	1.85	0.96 – 3.55	0.064*

Table 2.9 Continued

Manually cleaning animal stalls (hrs/yr)			
Zero	1.00	-	-
0.4 – 273	0.81	0.42 – 1.58	0.536
≥1275	1.16	0.63 – 2.13	0.632
Artificial Insemination (hrs/yr)			
Zero	1.00	-	-
3.5 – 728	1.06	0.61 – 1.86	0.830
Smoking			
Never Smoker	1.00	-	-
Ever Smoker	1.08	0.51 – 2.28	0.847
Body Mass Index (kg/m^2)	1.01	0.95 – 1.07	0.734

[A] Age and gender adjusted

* Significant at $p \leq 0.15$

Table 2.10 Adjusted Elbow MSS Odds Ratios for Dairy Farming Exposures

	Symptoms		Adjusted[A]		Adjusted[A]
	Yes	No	Odds Ratio	95% CI	Trend Test
Type of Milking Facility					
Parlor	26	77	1.00	-	
Stanchion	56	179	0.81	0.45 – 1.46	-
Milking (hrs/yr)					
≤727	11	55	1.00	-	
728 – 1137	21	83	1.15	0.49 – 2.70	
1138 – 1455	9	32	1.22	0.43 – 3.46	
≥1456	41	89	2.24	1.00 – 5.02	$p = 0.017$
Worked on a dairy farm (standardized yrs)					
≤42	14	68	1.00	-	
43 – 62	19	68	1.33	0.59 – 2.98	
63 – 86	25	59	1.86	0.81 – 4.27	
≥87	24	64	1.56	0.67 – 3.65	$p = 0.275$
Manually feeding (hrs/yr)				-	
≤317	15	70	1.00	-	
318 – 445	24	61	1.71	0.78 – 3.74	
446 – 727	16	42	1.57	0.66 – 3.72	
≥728	27	86	1.05	0.48 – 2.27	$p = 0.757$
Carrying or lifting ≥23 kg (hrs/yr)					
Zero	18	71	1.00	-	
0.5 – 363	23	93	1.12	0.54 – 2.31	
≥364	41	95	1.77	0.89 – 3.52	$p = 0.079$

[A] Age and gender adjusted

Table 2.11 Bivariate Wrist/hand MSS Odd Ratios for Dairy Farming Exposures

	Bivariate OR[A]	95% CI	*p*-value
Type of Milking Facility			
Parlor	1.00	-	-
Stanchion	1.09	0.68 – 1.76	0.715
Milking (hrs/yr)			
≤727	1.00	-	-
728 – 1137	1.01	0.53 – 1.94	0.976
1138 – 1455	0.65	0.28 – 1.54	0.328
≥1456	1.52	0.82 – 2.84	0.185
Worked on a dairy farm (standardized yrs)			
≤42	1.00	-	-
43 – 62	0.92	0.49 – 1.74	0.800
63 – 86	1.51	0.78 – 2.93	0.226
≥87	1.23	0.64 – 2.42	0.552
Manually feeding (hrs/yr)			
≤317	1.00	-	-
318 – 445	1.21	0.65 – 2.24	0.544
446 – 727	0.99	0.50 – 1.98	0.980
≥728	0.79	0.44 – 1.42	0.421
Tractor use (hrs/yr)			
≤545	1.00	-	-
546 – 1159	1.38	0.71 – 2.70	0.348
1160 – 1637	1.35	0.68 – 2.67	0.392
≥1638	1.10	0.56 – 2.18	0.776
Carrying or lifting ≥23 kg (hrs/yr)			
Zero	1.00	-	-
0.5 – 363	1.27	0.70 – 2.30	0.430
≥364	1.75	0.99 – 3.11	0.055*

Table 2.11 Continued

Manually cleaning animal stalls (hrs/yr)			
Zero	1.00	-	-
0.4 – 273	1.76	0.97 – 3.20	0.061*
≥1275	2.17	1.23 – 3.83	0.007*
Artificial Insemination (hrs/yr)			
Zero	1.00	-	-
3.5 – 728	1.02	0.62 – 1.67	0.933
Smoking			
Never Smoker	1.00	-	-
Ever Smoker	0.87	0.46 – 1.67	0.680
Body Mass Index (kg/m^2)	1.03	0.98 – 2.08	0.315

[A] Age and gender adjusted

* Significant at $p \leq 0.15$

Table 2.12 Adjusted Wrist/hand MSS Odds Ratios for Dairy Farming Exposures

	Symptoms		Adjusted[A]		Adjusted[A]
	Yes	No	Odds Ratio	95% CI	Trend Test
Type of Milking Facility					
Parlor	40	63	1.00	-	
Stanchion	97	138	0.92	0.55 – 1.53	-
Milking (hrs/yr)					
≤727	24	42	1.00	-	
728 – 1137	39	65	0.82	0.41 – 1.61	
1138 – 1455	12	29	0.56	0.23 – 1.35	
≥1456	62	68	1.34	0.71 – 2.54	$p = 0.190$
Carrying or lifting ≥23kg (hrs/yr)					
Zero	30	59	1.00	-	
0.5 – 363	45	71	1.11	0.59 – 2.09	
≥364	62	74	1.47	0.78 – 2.76	$p = 0.204$
Manually cleaning animal stalls (hrs/yr)					
Zero	31	70	1.00	-	
0.4 – 273	45	64	1.76	0.93 – 3.32	
≥1275	61	70	1.96	1.05 – 3.68	$p = 0.046$

[A] Age and gender adjusted

CHAPTER III

RISK FACTORS FOR PREVALENT MUSCULOSKELETAL SYMPTOMS OF THE BACK AND LOWER EXTREMITIES AMONG IOWA DAIRY FARMERS

Abstract

Background: Several studies have examined prevalent musculoskeletal symptoms among Scandinavian dairy farmers. No study has investigated prevalent musculoskeletal symptoms among U.S. dairy farmers. The lack of research is surprising considering dairy farmers in the U.S. work twice as many hours and milk more cows.

Methods: 813 randomly selected Iowa dairy farms were mailed questionnaires assessing demographic and farm exposure information, in addition to information on musculoskeletal symptoms and musculoskeletal disability. In an enclosed letter, the investigators asked that the individual who performs the majority of the milking, complete the questionnaires. Exposures specific to dairy farming such as type of milking facility (stanchion or parlor) and hours milking per year were examined for associations with prevalent MSS.

Results: Three hundred and forty one (44%) dairy farmers responded to the questionnaire. The low back was the body site where musculoskeletal symptoms were reported most frequently (67%), which was closely followed by the knee (60%). Milking between 728 - 1137 hrs per year was associated with lack of low back MSS (OR_{Adj}=0.44; 95% CI = 0.21–0.95) and milking ≥1456 hrs per yr was associated with lack of low back MSS (OR_{Adj}=0.41; 95% CI = 0.20–0.84). Additionally, manually cleaning animal stalls ≥1275 hrs per yr was associated with musculoskeletal symptoms in the upper back (OR_{Adj}=1.96; 95% CI = 1.05–3.68) and hip (OR_{Adj}=2.00; 95% CI = 1.00–4.00). Working on a dairy farm ≥87 (standardized years) (OR_{Adj}=3.00; 95% CI = 1.23–7.31) was associated with knee musculoskeletal symptoms.

<u>Conclusions:</u> Dairy farmers in Iowa reported prevalent musculoskeletal symptoms in the back and lower extremity. Some of these symptoms are associated with common dairy farming practices such as milking and manually cleaning animal stalls. Future studies need to more accurately assess exposures to physical risk factors for back and lower extremity musculoskeletal symptoms so that ergonomic interventions can be developed.

Background and Significance

Work-related musculoskeletal disorders (MSDs) have been identified as the leading cause of work disability and affect millions (Baldwin, 2004; NIAMS). There are considerable national and international data on the prevalence of various MSDs and musculoskeletal symptoms (MSS) among workers from many industries (NIOSH, 1997b; NRC, 2001).

Work related MSDs and MSS have been reported among agricultural workers, with back MSS being most prevalent (Anderson et al., 1989; Bovenzi, 1996; Croft et al., 1992; Gomez et al., 2003; Gustafsson et al., 1994; Holmberg et al., 2002; Holmberg et al., 2003; Holmberg et al., 2004; Lower et al., 1996; Park et al., 2001; S. Pinzke, 2003; Torèn et al., 2002; Xiang et al., 1999). A few studies have identified prevalent back MSS and knee MSDs and MSS as a greater problem among dairy farmers, compared to farmers who specialized on other types of production (Anderson et al., 1989; Gustafsson et al., 1994; Holmberg et al., 2003; Lower et al., 1996; S. Pinzke, 2003).

Dairy farmers in the U.S. work more hours per week compared to dairy farmers in countries that have been previously investigated (S. Pinzke, 2003; Pratt et al., 1992). Consequently, U.S. dairy farmers may be exposed for a longer duration to physical risk factors that are known to be associated with MSDs, and may have a greater risk of MSS than what has been reported for dairy farmers in countries other than the U.S. Dairy farm work involves exposure to physical risk factors such as heavy lifting, bending, squatting, twisting posture, repetition, forceful exertions, and vibration exposure (Bovenzi, 1996; Lower et al., 1996; Lundqvist et al., 1997; Nevala-Puranen et al., 1996; Perkiö-Mäkelä & H, 2005; S. Pinzke et al., 2001).

In the U.S., fewer dairy farmers are producing more milk which may adversely affect their musculoskeletal health. Milk production in the U.S. has increased 11% over the past ten years while the number of farms has decreased 45% (NASS, 2005).

Dairy farming is common in Iowa and the state ranks 15th in U.S. dairy production (NASS, 2005). Approximately 2600 dairy farms are found in Iowa with herd sizes varying from one cow to several hundred. A majority of Iowa dairy farms have small to moderate herd sizes of less than 100 head, with an average of 75 cows (NASS, 2005). In comparison, the average herd size in Sweden is about 30 head (MDC, 2003). Dairy cows are milked two to three times a day, 365 days a year.

Two types of milking facilities are commonly used in dairy farms: the stanchion facility and the parlor facility. Stanchion facility requires the milking machine to be carried from cow to cow, with the cow and the milker standing at the same level. Typically, the farmer must bend over and squat to milk the cow. In a parlor facility, the cows are herded to fixed milking station, where the milker is in a pit below the cow. The parlor facility does not require the farmer to carry the milking machine and parlor work has been associated with fewer awkward postures compared to stanchion facilities (Nevala-Puranen et al., 1996). Although the parlor system is efficient and productive with lower labor costs, these systems are expensive to purchase. Approximately 75% of the farms in Northeast Iowa have stanchion facilities (Tranel, L. 2004 personal communication).

To date, only one study has evaluated MSDs among dairy farmers in the U.S., and no study that we are aware of has evaluated prevalent MSS among U.S. dairy farmers (Anderson et al., 1989). Hence, the *purpose of this study* is to examine associations between exposure to specific dairy farming tasks and prevalent MSS of the back and lower extremity among U.S. dairy farmers.

Methods

Study Sample

Dairy farmers from five counties in Northeast Iowa (Dubuque, Clayton, Winneshiek, Delaware, and Allamakee) were recruited for this cross-sectional study. These five counties represent about half of the total dairy farms in the state of Iowa (1,706 farms) (NASS, 2005). Potential participants were identified from a list of dairy farm owner/operators provided by the Iowa Department of Agriculture and Land Stewardship (IDALS) (IDALS, 2003). From this list, 813 dairy farms comprising approximately 50% of the total dairy farms in the five counties were randomly selected in proportion to the number of farms of each county. Letters were addressed to the selected dairy farms or dairy farmers who were present on the IDLS list asking that the individual who performed the majority of the milking tasks participate in the study. Reminders were sent every two weeks for six weeks after the initial mailing. The investigators obtained University of Iowa Institutional Review Board approval prior to all contact.

Data Collection Instruments

Five self administered questionnaires were used in this study: 1) a demographic questionnaire, 2) a farm exposure questionnaire, 3) the Modified Nordic questionnaire, 4) Oswestry Disability and 5) the Western Ontario and McMaster Universities Osteoarthritis Index (Bellamy et al., 1988; Fairbank et al., 1980; Kuorinka et al., 1987).

Demographic questionnaire. The demographic questionnaire was used to collect information on potential covariates: age, gender, body mass index (BMI), and smoking status.

Farm questionnaire. The farm questionnaire was used to assess farm exposure information (Appendix A). Farm exposure information that was obtained includes years working at a dairy facility, hours worked per day, days worked per week, weeks worked per year and type of milking facility used (i.e., stanchion or parlor). Participants were asked how much time they spent performing specific tasks such as milking, tractor driving, manual feeding, carrying/lifting $\geq$23 kg, and artificial insemination. Participants were also asked to report the commodities produced on their farms as a percentage of their total farm production (e.g., 90% milk, 10% grain). The distribution of commodities produced was used as an indicator of the major farming activity that occurred on each farm. Additionally, information was collected on all current occupations. Participants were asked how much they worked at other occupations (hours per week and weeks per year), and what activities they performed at their other occupation (e.g. operate heavy equipment, lift boxes, computer work).

Modified Nordic Questionnaire. Musculoskeletal symptoms were assessed using the Modified Nordic Questionnaire (Appendix A) (Kuorinka et al., 1987). This questionnaire has been used widely by previous investigators and has good test-retest reliability (Anton et al., 2002; Gustafsson et al., 1994; Holmström & Engholm, 2003; Merlino et al., 2003; Morken et al., 2003; J. C. Rosecrance et al., 2002). In this study, the Modified Nordic Questionnaire was used to assess the 12-month period prevalence of MSS in the following areas: 1) neck, 2) shoulder, 3) elbow, and 4) wrist/hand. Each of the four outcome variables were obtained in a dichotomous response format (yes or no).

Oswestry Disability Index. Disability among participants who reported low back symptoms on the Modified Nordic questionnaire was assessed with the Oswestry Disability Index (Fairbank et al., 1980) (Appendix A). This questionnaire was developed to satisfy the need for a reliable method to assess the impact of low back pain on the subject's daily activities. The Oswestry is a one-page questionnaire that consists of 10 questions about activities of daily living that may be affected by low back pain, such as lifting ability, sitting, and social activities. Each question has six possible responses ranked 0 – 5, with 0 indicating no difficulty performing activity, and 5 indicating the low back symptoms are preventing the participant from doing the activity.

The Oswestry score indicates the extent to which the subject's functional ability is restricted by low back symptoms. A disability score of 0 – 20 indicates minimal disability, 20 – 40 modest disability, 40 – 60 severe disability, and > 60 indicates the subject is severely disabled by low back symptoms in several aspects of life (Fairbank et al., 1980). The Oswestry questionnaire has been used extensively over the last 20 years, and has been shown to be an accurate and valid measure of a participant's functional ability by many studies (Davidson & Keating, 2002; Deyo et al., 1994; Suarez-Almazor et al., 2000). The Oswestry has been shown to have good test-retest reliability, and has been used by previous researchers as a self report postal questionnaire (Holm et al., 2003).

Western Ontario and McMaster Universities Osteoarthritis Index. Among participants who reported knee MSS on the Modified Nordic questionnaire, disability of the knee was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index VA 3.0 (WOMAC) (Bellamy et al., 1988). The WOMAC consists of three sections addressing pain (questions 0 – 5), stiffness (questions 6 – 7), and physical function (questions 8 – 24) of the knee, for a total of 24 questions. Participants mark a visual analog scale of 10 cm in length with terminal descriptors of "*None*" and "*Extreme*." The subject is asked to place an "*x*" on the line to indicate the amount pain, stiffness or difficulty they have performing a specific task. The total WOMAC score is calculated by summing the scores from each section for a section score, and combining all the scores for an aggregate score (0 – 2400). An increasing WOMAC score indicated increasing disability related to knee MSS.

The WOMAC has been used in population studies to assess the impact of knee osteoarthritis and disability (Jinks et al., 2002). There are no recommendations for what score constitutes disability. Previous researchers have used the median aggregate score as an arbitrary boundary for disability (O'Reilly et al., 1998), or classified anyone who scored "Extreme" or "Severe" on any question using a Likert version of the WOMAC as having disability (Jinks et al., 2002).

Procedures

The five self-administered questionnaires were mailed to each of the 813 farms with a self-addressed stamped envelope. Reminder postcards were sent to non-responders two weeks after the initial mailing. A second mailing of the original letter, questionnaire, and envelope was sent to the non-respondents four weeks after the initial mailing. As an incentive for participation, the participants were entered into a drawing for five (5) \$100 prizes (one prize for each county).

Statistical Analysis

Summary statistics were calculated for the demographic and farm work variables. Prevalences of MSS were determined for the separate body sites by dividing the number of "yes" responses for each body site by the total number of participants. All questionnaire responses were examined for unlikely values and then reconciled with the original questionnaire. Prior to all analysis, a Pearson correlation matrix was performed examine colinearity between independent variables.

Most continuous independent exposure variables were categorized into quartiles, but some were categorized into three categories (unexposed, "low exposure," "high exposure") due to a skewed distribution of values among the study sample. In these cases, nearly a third or more of the study sample was unexposed. Consequently, a referent category was created from the unexposed group, and the "low exposure," and "high exposure" groups were created by splitting the exposed participants at the median of their exposure. In the case of artificial insemination, more than half of the study sample was unexposed, therefore exposure status was dichotomized into exposed (participants who had any exposure) and unexposed.

Bivariate logistic regression examining associations between the exposure variables (e.g. hours milking per year) and the outcome variables (e.g., yes or no to wrist/hand MSS in the last 12 months) was performed. The potential confounders, age and gender, were included in all bivariate analyses. The bivariate analysis was used to screen independent variables for inclusion in multivariable logistic regression models for the four outcome variables (lower back, shoulder, elbow, and wrist/hand MSS). The inclusion criterion for variables to be entered into the multivariable model was a significance level of $p \leq 0.15$ while controlling for age and gender.

The following independent variables were screened for inclusion in multivariable logistic regression model: BMI, smoking status, duration of work on a dairy farm (standardized years), manual feeding (hrs per yr), tractor use (hrs per yr), carrying or lifting ≥23 kg (hrs per yr), artificial insemination (hrs per yr). These independent variables were considered because they have been identified as potential confounders for MSS and MSDs, or represent tasks which may confound the association between the primary exposure variables (type of milking facility (stanchion or parlor) and milking (hrs per yr) and prevalent MSS. All variables significantly associated with the MSS outcomes were entered into a "final" multivariable model. Associations were considered statistically significant at $p \leq 0.05$. All final multivariable models included the independent variables of age, gender, type of milking facility (stanchion or parlor), and hours milking per year, in addition to other bivariately significant variables. Finally, effect measure modification (i.e. interaction) of the association between type of milking facility (stanchion or parlor) and MSS outcomes by hours milking per year was examined. For all analysis, odds ratios (OR) and 95% confidence intervals (CIs) were estimated. All statistical analyses were performed using Proc Logistic in SAS statistical software (SAS Institute, Cary, NC).

Results

Description of the Response

A total of 813 questionnaire packets were mailed to dairy farms in early February, 2004. Information about the response of this cohort is detailed in Figure 2.1. Of the 813 questionnaires that were mailed, 341 dairy farmers participated, 85 chose not to participate, 344 did not respond, 31 no longer worked on a dairy farm, and 12 were addressed incorrectly. After the non-farmers and incorrectly addressed questionnaires were removed, the study sample was 341. The response rate was 44% (341/ (813-31-12))

Demographic and Exposure Characteristics

The demographic, and exposure characteristics of the study sample are detailed in Table 2.1. The mean age of the dairy farmers was 50 years (SD = 10) and 90% were male. Regarding the two primary exposures of interest, approximately 70% of farms used the "traditional" stanchion milking facility, with the remaining 30% using the "modern" parlor milking facility. On average, each farmer milked cows about 1203 hrs per yr (SD = 625). The mean standardized years working on a dairy farm had was 32.4 years (SD = 11.5). However, because many participants reported working more than 2000 hours per year, when years working was standardized to 2000 hours worked per year, the mean years working on a dairy farm was 65.5 (SD = 31.3). The percentage of participants who worked at another occupation was low (10%). Of all the agricultural products produced by these farms, 83% were dairy farm products, indicating that dairy farming was the major farming activity that occurred with this study sample.

Prevalence and Indicators of Severity

The body site with the highest 12 month prevalence of MSS was the low back (67%), which was closely followed by the knee (60%). Additionally, two thirds of the participants (67%) experienced MSS in multiple sites (Table 3.2). As for the severity of reported MSS, there was a large difference between the percentage of participants who were unable to work and the percentage who sought health care due to MSS in the last 12 months (Table 3.3). In all body sites (upper back, low back, hip, knee, and feet) the presence of MSS due to a previous injury ranged from 21% -25%, with upper back being the highest. For participants who experienced low back MSS, the mean Oswestry score was 11.9 (SD = 6.6). For participants who experienced knee MSS the mean WOMAC score was 551 (SD = 415)

Risk Factors

Upper back: The primary exposures of interest were type of milking facility (stanchion or parlor), and milking (hrs per year). No variables included in the analysis were found to be collinear (Table 3.4). The independent variables that were associated with upper back MSS in the bivariate analysis controlling for age and gender included hours milking per year (p = 0.06), working on a dairy farm (standardized years) (p = 0.05), tractor use (p = 0.08) and hours manually cleaning animal stalls per year (p = 0.04) (Table 3.5). In the multivariable model, there was no significant difference in risk across exposure strata of type of milking facility (stanchion or parlor) or hours milking per year or for upper back MSS (Table 3.6).

Low back: In the bivariate analysis controlling for age and gender, low back MSS was associated with type of milking facility (stanchion) (p = 0.07), milking (p = 0.07), tractor use (p = 0.03) and manually cleaning animal stalls (p = 0.02) (Table 3.7). The multivariable analysis revealed no statistically significant association in risk for type of milking facility (stanchion or parlor) (Table 3.8). However, a statistically significant decrease in risk for low back MSS was observed for milking $\leq$727 hours per year (OR_{Adj}=0.44; 95% CI = 0.21–0.95), and for milking $\geq$1456 hours per year (OR_{Adj}=0.41; 95% CI = 0.20–0.84).

Hip: Statistically significant associations were observed between hip MSS and working on a dairy farm (standardized years) ($p = 0.07$), tractor use ($p = 0.07$), carrying or lifting ≥23 kg ($p = 0.04$), manually cleaning animal stalls ($p = 0.01$), and BMI ($p = 0.09$) (Table 3.9). In the multivariable model, there was no significant difference in risk across exposure strata of type of milking facility (stanchion or parlor) or hours milking per year, for upper back MSS (Table 3.10).

Knee: Knee MSS was associated with type of milking facility (stanchion) ($p = 0.06$), working on a dairy farm (standardized years) ($p = 0.02$), manual feeding ($p = 0.02$), tractor use ($p = 0.13$), carrying or lifting ≥23 kg ($p = 0.05$), and manually cleaning animal stalls ($p = 0.01$) in the bivariate analysis controlling for age and gender (Table 3.11). In the multivariable model, there was no significant difference in risk across exposure strata of type of milking facility (stanchion or parlor) or hours per year milking, for upper back MSS (Table 3.12).

Feet: No independent variables were significantly associated with feet MSS for the bivariate analysis controlling for age and gender (Table 3.13). In the multivariable model, there was no significant difference in risk across exposure strata of type of milking facility (stanchion or parlor) or hours milking per year or for upper back MSS (Table 3.14).

Discussion

Low back MSS was reported as most prevalent (67%) among the dairy farmers who participated in this study. Milking 728 - 1137 hrs per year was associated with lack of low back MSS (OR_{Adj}=0.44; 95% CI = 0.21–0.95) and milking ≥1456 hrs per yr was associated with lack of low back MSS (OR_{Adj}=0.41; 95% CI = 0.20–0.84). Additionally, working on a dairy farm ≥87 (standardized years) (OR_{Adj}=2.43; 95% CI = 1.01–5.80), and manually cleaning animal stalls ≥1275 hrs per yr (OR_{Adj}=1.96; 95% CI = 1.05–3.68) were associated with an increased risk of upper back MSS. Additionally, working on a dairy farm ≥87 years (standardized) (OR_{Adj}=2.87; 95% CI = 1.27–6.49), and both exposure categories of manually cleaning animal stalls were associated with an increased risk of hip MSS (OR_{Adj}=2.45; 95% CI = 1.19–5.29) and (OR_{Adj}=2.00; 95% CI = 1.00–4.00). Finally, working on a dairy farm ≥87 years (standardized) (OR_{Adj}=3.00; 95% CI = 1.23–7.31) was associated with knee MSS.

Prevalence

To our knowledge, this is the first cross-sectional study of risk factors for prevalent upper back, low back, hip, knee, and feet MSS among U.S. dairy farmers. Back and lower extremity MSS among dairy farmers appears to be widespread with low back and knee MSS being the most prevalent at 67% and 60%, respectively. Prevalence rates for MSS for all body sites among members of this study sample were much higher than what has been observed among dairy farmers by previous investigators (Gustafsson et al., 1994; Lower et al., 1996; S. Pinzke, 2003). The previous studies were specific to Swedish and Australian dairy farmers, indicating that Iowa dairy farmers report more MSS. Differences between Swedish and U.S. dairy farming, such as hours worked and number of cows milked per day, could account for more MSS among U.S. dairy farmers. U.S. dairy farmers work twice as many hours (80 hr per week; Table 3.3) and milk more than twice as many cows (75 cows) per day compared to their Swedish counterparts (MDC, 2003, ; S. Pinzke, 2003).

The prevalence of MSS observed in the current study was much greater than what has been previously reported among U.S. farmers and dairy farmers in countries other than the U.S. (Gomez et al., 2003; Gustafsson et al., 1994; Lower et al., 1996; Park et al., 2001; S. Pinzke, 2003; Xiang et al., 1999). Previous studies reported prevalent back MSS between 57% – 26% among U.S. farmers (Gomez et al., 2003; Park et al., 2001; Xiang et al., 1999), and dairy farmers in countries other than the U.S. (Gustafsson et al., 1994; Lower et al., 1996; S. Pinzke, 2003). In the current study, 67% of dairy farmers reported low back MSS. The difference between prevalent low back MSS among U.S. dairy farmers compared to other farmers may be due to differences in exposure to physical risk factors associated with low back MSS.

Some studies have estimated prevalent MSS of the lower extremity among U.S. farmers, and dairy farmers in countries other than the U.S. (Gomez et al., 2003; Gustafsson et al., 1994; S. Pinzke, 2003). All have reported a reduced prevalence of lower extremity MSS compared to the current study. Previous studies on U.S. farmers included both dairy farmers and farmers who specialize in other types of production (Gomez et al., 2003). It may be that the effect of dairy farming on the musculoskeletal system was attenuated by combining both dairy farmers and farmers who specialize in other types of production. Additionally, dairy farmers may not have as much variability in their daily tasks compared to crop or livestock farmers, resulting in increased daily musculoskeletal load on specific body sites. This stress may be in the form of forceful exertions, awkward postures and repetition which been identified with dairy farm work (Ahonen et al., 1990; Arborelius et al., 1986; Lundqvist et al., 1997; Nevala-Puranen et al., 1996; Stål et al., 1999; Stål et al., 2003).

Risk Factors

One of the primary objectives of this study was to examine the associations between milking exposures, such as type of milking facility (stanchion or parlor) and hours milking per year, and prevalent MSS of the upper back, low back, hip, knee, and feet. Of those two primary exposure variables, only milking 728 - 1137 hrs per year was associated with lack of low back MSS (OR_{Adj}=0.44; 95% CI = 0.21–0.95) and milking ≥ 1456 hrs per yr was associated with lack of low back MSS (OR_{Adj}=0.41; 95% CI = 0.20–0.84). Milking and low back MSS was the only statistically significant association between the primary exposure variables of facility type (stanchion or parlor) and milking (hrs per yr) and prevalent MSS for the back and lower-extremities.

The protective effect of milking (hrs per yr) on low back MSS may have been observed because milking may not involve as much lifting compared to other tasks. Lifting has been identified as a physical risk factor for low back MSS (NIOSH, 1997b). If a dairy farmer spends the majority of their work time milking, then other workers may be performing the majority of the other tasks that include lifting. The current study identified manually cleaning animal stalls as being associated with low back MSS (OR_{Adj}=1.88; 95% CI = 1.01–3.49) (Table 3.7). This task may include a significant amount of lifting. Gustafsson et al. (1994) associated hours worked per week with low back MSS among dairy farmers, however working on a dairy farm (standardized years) was not significant in the current study. In another study, dairy farmers reported tractor work, and milking tasks to be the major causes of prevalent back MSS (Lower et al., 1996). It is unclear as to why these variables were not associated with low back MSS in the current study.

There were several other variables that were significantly associated with prevalent MSS of the back and lower extremity. Working on a dairy farm ≥87 (standardized years) (OR_{Adj}=2.43; 95% CI = 1.01–5.80), and manually cleaning animal stalls ≥1275 hrs per yr (OR_{Adj}=1.96; 95% CI = 1.05–3.68) were associated with an increased risk of upper back MSS (Table 3.5). Additionally, working on a dairy farm ≥ 87 years (standardized) (OR_{Adj}=2.87; 95% CI = 1.27–6.49), and both exposure categories of manually cleaning animal stalls were associated with an increased risk of hip MSS (OR_{Adj}=2.45; 95% CI = 1.19–5.29) and (OR_{Adj}=2.00; 95% CI = 1.00–4.00) (Table 9). Finally, working on a dairy farm ≥87 years (standardized) (OR_{Adj}=3.00; 95% CI = 1.23–7.31) was associated with knee MSS (Table 3.11).

Working on a dairy farm (standardized years) was associated with back, hip and knee MSS in the current study. Previous studies have identified years in the farming profession as being associated with MSS (Croft et al., 1992; Xiang et al., 1999). Years working on a dairy farm (standardized) may represent the daily wear and tear induced on the musculoskeletal system by performing dairy farm tasks.

Previous studies on dairy farmers have found no statistically significant associations between dairy farming tasks and MSS of the back and lower extremity (Gustafsson et al., 1994; S. Pinzke, 2003). The current study identified manually cleaning animal stalls (hrs per year) as being associated with an increased risk of back, hip and knee MSS. Manually cleaning animal stalls may include physical risk factors such as awkward postures, heavy lifting and forceful exertions which have been associated with low back, hip and knee MSS (Holmberg et al., 2003; NIOSH, 1997b; Vingård et al., 1991). In fact, Allread et al. (2004) identified farm tasks such as dumping feed/water and spreading bedding as having similar trunk kinematics compared to industrial jobs that are considered high risk for low back MSS. The farm tasks of dumping feed/water and spreading bedding may be included in the variable of manually cleaning animal stalls (hrs per year) in the current study. Additionally, previous investigators have identified tractor use as being associated with low back and hip MSS among farmers (Bovenzi, 1996; Croft et al., 1992; Thelin et al., 1997; Torèn et al., 2002). However in the current study, tractor use (hrs per yr) was not significantly associated with any prevalent MSS of the back and lower extremity.

It is unclear why risk factors that have been identified with MSS in other studies (e.g. tractor use) were not statistically significant in the current study. Imprecision in exposure estimates may have attenuated observed associations between back and lower extremity MSS. Other studies of back and lower extremity MSS have shown associations between exposure variables such as physical load, forceful exertions, awkward postures, repetition and vibration (Bovenzi, 1996; Holmberg et al., 2003; NIOSH, 1997b; J. Rosecrance et al., 2001; Vingård et al., 1991). These physical risk factors were thought to be present in exposure variables such as milking facility type (stanchion or parlor), time milking, manual feeding, tractor use, lifting, and artificial insemination (hrs per year). Years working on a dairy farm (standardized) was an indicator of exposure duration, which is also a factor when estimating risk for MSDs (NIOSH, 1997a). Perhaps more precise ergonomic exposure assessment techniques such as direct methods are needed to accurately assess exposure to physical risk factors for MSS among dairy farmers (Spielholz et al., 2001).

Our expectation was that stanchion work would increase the risk of low back and knee MSS compared to parlor work. Previous studies have associated physical load, lifting and awkward postures with stanchion work (Lundqvist et al., 1997; Nevala-Puranen et al., 1996; Perkiö-Mäkelä & H, 2005). However, Gustafsson et al. (1994) also found no association between type of milking facility (stanchion or parlor) and prevalent MSS. The examination of the interaction of milking facility type (stanchion or parlor) and hours milking per year indicated no significant difference ($p \geq 0.10$) in risk between exposure strata for any body site.

The mean WOMAC disability score was 550 (SD=411). There are no recommendations for what WOMAC score constitutes disability, so interpretation of these results are challenging. However, the WOMAC disability score observed in this study was close to what has been previously published for patients who have knee pain and were diagnosed with knee osteoarthritis (Bellamy et al., 1988; Jinks et al., 2002). This observation suggests that knee MSS has a significant impact on their activities of daily living. Further evaluation of knee symptoms and better exposure assessment methods such as direct methods may allow for a better estimate of the risk associated with each type of milking facility (stanchion and parlor) and time spent milking. More precise methods to assess exposure to physical risk factors for low back and knee MSS may find differences between types of milking facilities.

Limitations

This study has several limitations. The primary limitation of this study was the inability to determine the temporal relationship between an exposure such as type of milking facility (stanchion or parlor) and back and lower extremity MSS. If stanchion milking resulted in MSS, then many of the highly symptomatic individuals may change to parlor milking. Consequently, the association of MSS with either type of milking facility would be attenuated, and could produce the results observed by this study.

Selective survival may also have affected the study sample, which may explain why participants who were in the highest exposure strata for hours milking per year were not at the highest risk for having low back MSS. This trend may represent the departure of highly exposed and symptomatic individuals from the workforce. Additionally, this trend may represent individuals decreasing their exposure to reduce their symptoms and thereby being classified as having lower exposure. Previous injury was a common cause (23 – 28%) of MSS among the participants.

Selection of the most able workers into the most demanding work is suggested by the low mean disability score for the Oswestry (SD=11.9). There are no recommendations for what Oswestry score constitutes disability, although several studies have reported mean scores from 57.3 – 42.2 for patients undergoing medical treatment for low back MSS (Holm et al., 2003; Suarez-Almazor et al., 2000; Walsh, Hanscom, Lurie, & Weinstein, 2003).

Another limitation was the response rate for this study was 44%. It is possible that the symptomatic individuals responded at a different rate than the non-symptomatic individuals resulting in over estimation of the prevalence of MSS. Additionally, individuals may report exposures differentially based on the presence or absence of MSS.

Information about the presence of co-morbidities that may cause MSS, but are not related to the exposures of interest was not collected. However, the population studied was a working population (i.e. the presence of the healthy worker effect) and the investigators feel that the confounding due to the presence of other disease which may cause MSS is small.

This study has several strengths. The study sample appeared to be fairly representative of dairy farmers and the exposures they experience. Only 10% of the participants had another occupation where they worked at least part time. Dairy farm products accounted for on average 83% of total production for the farms that participated. The amount of dairy farm products generated is of interest because it is an overall indication of a farm's dominant type of production. Some farms are considered dairy farms, but swine may be the largest proportion of commodities sold from the farm. Apparently with this study sample, dairy farming appears to be the dominant type of production, and the results were likely not confounded by the presence of another type of production.

Care should be taken when generalizing these results to other agricultural or non-agricultural workers who have a standard 40-hr work week. The majority of dairy farms in this study consisted of smaller "family" farms, where the owner, operator, and milker are the same individual, resulting in long work days (11.4 hrs per day, 7 days per week, and 51 weeks per year).

Conclusion

In this study, a high prevalence of MSS of the back and lower extremity was observed among U.S. dairy farmers (Gomez et al., 2003; Gustafsson et al., 1994; S. Pinzke, 2003). Dairy farmers may be especially affected by MSS of the back and lower extremity, compared to farmers who specialize in other types of production.

Determining exposures associated with MSS of the back and lower extremity is important so that the interventions that are implemented can have the greatest impact on reducing MSS and MSDs among dairy farmers. In this study, hours milking per year was associated with a decreased risk of low back MSS indicating that dairy farmers who milk more, may have a lower exposure to physical risk factors for low back MSS. Years working on a dairy farm (standardized) was associated with back, hip, and knee MSS. This association may be related to the daily musculoskeletal load on these body sites from dairy farming tasks. Additionally, time manually cleaning animal stalls was associated with an increased risk of back and hip MSS which warrants further investigation of this task, possibly with better exposure assessment methods. The mean WOMAC score for participants was close to what has been reported for individuals who are being treated for knee MSS. Exposure assessment methods such as direct methods need to be used to more accurately assess exposure to physical risk factors that may contribute to knee MSS.

In this study, a higher prevalence of low back and knee MSS were noted among dairy farmers compared to previous studies. However, few associations were found with exposure variables and prevalent MSS in previous studies (Gomez et al., 2003; Gustafsson et al., 1994; Park et al., 2001; S. Pinzke, 2003; Xiang et al., 1999). Future studies should focus on accurate and precise exposure assessment methods in order to identify what exposures are contributing to prevalent MSS of the back and lower extremity among dairy farmers. Once exposure to physical risk factors is clearly understood, intervention research should be performed to identify ways to reduce exposures to these risk factors for MSS and MSDs.

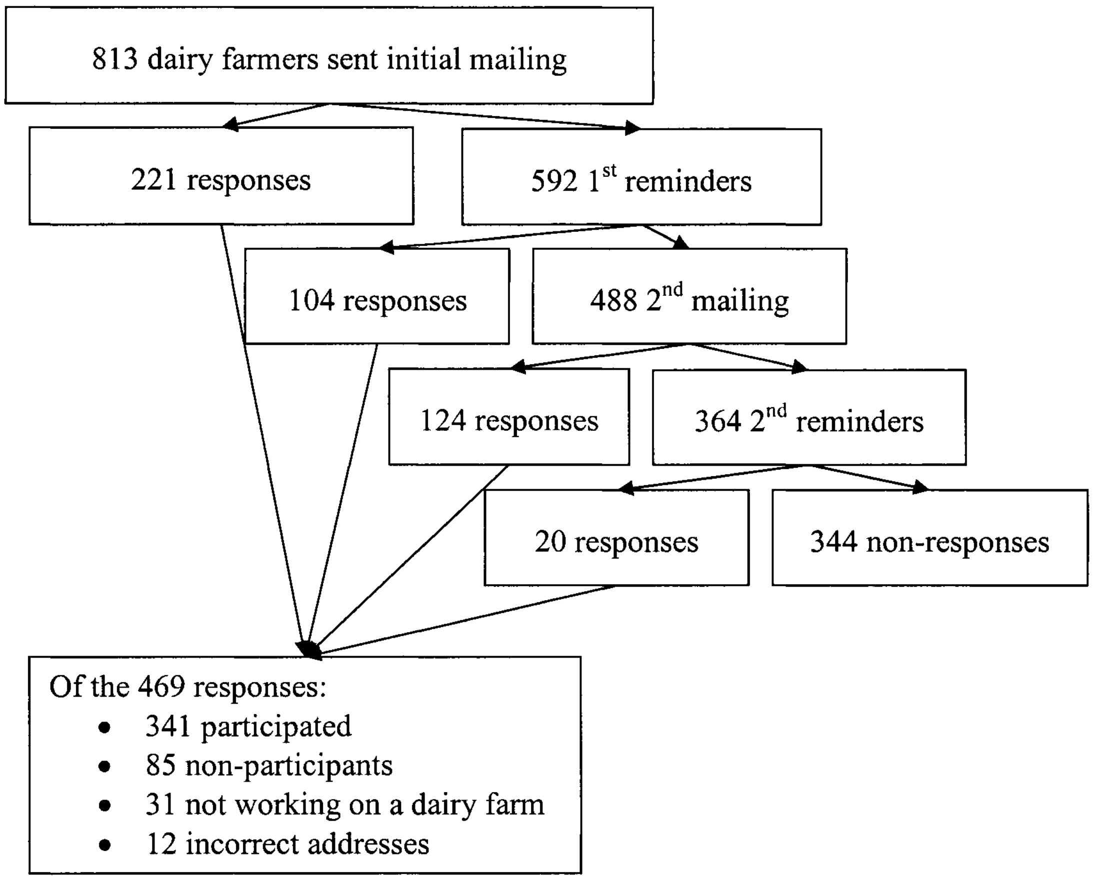


Figure 3.1 Participation Characteristics of the Study Sample

Table 3.1 Demographic and Exposure Characteristics of the Study Sample (N = 341).

Characteristic	Mean (SD), Number (%)
Demographic Characteristics	
Age (years)	49.6 (9.9)
Gender (male)	305 (90%)
Body Mass Index (kg/m^2) (N=300)	27.8 (4.5)
Non Smokers (N=307)	260 (85%)
Current and ever smokers (N=307)	47 (15%)
Farm Characteristics	
Type of milking facility (stanchion) (N=338)	238 (70%)
Milking (hrs/yr)	1202.9 (624.9)
Worked on a dairy farm (hrs/day)	11.4 (3.3)
Worked on a dairy farm (days/week)	7.0 (0.4)
Worked on a dairy farm (weeks/yr)	51.1 (4.2)
Working on a dairy farm (years)	32.4 (11.5)
Worked on a dairy farm (standardized years)	65.5 (31.3)
Manual feeding (hrs/yr)	553.9 (430.9)
Tractor use (hrs/yr)	1148.9 (777.4)

Table 3.1 Continued

Carrying or lifting ≥23 kg (hrs/yr)	298.1 (320.4)
Manually cleaning stalls (hrs/yr)	214.6 (205.4)
Artificial insemination (hrs/yr)	56.4 (110.7)
Herd size (milk cows/farm)	73.7 (64.2)
Sales from dairy farm products (%) (i.e. milk, heifers, bulls, etc) (N = 317)	83 (19)
Primary occupation other than farming	34 (10)

Table 3.2 12-Month Prevalence of Musculoskeletal Symptoms (MSS) Among Dairy Farmers in Northeast Iowa.

Body Region (N=341)	Frequency	% (95% CI)
Upper back	77	23 (18 – 27)
Low back	227	67 (61 – 71)
Hip	129	38 (32 – 43)
Knee	204	60 (54 – 65)
Feet	117	34 (29 – 39)
MSS Any Site	274	80 (75 – 84)
MSS Multiple Sites	255	75 (70 – 79)

Table 3.3 Lost Work, Health Care Use, Previous Injury, and Disability Characteristics of the Study Sample (N = 341).

	Number (%) or Mean (SD)
Upper back Symptoms (N=77)	
Lost work due to MSS	7 (9)
Accessed health care due to MSS	40 (52)
MSS was due to previous injury	19 (25)
Low back Symptoms (N=227)	
Lost work due to MSS	12 (4)
Accessed health care due to MSS	114 (50)
MSS was due to previous injury	50 (22)
Hip Symptoms (N=129)	
Lost work due to MSS	11 (9)
Accessed health care due to MSS	50 (39)
MSS was due to previous injury	27 (21)
Knee Symptoms (N=204)	
Lost work due to MSS	25 (12)
Accessed health care due to MSS	58 (28)
MSS was due to previous injury	47 (23)

Table 3.3 Continued.

Feet Symptoms (N=117)	
Lost work due to MSS	6 (5)
Accessed health care due to MSS	32 (27)
MSS was due to previous injury	27 (23)
Disability Characteristics	
Oswestry Score (N=266)	11.9 (6.6)
WOMAC Score (N=200)	551 (411)

Table 3.4 Pearson Correlation Matrix of Continuous Independent Variables

	Body Mass Index (kg/m^2)	Age	Working on a dairy farm (standardized years)	Manually feeding (hrs/yr)	Tractor use (hrs/yr)	Carrying or lifting ≥23 kg (hrs/yr)	Milking (hrs/yr)	Manually cleaning animal stalls (hrs/yr)	Artificial Insemination (hrs/yr)
Body Mass Index (kg/m^2)	1.000								
Age	0.042	1.000							
Working on a dairy farm (standardized years)	0.032	0.298	1.000						
Manually feeding (hrs/yr)	0.033	0.043	0.172	1.000					
Tractor use (hrs/yr)	-0.015	0.163	0.021	0.166	1.000				
Carrying or lifting ≥23 kg (hrs/yr)	-0.049	0.090	0.128	0.138	0.146	1.000			
Milking (hrs/yr)	-0.041	0.175	0.130	0.159	0.099	0.108	1.000		
Manually cleaning animal stalls (hrs/yr)	-0.044	0.129	0.140	0.269	0.131	0.247	0.119	1.000	
Artificial Insemination (hrs/yr)	0.276	0.164	0.077	0.193	0.156	0.162	0.041	0.033	1.000

Table 3.5 Bivariate Upper Back MSS Odd Ratios for Dairy Farming Exposures

	Bivariate OR^A	95% CI	*p*-value
Type of Milking Operation			
Parlor	1.00	-	-
Stanchion	0.86	0.49 – 1.50	0.596
Milking (hrs/yr)			
≤727	1.00	-	-
728 – 1137	1.63	0.72 – 3.71	0.245
1138 – 1455	2.46	0.95 – 6.39	0.064*
≥1456	1.34	0.60 – 3.01	0.481
Worked on a dairy farm (standardized yrs)			
≤42	1.00	-	-
43 – 62	0.91	0.42 – 1.93	0.800
63 – 86	0.92	0.39 – 2.14	0.837
≥87	2.20	0.99 – 4.88	0.053*
Manually feeding (hrs/yr)			
≤317	1.00	-	-
318 – 445	1.57	0.75 – 3.29	0.235
446 – 727	1.69	0.76 – 3.78	0.199
≥728	1.02	0.49 – 2.14	0.960
Tractor use (hrs/yr)			
≤545	1.00	-	-
546 – 1159	1.90	0.83 – 4.36	0.129*
1160 – 1637	2.14	0.92 – 4.98	0.078*
≥1638	1.20	0.49 – 2.90	0.693
Carrying or lifting ≥23 kg (hrs/yr)			
Zero	1.00	-	-
0.5 – 363	0.98	0.49 – 1.96	0.957
≥364	1.10	0.56 – 2.15	0.781

Table 3.5 Continued

Manually cleaning animal stalls (hrs/yr)			
Zero	1.00	-	-
0.4 – 273	1.75	0.85 – 3.63	0.130*
≥1275	2.06	1.04 – 4.12	0.040*
Artificial Insemination (hrs/yr)			
Zero	1.00	-	-
3.5 – 728	1.05	0.58 – 1.88	0.877
Smoking			
Never Smoker	1.00	-	-
Ever Smoker	0.89	0.40 – 2.02	0.788
Body Mass Index (kg/m^2)	0.96	0.90 – 1.03	0.279

[A] Age and gender adjusted

* Significant at $p \leq 0.15$

Table 3.6 Adjusted Upper Back MSS Odds Ratios for Dairy Farming Exposures

	Symptoms		Adjusted[A]		Adjusted[A]
	Yes	No	Odds Ratio	95% CI	Trend Test
Type of Milking Operation					
Parlor	25	78	1.00	-	
Stanchion	51	184	0.66	0.35 – 1.23	-
Milking (hrs/yr)					
≤727	10	56	1.00	-	
728 – 1137	25	79	1.42	0.59 – 3.41	
1138 – 1455	14	27	1.98	0.72 – 5.41	
≥1456	28	102	1.04	0.44 – 2.44	$p = 0.773$
Worked on a dairy farm (standardized yrs)					
≤42	21	61	1.00	-	
43 – 62	18	69	0.95	0.43 – 2.10	
63 – 86	13	71	0.80	0.31 – 2.03	
≥87	25	63	2.43	1.01 – 5.80	$p = 0.045$*
Tractor use (hrs/yr)					
≤545	17	67	1.00	-	
546 – 1159	22	62	1.45	0.60 – 3.52	
1160 – 1637	23	62	1.67	0.68 – 4.12	
≥1638	15	73	0.81	0.32 – 2.15	$p = 0.122$
Manually cleaning animal stalls (hrs/yr)					
Zero	16	85	1.00	-	
0.4 – 273	26	83	1.78	0.81 – 3.89	
≥1275	35	96	2.33	1.09 – 5.00	$p = 0.032$*

[A] Age, gender adjusted

Table 3.7 Bivariate Low Back MSS Odd Ratios for Dairy Farming Exposures

	Bivariate OR[A]	95% CI	*p*-value
Type of Milking Operation			
Parlor	1.00	-	-
Stanchion	1.58	0.97 – 2.59	0.066*
Milking (hrs/yr)			
≤727	1.00	-	-
728 – 1137	0.66	0.33 – 1.31	0.230
1138 – 1455	1.16	0.46 – 2.96	0.751
≥1456	0.54	0.28 – 1.05	0.067*
Worked on a dairy farm (standardized yrs)			
≤42	1.00	-	-
43 – 62	0.95	0.50 – 1.83	0.881
63 – 86	1.41	0.70 – 2.81	0.334
≥87	1.49	0.74 – 3.00	0.261
Manually feeding (hrs/yr)			
≤317	1.00	-	-
318 – 445	1.11	0.58 – 2.11	0.753
446 – 727	1.64	0.77 – 3.50	0.200
≥728	0.98	0.54 – 1.79	0.958
Tractor use (hrs/yr)			
≤545	1.00	-	-
546 – 1159	0.77	0.39 – 1.52	0.453
1160 – 1637	2.27	1.07 – 4.79	0.032
≥1638	1.01	0.51 – 1.99	0.984
Carrying or lifting ≥23 kg (hrs/yr)			
Zero	1.00	-	-
0.5 – 363	1.30	0.72 – 2.38	0.386
≥364	1.03	0.58 – 1.82	0.929

Table 3.7 Continued

Manually cleaning animal stalls (hrs/yr)			
Zero	1.00	-	-
0.4 – 273	1.44	0.81 – 2.57	0.218
≥1275	1.98	1.12 – 3.49	0.018
Artificial Insemination (hrs/yr)			
Zero	1.00	-	-
3.5 – 728	0.88	0.53 – 1.47	0.629
Smoking			
Never Smoker	1.00	-	-
Ever Smoker	1.26	0.66 – 2.42	0.489
Body Mass Index (kg/m^2)	1.00	0.95 – 1.06	0.998

[A] Age and gender adjusted

* Significant at $p \leq 0.15$

Table 3.8 Adjusted Low Back MSS Odds Ratios for Dairy Farming Exposures

	Symptoms		Adjusted[A]		Adjusted[A]
	Yes	No	Odds Ratio	95% CI	Trend Test
Type of Milking Operation					
Parlor	62	41	1.00	-	
Stanchion	164	71	1.55	0.90 – 2.65	-
Milking (hrs/yr)					
≤727	37	19	1.00	-	
728 – 1137	78	36	0.44	0.21 – 0.95	
1138 – 1455	32	9	0.88	0.33 – 2.38	
≥1456	80	50	0.41	0.20 – 0.84	$p = 0.062$
Tractor use (hrs/yr)					
≤545	54	30	1.00	-	
546 – 1159	49	35	0.71	0.34 – 1.48	
1160 – 1637	68	17	2.16	0.97 – 4.80	
≥1638	56	32	0.93	0.45 – 1.93	$p = 0.490$
Manually cleaning animal stalls (hrs/yr)					
Zero	58	43	1.00	-	
0.4 – 273	73	36	1.34	0.72 – 2.49	
≥1275	96	35	1.88	1.01 – 3.49	$p = 0.046$

[A] Age and gender adjusted

Table 3.9 Bivariate Hip MSS Odd Ratios for Dairy Farming Exposures

	Bivariate OR[A]	95% CI	*p*-value
Type of Milking Operation			
Parlor	1.00	-	-
Stanchion	1.14	0.70 – 1.84	0.606
Milking (hrs/yr)			
≤727	1.00	-	-
728 – 1137	1.43	0.74 – 2.75	0.290
1138 – 1455	1.26	0.55 – 2.90	0.582
≥1456	1.47	0.78 – 2.78	0.238
Worked on a dairy farm (standardized yrs)			
≤42	1.00	-	-
43 – 62	0.86	0.45 – 1.63	0.641
63 – 86	0.97	0.49 – 1.91	0.925
≥87	1.86	0.95 – 3.64	0.068*
Manually feeding (hrs/yr)			
≤317	1.00	-	-
318 – 445	1.30	0.70 – 2.40	0.405
446 – 727	1.35	0.68 – 2.69	0.390
≥728	0.87	0.48 – 1.58	0.650
Tractor use (hrs/yr)			
≤545	1.00	-	-
546 – 1159	1.53	0.78 – 3.02	0.221
1160 – 1637	1.88	0.94 – 3.74	0.074*
≥1638	1.31	0.66 – 2.61	0.442
Carrying or lifting ≥23 kg (hrs/yr)			
Zero	1.00	-	-
0.5 – 363	1.84	1.02 – 3.32	0.042*
≥364	1.29	0.72 – 2.31	0.387

Table 3.9 Continued

Manually cleaning animal stalls (hrs/yr)			
Zero	1.00	-	-
0.4 – 273	2.33	1.28 – 4.22	0.005*
≥1275	1.85	1.04 – 3.28	0.035*
Artificial Insemination (hrs/yr)			
Zero	1.00	-	-
3.5 – 728	0.78	0.47 – 1.28	0.321
Smoking			
Never Smoker	1.00	-	-
Ever Smoker	0.76	0.40 – 1.44	0.395
Body Mass Index (kg/m^2)	1.05	0.99 – 1.10	0.090*

[A] Age and gender adjusted

* Significant at $p \leq 0.15$

Table 3.10 Adjusted Hip MSS Odds Ratios for Dairy Farming Exposures

	Symptoms		Adjusted[A]		Adjusted[A]
	Yes	No	Odds Ratio	95% CI	Trend Test
Type of Milking Operation					
Parlor	37	92	1.00	-	
Stanchion	66	143	1.00	0.56 – 1.78	-
Milking (hrs/yr)					
≤727	21	45	1.00	-	
728 – 1137	41	63	0.95	0.43 – 2.07	
1138 – 1455	15	26	0.98	0.38 – 2.58	
≥1456	52	78	1.08	0.52 – 2.26	$p = 0.718$
Worked on a dairy farm (standardized yrs)					
≤42	30	52	1.00	-	
43 – 62	28	59	0.99	0.46 – 2.09	
63 – 86	28	56	1.46	0.66 – 3.24	
≥87	43	45	2.87	1.27 – 6.49	$p = 0.007$
Tractor use (hrs/yr)					
≤545	28	56	1.00	-	
546 – 1159	33	51	1.07	0.49 – 2.34	
1160 – 1637	37	48	1.19	0.53 – 2.69	
≥1638	31	57	0.98	0.44 – 2.20	$p = 0.967$
Carrying or lifting ≥23 kg (hrs/yr)					
Zero	28	61	1.00	-	
0.5 – 363	52	64	1.34	0.66 – 2.72	
≥364	49	87	0.88	0.43 – 1.78	$p = 0.522$
Manually cleaning animal stalls (hrs/yr)					
Zero	28	73	1.00	-	
0.4 – 273	49	60	2.45	1.19 – 5.29	
≥1275	52	79	2.00	1.00 – 4.00	$p = 0.090$

[A] Age, gender and BMI adjusted

Table 3.11 Bivariate Knee MSS Odd Ratios for Dairy Farming Exposures

	Bivariate OR[A]	95% CI	*p*-value
Type of Milking Operation			
Parlor	1.00	-	-
Stanchion	1.57	0.98 – 2.51	0.061*
Milking (hrs/yr)			
≤727	1.00	-	-
728 – 1137	1.50	0.80 – 2.83	0.210
1138 – 1455	1.12	0.51 – 2.49	0.773
≥1456	1.35	0.73 – 2.49	0.333
Worked on a dairy farm (standardized yrs)			
≤42	1.00	-	-
43 – 62	1.51	0.81 – 2.79	0.192
63 – 86	1.60	0.83 – 3.06	0.159
≥87	2.22	1.13 – 4.34	0.020*
Manually feeding (hrs/yr)			
≤317	1.00	-	-
318 – 445	1.36	0.74 – 2.51	0.318
446 – 727	2.34	1.15 – 4.79	0.020*
≥728	1.49	0.84 – 2.64	0.176
Tractor use (hrs/yr)			
≤545	1.00	-	-
546 – 1159	1.47	0.76 – 2.83	0.248
1160 – 1637	1.68	0.86 – 3.29	0.131*
≥1638	1.52	0.78 – 2.93	0.217
Carrying or lifting ≥23 kg (hrs/yr)			
Zero	1.00	-	-
0.5 – 363	1.54	0.88 – 2.73	0.134*
≥364	1.74	1.00 – 3.03	0.051*

Table 3.11 Continued

Manually cleaning animal stalls (hrs/yr)			
Zero	1.00	-	-
0.4 – 273	1.53	0.87 – 2.68	0.139*
≥1275	2.10	1.22 – 3.62	0.008*
Artificial Insemination (hrs/yr)			
Zero	1.00	-	-
3.5 – 728	0.85	0.52 – 1.38	0.514
Smoking			
Never Smoker	1.00	-	-
Ever Smoker	0.46	0.23 – 0.94	0.033*
Body Mass Index (kg/m^2)	1.05	0.99 – 1.11	0.093*

[A] Age and gender adjusted

* Significant at $p \leq 0.15$

Table 3.12 Adjusted Knee MSS Odds Ratios for Dairy Farming Exposures

	Symptoms		Adjusted[A]		Adjusted[A]
	Yes	No	Odds Ratio	95% CI	Trend Test
Type of Milking Operation					
Parlor	54	49	1.00	-	
Stanchion	149	86	1.41	0.77 – 2.56	-
Milking (hrs/yr)					
≤727	36	20	1.00	-	
728 – 1137	66	38	0.88	0.39 – 1.96	
1138 – 1455	23	18	0.97	0.35 – 2.70	
≥1456	79	51	0.96	0.45 – 2.08	$p = 0.952$
Worked on a dairy farm (standardized yrs)					
≤42	41	41	1.00	-	
43 – 62	52	35	1.90	0.87 – 4.14	
63 – 86	51	33	1.92	0.85 – 4.35	
≥87	60	28	3.00	1.23 – 7.31	$p = 0.023$
Manually feeding (hrs/yr)					
≤317	44	41	1.00	-	
318 – 445	50	35	1.27	0.58 – 2.79	
446 – 727	41	17	1.29	0.53 – 3.14	
≥728	69	44	0.90	0.42 – 1.93	$p = 0.644$
Tractor use (hrs/yr)					
≤545	45	39	1.00	-	
546 – 1159	51	33	1.10	0.42 – 2.53	
1160 – 1637	54	31	1.15	0.48 – 2.76	
≥1638	54	34	1.15	0.48 – 2.74	$p = 0.750$
Carrying or lifting ≥23 kg (hrs/yr)					
Zero	46	43	1.00	-	
0.5 – 363	71	45	1.17	0.57 – 2.42	
≥364	87	49	1.30	0.62 – 2.74	$p = 0.489$

Table 3.12 Continued

Manually cleaning animal stalls (hrs/yr)					
Zero	51	50	1.00	-	
0.4 – 273	65	44	1.29	0.62 – 2.71	
≥1275	88	43	1.53	0.74 – 3.16	$p = 0.252$

[A] Age, gender, smoking and BMI adjusted

Table 3.13 Bivariate Feet MSS Odd Ratios for Dairy Farming Exposures

	Bivariate OR[A]	95% CI	p-value
Type of Milking Operation			
Parlor	1.00	-	-
Stanchion	0.85	0.52 – 1.38	0.505
Milking (hrs/yr)			
≤727	1.00	-	-
728 – 1137	0.774	0.40 – 1.51	0.453
1138 – 1455	0.90	0.39 – 2.09	0.806
≥1456	1.24	0.66 – 2.33	0.500
Worked on a dairy farm (standardized yrs)			
≤42	1.00	-	-
43 – 62	0.73	0.38 – 1.42	0.354
63 – 86	1.07	0.54 – 2.09	0.854
≥87	1.27	0.65 – 2.50	0.487
Manually feeding (hrs/yr)			
≤317	1.00	-	-
318 – 445	0.73	0.38 – 1.40	0.340
446 – 727	1.23	0.61 – 2.46	0.565
≥728	1.01	0.56 – 1.82	0.984
Tractor use (hrs/yr)			
≤545	1.00	-	-
546 – 1159	1.19	0.60 – 2.35	0.621
1160 – 1637	0.84	0.41 – 1.72	0.633
≥1638	1.47	0.75 – 2.90	0.264
Carrying or lifting ≥23 kg (hrs/yr)			
Zero	1.00	-	-
0.5 – 363	1.33	0.74 – 2.40	0.337
≥364	0.97	0.54 – 1.74	0.915

Table 3.13 Continued

Manually cleaning animal stalls (hrs/yr)			
Zero	1.00	-	-
0.4 – 273	1.49	0.83 – 2.67	0.179
≥1275	1.00	0.57 – 1.76	0.997
Artificial Insemination (hrs/yr)			
Zero	1.00	-	-
3.5 – 728	1.21	0.74 – 2.00	0.449
Smoking			
Never Smoker	1.00	-	-
Ever Smoker	1.38	0.69 – 2.74	0.361
Body Mass Index (kg/m^2)	1.01	0.96 – 1.07	0.618

[A] Age and gender adjusted

* Significant at $p \leq 0.15$

Table 3.14 Adjusted Feet MSS Odds Ratios for Dairy Farming Exposures

	Symptoms		Adjusted[A]		Adjusted[A]
	Yes	No	Odds Ratio	95% CI	Trend Test
Type of Milking Operation					
Parlor	38	78	1.00	-	
Stanchion	65	157	0.90	0.55 – 1.47	-
Milking (hrs/yr)					
≤727	23	43	1.00	-	
728 – 1137	30	74	0.75	0.38 – 1.49	
1138 – 1455	13	28	0.86	0.37 – 1.99	
≥1456	51	79	1.16	0.62 – 2.19	$p = 0.329$

[A] Age and gender adjusted

CHAPTER IV

KNEE FLEXION EXPOSURE AMONG DAIRY FARMERS

Abstract

Background: Musculoskeletal disorders are common among agricultural workers. Among agricultural workers, dairy farmers have been identified as being at risk for knee osteoarthritis. Physical risk factors that may contribute to knee osteoarthritis include awkward postures of the knee. The purpose of this study was to quantify knee flexion exposure among dairy farmers 1) while milking and 2) while feeding in two common types of milking facilities (stanchion and parlor).

Methods: Twenty-three dairy farmers performed milking and feeding tasks, 11 worked in a stanchion milking facility, and 12 worked in a parlor milking facility. An electrogoniometer was used to measure knee flexion during 30 minutes of the milking and feeding tasks. A split-plot repeated measures ANOVA was used to test for statistically significant differences in exposure to knee flexion while milking and feeding in both stanchion and parlor facilities.

Results: Stanchion milking results in a greater magnitude and duration of knee flexion exposure compared to feeding in a stanchion, and milking and feeding in a parlor. All tasks (milking and feeding) and milking facilities (stanchion and parlor) result in exposure to knee moments and compressive forces which are greater than what is experienced while rising from a chair.

Conclusions: The results suggest that working in stanchion milking facility results in greater exposure to physical risk factors for knee musculoskeletal symptoms such as awkward postures compared to working in a parlor milking facility. The results of this study may lead to future studies on ways to prevent exposure to knee flexion.

Background and Significance

Work-related musculoskeletal disorders (MSDs) are painful, often disabling, and expensive (NIAMS). Among MSDs, knee osteoarthritis (OA) is often associated with disability (Felson et al., 1991; Manninen et al., 2002). Farm workers have been identified as being at an increased risk of developing knee MSDs and OA compared to the general population (Manninen et al., 2002; Sandmark et al., 2000)[Vingård, 1991]. Dairy farmers are especially at risk for developing knee OA (Anderson et al., 1989; Gomez et al., 2003; Gustafsson et al., 1994; Holmberg et al., 2002).

Physical risk factors for knee OA that have been identified with agricultural work are frequent knee flexion exposure including knee bending, kneeling, squatting, and climbing (Anderson et al., 1989; Cooper et al., 1994; McAlindon et al., 1999; Vingård et al., 1991). Activities that including knee bending, kneeling, squatting, and climbing are thought to generate high knee moments and compressive forces which may contribute to knee OA (Dahlkvist et al., 1982; Escamilla, 2001; Felson et al., ; Felson et al., 1997; McAlindon et al., 1999; Nagura et al., 2002; Reilly & Martens, 1972).

Multiple studies have evaluated the physical risk factors associated with MSDs among dairy farmers (Ahonen et al., 1990; Arborelius et al., 1986; Ekholm et al., 1985; Lundqvist et al., 1997; Nemeth et al., 1990; Nevala-Puranen et al., 1996; Nevala-Puranen et al., 1993; Perkiö-Mäkelä & H, 2005; Stål et al., 1999; Stål et al., 1996; Stål et al., 2003; Svensson et al., 1985), but few have assessed the lower extremity. Ekholm et al. (1985) found that 108° knee flexion angle had produced the peak knee loading moment during simulated cow milking. Svensson et al. (1985) found that working with bent knee postures produced greater mechanical forces on the lower extremities compared to straight knee postures.

Knee flexion exposures may be different among dairy farmers who work in the two predominant types of milking facilities (stanchion and parlor). Several have evaluated awkward postures among dairy farmers who work these milking facilities.

Nevala-Puranen et al. (1996) observed a combination of flexed knee postures that accounted for 32% of the working time among stanchion milkers. In contrast, Perkiö-Mäkelä et al. (2005) noted a combination of flexed knee postures that accounted for 2% of the working time among parlor milkers. Clearly, workers who use stanchion milking technologies utilize different postures for the lower extremity to complete the work. These studies were done on Scandinavian dairy farmers, and dairy farm tasks may be quite different than the tasks performed by U.S. dairy farmers. Additionally, Nevala-Puranen et al. (1996) and Perkiö-Mäkelä et al. (2005) estimated exposure to awkward postures using observational methods. Other researchers have determined that observational methods of exposure assessment are not as accurate as direct methods, such as electrogoniometry (Burdorf, 1992). To date, no study has evaluated the intensity, frequency and duration of knee flexion exposure among dairy farmers using direct methods. Hence, more studies using direct methods are needed to assess awkward postures among dairy farmers.

The purpose of this study was to determine the knee flexion exposure associated with milking and feeding tasks for both stanchion and parlor milking facilities. When the extent of knee flexion exposure to dairy farmers has been determined for milking and feeding in stanchion and parlor milking facilities, recommendations can be made as to which combination of task and facility results in lower knee flexion exposure among dairy farmers. Reducing knee flexion exposure is important as it may decrease incident knee musculoskeletal symptoms and knee MSDs. In addition, this study could lead to the research and development of other interventions to prevent future MSDs and knee OA in dairy farmers.

Methods

Study Sample

Twenty-four male dairy farmers participated in this exposure assessment study; 12 worked in a stanchion facility and 12 worked in a parlor facility. The mean age of the dairy farmers was 42.8 years (SD=9.9), the mean weight was 80.8 m (SD=9.2), and the mean height was 1.8 m (SD=0.05). An attempt was made to match stanchion and parlor workers on age, gender, height, and weight (Table 4.1).

The study inclusion criteria were the lack of knee pain or knee disorder within the last 12 months and lack of previous knee surgery. The investigators obtained University of Iowa Institutional Review Board approval prior to all contact, and participants were compensated $40 for participating in the study.

Instrumentation

A flexible biaxial knee electrogoniometer (electrogoniometer) SG150 (Biometrics Ltd, Cwmfelinfach, UK), was used to measure knee flexion exposure. The electrogoniometer consisted of two end blocks attached by an electrical resistor which was covered by a flexible spring. The flexibility of the resistor followed the joint articulation allowing complete freedom of movement. When the resistor was bent during joint articulation the electrical resistance changes, thus creating a voltage differential across the electrogoniometer end blocks. The voltage differential was linearly proportional to the angular relationship between the electrogoniometer end blocks and has been reported to be accurate to $\pm 2^{o}$ (Goniometer and Torsiometer Operating Manual, Biometrics Ltd, Cwmfelinfach, UK) (Appendix B). The electrogoniometer was connected to a personal data logger (DataLOG, Biometrics Ltd, Cwmfelinfach, UK) and data was recorded at 50 Hz (Winter, 1990). Previous researchers have used these methods to determine knee flexion in a laboratory setting and to compare the level of knee flexion between two populations (Maupas, Paysant, Martinet, & Andre, 1999; Walker, Myles, Nutton, & Rowe, 2001).

Procedures

Using double sided tape, the electrogoniometer was affixed to the lateral aspect of the dominant knee. The electrogoniometer and leg were then wrapped with Coban™ (3M, Minneapolis, MN) (Figure 4.1). The Coban™ also served as a way to protect the electrogoniometer from bumps and environmental factors (e.g. manure) while under the clothing.

The dominant knee was determined by handedness of the participant. Hair was removed from the skin to allow placement of the electrogoniometer. The subject was asked to stand comfortably, while the researcher applied the electrogoniometer to the skin surface. Electrogoniometer placement on the lower thigh was determined by estimating the location of the femur from a sagittal view of the subject's thigh, and then placing the electrogoniometer directly over the femur.

The electrogoniometer placement on the calf was determined by palpating fibular head, and placing the electrogoniometer just below the landmark. Additionally, when placing the electrogoniometer an attempt was made to visually orient the angular relationship between the electrogoniometer end blocks to zero degrees.

The electrogoniometer voltage was "zeroed" by asking the subject to stand comfortably at full knee extension. Zeroing the electrogoniometer balanced the voltage across the electrogoniometer. This balancing provided a reference point from which all future knee movement would be based upon. This calibration method has been used by previous investigators (Stål et al., 1999). Knee flexion exposure was measured for approximately 35 minutes per task (milking or feeding) with the data being analyzed from five minutes after the task began, up until 35 minutes into the task.

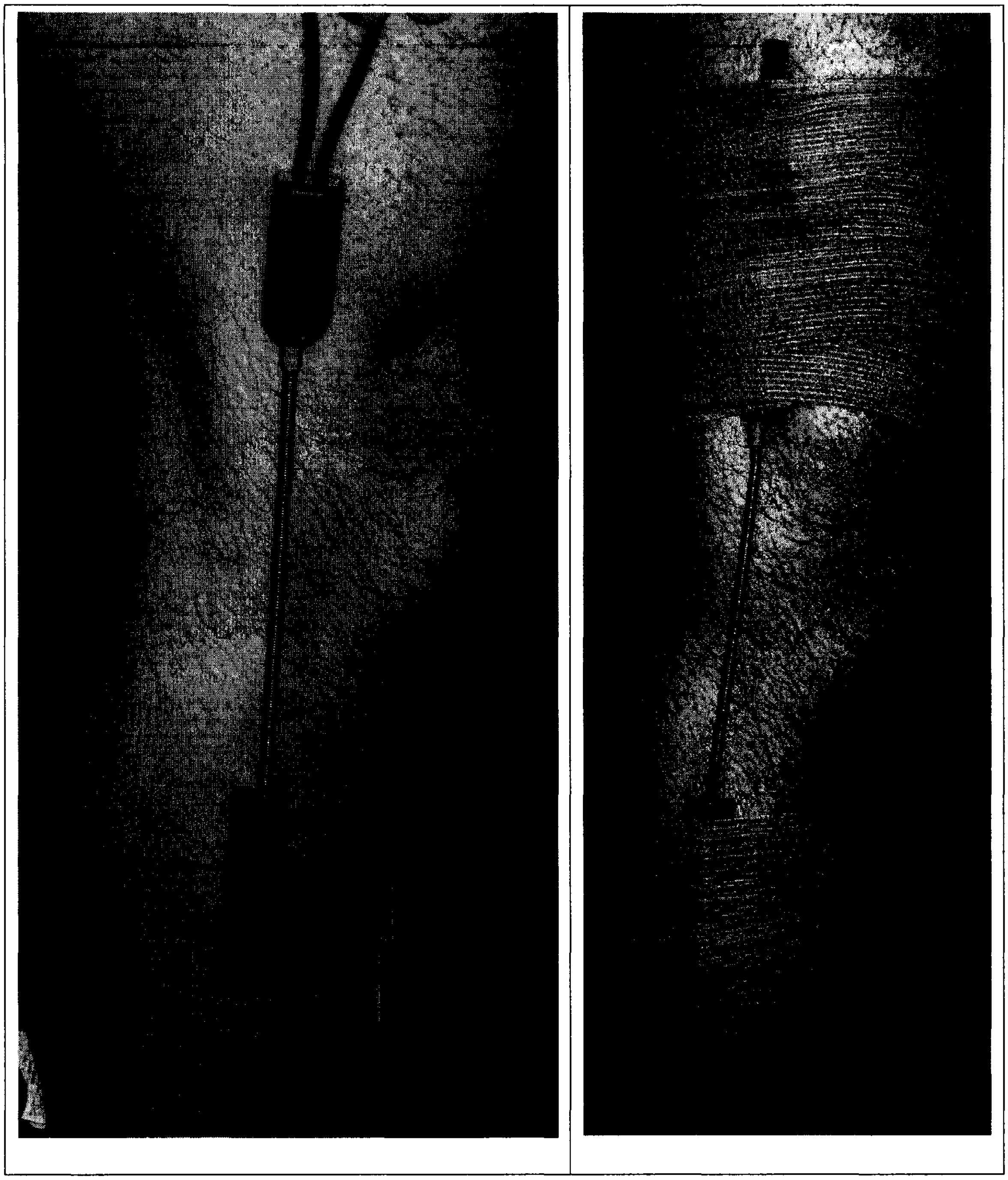


Figure 4.1. Placement of the Electrogoniometer on the Leg and Coban™ (3M, Minneapolis, MN) Was Used to Secure Electrogoniometer During Data Collection.

The first five minutes of data were excluded from analyses to allow the participant appropriate time to become comfortable performing the task, while data were collected. Milking and feeding tasks were performed at least once per day, and in some cases three to four times per day, which allowed many opportunities for data collection. Discussions with each participant took place after monitoring to ensure that the work observed was typical. If the observed work was considered atypical, the data were recollected. The data were downloaded to a personal computer for storage and analysis. All data collected with the electrogoniometer were entered into SPSS (SPSS Inc, Chicago, IL) data analysis software.

Analysis of Electrogoniometric Results

Knee posture was categorized *a priori* into percent time spent ≥70° knee flexion, and ≥110° knee flexion. The analysis of knee posture compared the percent time parlor workers spent in each posture category to the percent time stanchion workers spent in each posture category for milking and feeding tasks. The ≥70° category was based on the typical knee moment and compressive forces generated on the knee while rising from a chair (Rodosky et al., 1989). This activity was chosen as a benchmark for exposure to knee forces because rising from a chair is a normal activity and is performed daily. The ≥ 110° category was based on the peak moment and compressive forces typically generated on the knee during squatting (Dahlkvist et al., 1982; Escamilla, 2001; Nagura et al., 2002; Reilly & Martens, 1972). Squatting was thought to represent occupational activities that occur on a dairy farm, such as milking and feeding.

Statistical Analysis

A split-plot repeated measures analysis of variance (ANOVA) was used to test for significant differences in percent time spent in each of the knee flexion categories (% time ≥70°; % time ≥110°) for each facility and task. The between subjects factor was type of milking facility (stanchion or parlor) and the within subjects factor was task (milking and feeding). Means and SDs were calculated for percent time spent knee flexion categories for both tasks (milking and feeding) and types of milking facilities (stanchion or parlor). Associations are considered statistically significant at $p = 0.05$. When a statistically significant interaction existed between the main effects variables (type of milking facility and task), simple effects analyses were used (Page, 2003).

Results

A full 30 minute period of data collection could not be obtained from 13 of the 23 feeding tasks. In total, 23 participants performed both milking and feeding tasks for this study for an average of 26.3 minutes per task. One participant performed only the milking task, and was subsequently removed from the analysis. Although normality was not assessed, this assumption was robust to violation since there was at least 20 degrees of freedom for each error term (Tabachnick & Fidell).

Descriptive Data by Type of Milking Facility and Task

Descriptive statistics (means and standard deviations) for knee posture and for the percentage of time spent in categories of knee flexion are presented in Tables 4.2 and 4.3. Parlor milking resulted in the least amount of knee flexion compared to all other combinations of tasks and milking facilities. Additionally, the mean knee flexion associated with the feeding tasks for both types of milking facilities (stanchion or parlor) was similar to the mean knee flexion observed in stanchion milking. Parlor milking resulted in the least amount of time spent in categories of exposure to knee flexion.

Statistical Comparison of Percent Time in Posture Categories by Type of Milking Facility and Farm Task

A main-effects analysis revealed a statistically significant interaction between the type of milking facility (stanchion and parlor) and task (milking and feeding) ($p \leq 0.02$)

for both knee posture categories ($\geq 70°$ and $\geq 110°$ knee flexion). As a result of this interaction, simple effects analyses were performed.

The proportion of time that stanchion milkers were in the knee flexion exposure categories ($\geq 70°$ and $\geq 110°$ knee flexion) was significantly greater than for parlor milkers ($p \leq 0.001$, Tables 4.4 – 4.5). Additionally, parlor feeding resulted in significantly more time spent in $\geq 70°$ knee flexion compared to parlor milking ($p \leq 0.03$, Table 4.8). Stanchion milking also resulted significantly more time spent in knee postures $\geq 110°$ knee flexion compared to stanchion feeding ($p \leq 0.001$, Table 4.9). However, there was no statistically significant difference in time spent in either of the knee flexion exposure categories for the task of feeding across type of milking facility (stanchion or parlor) ($p \geq 0.19$, Tables 4.6 – 4.7).

Discussion

The milking parlor was originally designed as a more productive method of cow milking, compared to stanchion milking (Tranel, L. 2004 personal communication). The results of this study suggest that the milking parlor also results in decreased musculoskeletal load of the knee compared to stanchion milking. When compared to stanchion milking, parlor milkers spent less time in both knee flexion exposure categories ($\geq 70°$ knee flexion and $\geq 110°$ knee flexion). Specifically, parlor milkers spent about 0.05% of the milking task in knee postures that have been identified as having peak knee moments and compressive forces ($\geq 110°$ knee flexion) compared to nearly 18% for stanchion milkers (Table 4.2) (Dahlkvist et al., 1982; Escamilla, 2001; Nagura et al., 2002; Reilly & Martens, 1972). Consequently, the parlor milking facility may be an expensive, but good intervention for decreasing knee flexion exposures during milking tasks among dairy farmers.

When milking in a stanchion facility, dairy farmers flexed their knee $\geq 70°$ for 22% of the time. Additionally, when milking in a stanchion dairy farmers flexed their knee ≥110° for nearly 18% of the time. The difference between the knee flexion exposure categories (% time ≥70° and ≥110°) was only about 4% for stanchion milkers. This small difference indicates that majority of the knee flexion exposure ≥70° is in fact ≥110°, which has been identified with peak knee moments and compressive forces (Dahlkvist et al., 1982; Escamilla, 2001; Nagura et al., 2002; Reilly & Martens, 1972). These high knee moments and compressive forces may contribute to knee OA (Felson et al., ; McAlindon et al., 1999). Stanchion milking is more common than parlor milking (Tranel, L.2004 personal communication). Consequently, knee flexion exposure that results from stanchion milking may account for the observed higher proportion of knee OA among dairy farmers compared to farmers who specialize in other types of production (Anderson et al., 1989).

Feeding tasks associated with both types of milking facilities (stanchion or parlor) were also assessed for awkward postures of the knee. No statistical difference was found between the feeding tasks associated with stanchion or parlor milking facilities, and a small proportion of the feeding in both types of milking facilities resulted in knee flexion ≥110°. The inability to determine a difference between feeding tasks across milking facilities may be due to the high variability of the task within and across type of milking facility (stanchion or parlor).

However, feeding in both types of facilities resulted in a substantial proportion of the task (about 20%) requiring knee flexion ≥70°. Additionally, significantly more knee flexion exposure (≥70°) occurs while feeding in a parlor facility compared to milking in a parlor facility. Knee flexion beyond 70° resulted in knee moments greater than what is experienced from daily activities such as rising from a chair (Rodosky et al., 1989). Exposure to knee flexion above what is experienced from daily activities may contribute to knee OA.

Parlor feeding resulted in more knee flexion exposure (≥70° knee flexion) compared to parlor milking. This difference was statistically significant (Table 4.8).

Additionally, stanchion milking resulted in more knee flexion exposure (≥110° knee flexion) compared to stanchion feeding. This difference was also statistically significant (Table 4.9). Comparing tasks within type of milking facility was not the primary goal of this study. However, finding a significant difference between tasks (milking and feeding) was an indication of the variability of exposures within a milking facility.

Variability of exposure can be used as an advantage for ergonomic interventions Workers can be rotated between tasks to dilute the work exposure across all rotating workers, and not have one worker highly exposed (NIOSH, 1997a). This practice of worker rotation is often described as an administrative control (NIOSH, 1997a). In the specific case of dairy farming, where parlor feeding results in significantly more knee flexion exposure compared to parlor milking, the practice of worker rotation might be a good ergonomic intervention. If more that one person is involved in the work process, the time spent feeding may be divided up between the workers, which would reduce individual exposure. However, in the case of the stanchion milking facility, rotation may not be an advantage because both tasks (milking and feeding) result in exposures that may be harmful to the knee.

Previous investigators have identified stanchion work as being associated with awkward postures, and have reported results similar to what was observed in the current study (Lundqvist et al., 1997; Nevala-Puranen et al., 1996; Perkiö-Mäkelä & H, 2005). Perkiö-Mäkelä et al. (2005) found similar results for milking in a parlor. The investigators reported that parlor milkers spent about 1% of the task with one or both knees bent. However, the parlor feeding task resulted in one or both knees bent about 4% of the time. This observation is quite different from what was observed in the current study (20% of the time ≥70°). Lundqvist et al. (1997) found "unacceptable working postures" 38% of the time in stanchion milking facilities, compared to only 10% of the time in parlor milking facilities. However, the investigators did not differentiate awkward postures by body site (e.g. back, arms, and legs), so comparing results to the current study is difficult. Nevala-Puranen et al. (1996) found results similar to what was observed in the current study. Bent knee postures were observed among stanchions milkers for 29% of the time, compared to 2% for parlor milkers (Nevala-Puranen et al., 1996).

Differences between previous studies and the current study may be explained by the accuracy of exposure assessment techniques that were employed. Previous studies used observational exposure assessment techniques (Lundqvist et al., 1997; Perkiö-Mäkelä & H, 2005). The current study employed a direct exposure assessment method, which has been identified as a more accurate and precise method to assess exposure to physical risk factors for MSDs (Burdorf, 1992; Spielholz et al., 2001).

Limitations

A limitation of this study is that posture duration was the only exposure metric employed. Physical risk factors that were not evaluated and have been associated with MSDs in other body sites may also contribute to knee MSDs (e.g. physical load). Additionally, the postures that were identified as hazardous were based on 2-dimesional biomechanical analysis (Nagura et al., 2002; Rodosky et al., 1989). Other methods of biomechanical analysis such as 3-dimensional modeling and *in vivo* knee measurements may be better estimates of knee moments and compressive forces. However, this study is the first study that has evaluated knee flexion exposure among dairy farmers using direct methods. To our knowledge, this is the first study to evaluate knee flexion exposure using direct methods in any occupational setting.

An additional limitation of this study is that only one knee was measured during the milking and feeding tasks. The knee flexion exposure that the other knee may experience is unknown. However, even if the other knee of the participant experienced zero exposure to knee flexion, the level of exposure observed for one knee among stanchion milkers warrants further investigation.

Another limitation of this study is that the task observed (milking or feeding) may not accurately represent typical work for that task. To address this issue, data was collected on the majority of participants for about 30 minutes, and participants were allowed 5 minutes to settle in to the task prior to data collection. Additionally at the end of each data collection period, participants were asked if the task (milking or feeding) they just performed were typical. Participants were also asked if the milking and feeding tasks they performed were typical for the dairy industry. Any work that was deemed atypical was not included in the study.

The electrogoniometer calibration technique used in this study may cause an over estimation of knee flexion. To calibrate the electrogoniometer, the minimum knee flexion value for each subject was recoded as zero knee flexion. It may be the case that knee flexion values were overestimated due to genu recurvatum. This may have been the case for one participant who had a knee flexion range from 0° – 181° knee flexion. However, genu recurvatum was not likely differentially distributed across types of milking facilities (stanchion or parlor).

Properly securing the electrogoniometer across the knee is important so that the data collected reflects the knee motion (Biometrics). For one participant, the sweat produced during monitoring had an effect on the adherence of the double sided tape to the participant's skin. To combat this problem, Coban™ was using in addition to the double sided tape during all tasks to secure the electrogoniometer.

Future research should focus on simple and inexpensive ergonomic interventions to reduce the incidence of MSDs. Some simple interventions may include installing a structure in stanchion facilities so the upper extremity can assist in rising from a squat. This structure could be in the form of a rope hanging from the ceiling, or a more rigid structure with a handle. The authors have observed stanchion milkers using the tail of the milk cow to assist in rising from a squat, but possibly a permanently fixed structure would be better suited for the task. Using the upper extremity to assist in rising from a squat will likely reduce the moment and compressive forces on the knee while rising from a squat.

Future research should focus on biomechanical modeling to more accurately assess knee moments, compressive forces, and mechanical loads associated with squatting. The data collected in this study could be applied to this biomechanical model to gain a better estimation of knee flexion exposure during stanchion milking. Additionally, this new biomechanical model could also be applied to estimated knee flexion exposure in any industry where squatting is common during daily work tasks (e.g. construction).

Conclusion

Of the tasks assessed in this study (stanchion milking, stanchion feeding, parlor milking, parlor feeding) stanchion milking resulted the most time spent in knee flexion postures. Knee flexion exposure was much lower among parlor milkers. These data provide evidence that parlor milking may reduce the risk for developing knee MSS compared to stanchion milking.

Little difference was found between types of milking facilities (stanchion or parlor) for the feeding task. This task was highly variable, but stanchion feeding resulted in significantly less knee flexion exposure compared to stanchion milking. Future studies should focus on reducing exposures to knee moments and compressive forces through ergonomic interventions. Implementing interventions that reduce the moment and compressive forces associated with knee flexion exposure may reduce the risk of developing knee MSS.

Table 4.1 Demographic Data of Participants

	All Subjects (n = 24)	Stanchion (n =12)	Parlor (n =12)
Characteristic	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	42.8 (9.92)	43.8 (9.67)	41.7 (10.48)
Weight (kg)	80.8 (9.23)	82.8 (10.15)	78.9 (8.21)
Height (m)	1.80 (0.05)	1.80 (0.05)	1.80 (0.02)

Table 4.2. Summary Statistics of Knee Flexion by Type of Milking Facility and Task

	Stanchion		Parlor	
	Milking	Feeding	Milking	Feeding
Mean (SD; ° flexion)	44 (16)	40 (11)	19 (4)	45 (20)
Range (° flexion)	0 - 181	0 - 170	0- 172	0 - 144

Table 4.3. Summary Statistics for Percent Time Spent in Knee Flexion Exposure Categories by Task and Type of Milking Facility

	Stanchion		Parlor	
Facility by Task by Knee Flexion Exposure Category	Milking	Feeding	Milking	Feeding
Percent Time ≥70° Knee Flexion	22 (15)	17.3 (14.1)	1.39 (1.8)	19.9 (24.9)
Percent Time ≥110° Knee Flexion	17.7 (14.7)	2.3 (3.7)	0.05 (0.15)	1.0 (1.9)

Table 4.4. Simple Effects Analysis for the Percent Time Spent in ≥70° Knee Flexion Exposure for the Between Subjects Factor of Facility Within Milking Task

Source	*df*	*SS*	*MS*	*F*
Within Subjects				
Milking	1	3462.61	3462.61	29.20
Facility within milking task	1	2722.43	2722.43	22.96*
Error (Within)	21	2490.04	118.57	
Total	23	8675.08		

* $p \leq 0.001$

Table 4.5. Simple Effects Analysis for the Percent Time Spent in ≥110° Knee Flexion Exposure for the Between Subjects Factor of Facility Within Milking Task

Source	*df*	*SS*	*MS*	*F*
Within Subjects				
Milking	1	1941.65	1941.65	17.55
Facility within milking	1	1920.38	1920.38	17.36*
Error (Within)	21	2322.80	110.61	
Total	23	1257.17		

p ≤0.001

Table 4.6. Simple Effects Analysis for the Percent Time Spent in ≥70° Knee Flexion Exposure for the Between Subjects Factor of Facility within Feeding Task

Source	*df*	*SS*	*MS*	*F*
Within Subjects				
Feeding	1	7962.79	7962.79	19.06
Facility within feeding task	1	38.71	38.71	0.09
Error (Within)	21	8772.26	417.73	
Total	23	16773.76		

Table 4.7. Simple Effects Analysis for the Percent Time Spent in ≥110° Knee Flexion Exposure for the Between Subjects Factor of Facility Within Feeding Task

Source	*df*	*SS*	*MS*	*F*
Within Subjects				
Feeding	1	58.78	58.78	7.04
Facility within feeding	1	9.72	9.72	1.16
Error (Within)	21	175.42	8.35	
Total	23	1257.17		

Table 4.8. Simple Effects Analysis for the Percent Time Spent in ≥70° Knee Flexion Exposure for the Within Subjects Factor of Task (Milking or Feeding) by Type of Facility

Source	*df*	*SS*	*MS*	*F*
Stanchion Tasks (milking and feeding)	1	187.94	187.94	0.67
Parlor Tasks (milking and feeding)	1	2060.46	2060.46	7.30*
Error (Within)	21	282.42	282.42	
Total	23	5061.64		

* p $\leq$0.02

Table 4.9. Simple Effects Analysis for the Percent Time Spent in ≥110° Knee Flexion Exposure for the Within Subjects Factor of Task (Milking or Feeding) by Type of Facility

Source	*df*	*SS*	*MS*	*F*
Stanchion Tasks (milking and feeding)	1	1424.27	1424.27	20.49*
Parlor Tasks (milking and feeding)	1	4.85	4.85	0.7
Error (Within)	21	1459.77	69.51	
Total	23	2888.89		

* $p \leq 0.001$

CHAPTER V

CONCLUSION

The research questions that Chapters 2 and 3 attempted to address were: 1) are MSS prevalent among the study sample of Iowa dairy farmers?, 2) what exposures (e.g. hours milking per year) or personal factors (e.g. smoking status) were associated with prevalent MSS? The results indicated that MSS were prevalent among the study sample of Iowa dairy farmers, and may be present among other dairy farmers in the U.S. Low back, knee and shoulder MSS appeared to be the most prevalent at 67, 60, and 54% respectively. Exposures such as milking ≥1456 hrs per year was associated with an increased risk of elbow MSS and a decreased risk of low back MSS. Additionally, manually cleaning animal stalls (hours per year) was associated with and increased risk for wrist/hand, upper back and hip MSS.

Surprisingly, no associations were found between prevalent MSS and type of milking facility in the current study. Comparably, few previous studies have observed statistically significant associations between agricultural tasks and prevalent MSS among U.S. agricultural workers (Gomez et al., 2003; Xiang et al., 1999). Additionally, no study that the investigators are aware of has identified prevalent MSS, and observed statistically significant associations between agricultural tasks and prevalent MSS among U.S. dairy farmers. It may be that associations exist between exposures such as lifting and low back MSS among agricultural workers, but weakness in cross-sectional study design fail to observe these associations.

The current research presented in Chapters 2 and 3 identified dairy farming tasks such as milking, and manually cleaning animal stalls as being associated with wrist/hand, elbow, upper back, and hip MSS. More research is needed to evaluate these tasks to identify specific exposures within each task that may contribute to MSS in the wrist/hand, elbow, upper back, and hip. Some exposures that may occur in the tasks of milking and manually cleaning animal stalls may include awkward postures, repetition, forceful exertions, and vibration (NIOSH, 1997b).

Few specific tasks (e.g. milking) were statistically associated with low back, knee, and shoulder MSS. Symptoms at these body sites were among the most prevalent in the study sample. Research should be conducted to evaluate dairy farm work that may result in exposure to physical risk factors for low back, shoulder and knee (NIOSH, 1997b). It may be that multiple physical risk factors exist in frequent dairy farm tasks such as manual feeding that were not identified due to limitations (e.g. exposure misclassification) in the studies presented in Chapters 2 and 3. Ideally, future research should use ergonomic exposure assessment methods which have better accuracy and precision (e.g. direct methods) compared to self report (Spielholz et al., 2001).

The two body sites where MSS was reported as most prevalent were the low back (67%) and the knee (60%). Clearly, exposure to physical risk factors for low back and knee MSS among these dairy farmers needed to be evaluated. The study in Chapter 4 assessed exposures that may contribute to knee MSS and possibly knee OA. However exposures that may contribute to low back MSS should not be ignored. The ease of measurement and relatively low cost of equipment was the reasoning behind choosing to evaluate exposures to physical risk factors for knee MSS (e.g. knee flexion exposure) among dairy farmers instead of risk factors for low back MSS. Future investigations should focus on exposures to physical risk factors for low back MSS.

The research questions that Chapter 4 attempted to address are: 1) are exposures to awkward postures of the knee (i.e. knee flexion) more prevalent while performing milking tasks in a stanchion or a parlor milking facility?, 2) are knee flexion exposures more prevalent while feeding in a stanchion or a parlor milking facility?, 3) are knee flexion exposures more prevalent while milking compared to feeding in a stanchion milking facility?, and 4) are knee flexion exposures more prevalent while milking compared to feeding in a parlor milking facility? The results indicated that knee flexion exposure is more common while milking in a stanchion facility compared to a parlor facility. Additionally, knee flexion exposure was found to be significantly greater while performing the feeding tasks associated with parlor facilities compared to milking in a parlor facility. Also, stanchion milking resulted in significantly more knee flexion exposure compared to feeding in a stanchion facility. However, no statistically significant differences were found for knee flexion exposures while feeding between stanchion and parlor milking facilities.

No study that the author is aware of has assessed knee flexion exposure using direct ergonomic exposure assessment methods among agricultural workers, let alone among dairy farmers. Additionally, the data presented in Chapter 4 is the first data published on exposure to physical risk factors for knee MSS (i.e. knee flexion exposure) among U.S. dairy farmers. The results reported in Chapter 4 may provide a more accurate estimate of knee flexion exposure among stanchion and parlor milkers compared to previous Scandinavian studies (Nevala-Puranen et al., 1996; Perkiö-Mäkelä & H, 2005). However, the results reported in Chapter 4 are similar what has been previously published.

Future investigations on exposure to risk factors for MSS among dairy farmers should be directed in several areas. Exposure to other factors that may contribute to knee OA, such as heavy lifting, should be identified. Knee posture may not be the only important exposure metric to assess while performing milking and feeding on a dairy farm. Future research should attempt to identify simple and inexpensive ergonomic interventions. One example of an ergonomic intervention might be a fixture in each stanchion stall to assist in rising from a squat. For example, a loop of rope or a U shaped steel rod could be attached to the ceiling of the stanchion barn adjacent to the milk cow. If a stanchion milker squats while working, they can use their upper extremity to grab the structure and assist in rising from a squat. The author is not aware of these structures being present in stanchion barns, and using the upper extremity to assist in rising from a squat may reduce the compressive forces generated on the knee while milking. Perhaps, future knee MSS among dairy farmers will be reduced by implementing similar interventions.

Future investigations should also focus on a more accurate 3-dimensional biomechanical model to accurately determine knee moments, compressive forces, and mechanical loads associated with squatting. Furthermore, the data collected in this study could be applied to this biomechanical model to gain a better estimation of knee flexion exposure during stanchion milking. Additionally, this new biomechanical model could also be applied to estimate knee flexion exposure in any industry where squatting is common during daily work tasks (e.g. construction).

One of the challenges of performing occupational health and safety research among farmers is that farmers are not regulated by the department of Occupational Safety and Health, unless they employ more that ten employees (OSHA). Consequently, most farmers are not required to have a health and safety program or institute safety and health changes on their farm. Due to the economic situation of farmers, many may be unwilling to spend money on safer equipment, when a clear economic advantage may not be apparent. As seen in other industries, much of the cost savings for the prevention of MSS and MSDs are indirect (NRC, 2001). Getting farmers to take an interest in their own musculoskeletal health may be difficult due to the lack of immediate direct monetary benefit (e.g. reduction in insurance premiums). However, the results from Chapters 2 and 3 indicate that dairy farmers commonly work with MSS. Prevention of MSS may allow farmers to work more pain free days, may reduce health care costs, and reduce lost work days due to MSS.

Dissemination of the results reported in Chapters 2, 3 and 4 to dairy farmers is important so that the results can have an impact on the dairy farmers. The information in Chapters 2 and 3 will provide dairy farmers information about common MSS among others in their industry. If these dairy farmers have MSS, the results of these studies may allow an individual to identify work processes that may contribute their MSS.

Education may be successful at reducing exposure to physical risk factors for MSS among dairy farmers. Disseminating information about physical risk factors for MSS (e.g. awkward postures, forceful exertions, repetition), and common dairy farming practices that may include these exposures (e.g. milking) may be one approach for preventing MSS among dairy farmers. This dissemination could be in the form of training sessions at dairy farming trade shows, or training dairy extension specialists on common risk factors found in dairy farming work. Educating dairy farmers about what exposures to look for in their own work practices and common ways to help reduce or eliminate these exposures may help reduce MSS.

In conclusion, the work presented in the previous Chapters will be the first epidemiological and exposure assessment studies of risk factors for MSS among U.S. dairy farmers. These studies will provided a better understanding of problematic MSS among U.S. dairy farmers, and allow for more focused investigations into dairy farming exposures which may increase the risk of developing MSS. Additionally, this study has further evaluated knee flexion exposures associated with milking and feeding tasks in two types of milking facilities (stanchion or parlor). Future research may focus on determining and evaluating interventions that will reduce exposure to physical risk factors for MSS and MSDs among dairy farmers.

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APPENDIX A

Demographic and Farm Questionnaire

Dairy Producer Joints and Muscle Questionnaire

Name:________________________________ Date of Birth: ____ Mo ____ Day _____ Year
(must be at least 18 years old to answer to the questionnaire)

Gender ____ Male Height: ____ Feet ___ Inches
___ Female Weight: ____ lbs
Which hand do you write with? ____ Right ____ Left ____ Both

1. Do you currently work in a dairy operation? ___ Yes ___ No
(If Yes, please continue; if No, thank you for your time, you are finished).

2. How many years have you worked in a dairy operation?____________

3. Which best describes your position in this dairy operation? (circle one)
   a. Owner
   b. Co-owner- partnership
   c. Herd Manager
   d. Parlor Manager
   e. Milker
   f. Calf feeder
   g. Crop supervisor
   h. Heifer grower

4. Please complete the table below regarding your work in the dairy operation in 2003

Number of weeks worked (exclude time away).	
Number of days per week worked	
Number of hours per day worked	

5. In addition to farming, do you have another job? ___ Yes ___ No (if no, Go to question 6)

If yes, what is your other occupation (for example, teacher, assembly worker, truck driver, etc.)

____

How many ***weeks per year*** do you work at this other occupation? ____________

How many ***hours per week*** do you work at this other occupation? ____________

What are your usual activities or duties at this other job? (for example, operate heavy equipment, lift boxes, enter data on computer etc).

____

6. How many of the following were in your operation this past year:

Milking cows_______ Dry Cows_____ Heifers______ Calves ______ Bulls _________

7. What was your total milk production in 2003? ________________________pounds

8. On average, how many cows are milked each day in your operation? ___________________

9. How many times per day do you milk cows? _____________________

Please complete the following table by filling in the areas that best describes your milking system.

	Number of Milking Units	Number of Turns through the barn
Stanchion		
Tie Stall		
Parlor		

10. What year was your milking facility built? __________ modified? _________________

11. Please mark the box next to the feeding option that best describes your operation.

	Total mixed ration with wagon/ conveyor belt delivery
	Partial mixed ration with hay fed separately
	Total mixed ration with manual delivery (shovel/ forked to the feed manger)
	Component fed by hand in stanchion/ tie stall barn
	Hay fed free choice delivered manually
	Hay fed free choice delivered by tractor
	Rotational grazing in summer- make second selection for winter feeding

12. Do you do the majority of feeding in this operation? ____Yes____ No

13. Do you currently smoke cigarettes? ____yes ____no (if no, please answer question 14)

Packs per day________ Number of years smoke_______

14. Have you ever smoked cigarettes? ____yes ____no

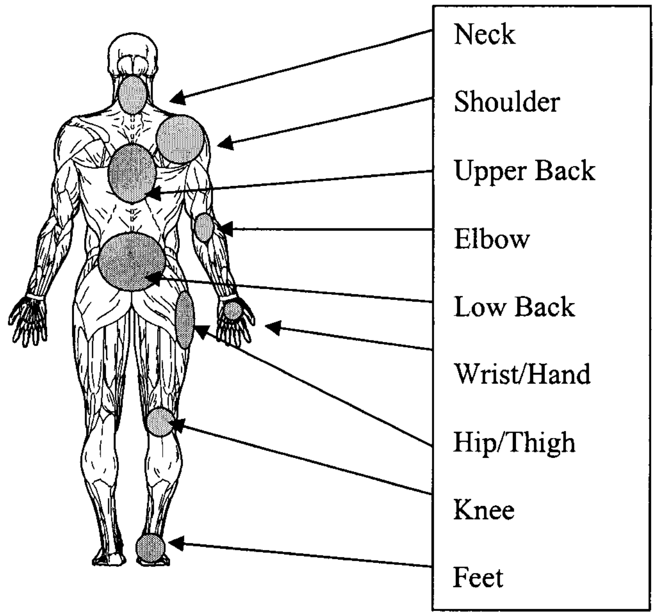
Packs per day_______ Number of years smoke_______ Year quit ________

15. What percent of each of the following agricultural operations contributed to your sales in the year 2003? (If the category does not apply to your operation, please place a 0)

Cash grain (corn, soybeans, oats)	_________%
Field crops (hay, straw)	_________%
Dairy	
Milk	_________%
Dairy cattle sales	_________%
Dairy culls	_________%
Heifers	_________%
Breeding bulls	_________%
Other Livestock	
Beef Cattle	_________%
Hogs	_________%
Other	_________%
Animal specialties (chickens, horses, furbearing animals, etc.)	_________%
Specialty items (eggs, fruits, vegetables, etc.)	_________%
Horticultural specialty (flowers, nursery, etc.)	_________%
Other (specify) ____________________	_________%
TOTAL	**100%**

16. Please think about the past year and indicate the number of hours spent doing each of the following chores during your "typical" DAY in each season

	WINTER (December-February)	SPRING (March-May)	SUMMER (June-August)	FALL (September-November)
	Typical Number of Hours per **Day**	Typical Number of Hours per **Day**	Typical Number of Hours per **Day**	Typical Number of Hours per **Day**
For each of the following activities, please indicate the number of hours you perform each of the activities.				
Feed cows/calves by hand				
Time spent milking				
Clean stalls by hand				
Tractor use				
Repair and maintenance				
Carry, lift 50 lbs or more				
Artificial Insemination				
Other: ______________				
Total Hours Worked For Each Season Should not exceed 24 hours				



17. **Please check YES or NO for all of the following:**

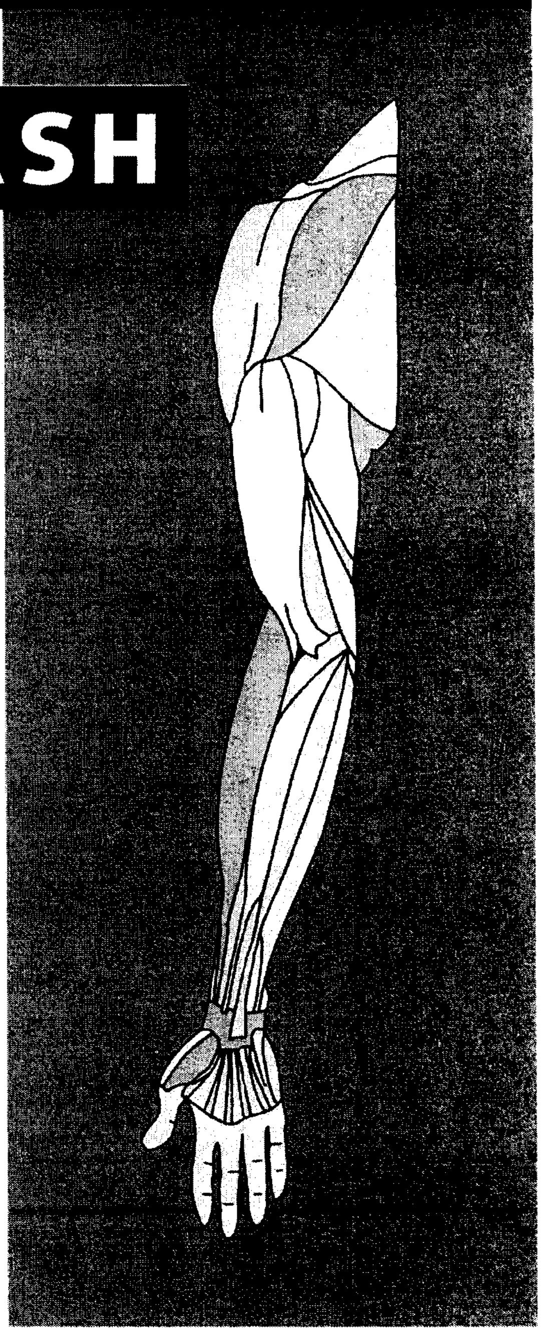
	A. During **the last 12 months** have you had an ache, pain, discomfort, etc in:		**B**. If yes in part A, during the last 12 months have you been **prevented from doing your day's work** due to this condition?		**C**., If yes in part A, during the last 12 months have you **seen a physician** (M.D., Osteopath, Chiropractor) for this condition?		**D**. If yes in part A, was this pain due to a **traumatic injury** such as a fall, cow kick, car accident, run over by machinery, etc.?	
Neck	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes
Shoulder	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes
Upper Back	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes
Elbow	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes
Low Back	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes
Wrist/Hand	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes
Hip/Thigh	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes
Knee	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes
Feet	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes	___ No	___ Yes

IF YOU MARKED "YES" TO **LOW BACK PAIN**, PLEASE COMPLETE THE GREEN PAGES
IF YOU MARKED "YES" TO **SHOULDER, ELBOW OR WRIST/HAND PAIN**, PLEASE COMPLETE THE YELLOW PAGES
IF YOU MARKED "YES" TO **KNEE PAIN**, PLEASE COMPLETE THE BLUE PAGES

Disorders of the Arm Shoulder and Hand (DASH)

DISABILITIES OF THE ARM, SHOULDER AND HAND

THE DASH



INSTRUCTIONS

This questionnaire asks about your symptoms as well as your ability to perform certain activities.

Please answer *every question*, based on your condition in the last week, by circling the appropriate number.

If you did not have the opportunity to perform an activity in the past week, please make your *best estimate* on which response would be the most accurate.

It doesn't matter which hand or arm you use to perform the activity; please answer based on your ability regardless of how you perform the task.

Disabilities of the Arm, Shoulder and Hand

Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. Open a tight or new jar.	1	2	3	4	5
2. Write.	1	2	3	4	5
3. Turn a key.	1	2	3	4	5
4. Prepare a meal.	1	2	3	4	5
5. Push open a heavy door.	1	2	3	4	5
6. Place an object on a shelf above your head.	1	2	3	4	5
7. Do heavy household chores (e.g., wash walls, wash floors).	1	2	3	4	5
8. Garden or do yard work.	1	2	3	4	5
9. Make a bed.	1	2	3	4	5
10. Carry a shopping bag or briefcase.	1	2	3	4	5
11. Carry a heavy object (over 10 lbs).	1	2	3	4	5
12. Change a lightbulb overhead.	1	2	3	4	5
13. Wash or blow dry your hair.	1	2	3	4	5
14. Wash your back.	1	2	3	4	5
15. Put on a pullover sweater.	1	2	3	4	5
16. Use a knife to cut food.	1	2	3	4	5
17. Recreational activities which require little effort (e.g., cardplaying, knitting, etc.).	1	2	3	4	5
18. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g., golf, hammering, tennis, etc.).	1	2	3	4	5
19. Recreational activities in which you move your arm freely (e.g., playing frisbee, badminton, etc.).	1	2	3	4	5
20. Manage transportation needs (getting from one place to another).	1	2	3	4	5
21. Sexual activities.	1	2	3	4	5

Disabilities of the Arm, Shoulder and Hand

	NOT AT ALL	SLIGHTLY	MODERATELY	QUITE A BIT	EXTREMELY
22. During the past week, *to what extent* has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups? *(circle number)*	1	2	3	4	5

	NOT LIMITED AT ALL	SLIGHTLY LIMITED	MODERATELY LIMITED	VERY LIMITED	UNABLE
23. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem? *(circle number)*	1	2	3	4	5

Please rate the severity of the following symptoms in the last week. *(circle number)*

	NONE	MILD	MODERATE	SEVERE	EXTREME
24. Arm, shoulder or hand pain.	1	2	3	4	5
25. Arm, shoulder or hand pain when you performed any specific activity.	1	2	3	4	5
26. Tingling (pins and needles) in your arm, shoulder or hand.	1	2	3	4	5
27. Weakness in your arm, shoulder or hand.	1	2	3	4	5
28. Stiffness in your arm, shoulder or hand.	1	2	3	4	5

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	SO MUCH DIFFICULTY THAT I CAN'T SLEEP
29. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? *(circle number)*	1	2	3	4	5

	STRONGLY DISAGREE	DISAGREE	NEITHER AGREE NOR DISAGREE	AGREE	STRONGLY AGREE
30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem. *(circle number)*	1	2	3	4	5

DASH DISABILITY/SYMPTOM SCORE = $\left[\left(\frac{\text{sum of n responses}}{n}\right) - 1\right] \times 25$, where n is equal to the number of completed responses.

A DASH score may not be calculated if there are greater than 3 missing items.

DISABILITIES OF THE ARM, SHOULDER AND HAND

WORK MODULE (OPTIONAL)

The following questions ask about the impact of your arm, shoulder or hand problem on your ability to work (including homemaking if that is your main work role).

Please indicate what your job/work is:____________________

❑ I do not work. (You may skip this section.)

Please circle the number that best describes your physical ability in the past week. Did you have any difficulty:

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. using your usual technique for your work?	1	2	3	4	5
2. doing your usual work because of arm, shoulder or hand pain?	1	2	3	4	5
3. doing your work as well as you would like?	1	2	3	4	5
4. spending your usual amount of time doing your work?	1	2	3	4	5

SPORTS/PERFORMING ARTS MODULE (OPTIONAL)

The following questions relate to the impact of your arm, shoulder or hand problem on playing *your musical instrument or sport or both*.

If you play more than one sport or instrument (or play both), please answer with respect to that activity which is most important to you.

Please indicate the sport or instrument which is most important to you:____________________

❑ I do not play a sport or an instrument. (You may skip this section.)

Please circle the number that best describes your physical ability in the past week. Did you have any difficulty:

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. using your usual technique for playing your instrument or sport?	1	2	3	4	5
2. playing your musical instrument or sport because of arm, shoulder or hand pain?	1	2	3	4	5
3. playing your musical instrument or sport as well as you would like?	1	2	3	4	5
4. spending your usual amount of time practising or playing your instrument or sport?	1	2	3	4	5

SCORING THE OPTIONAL MODULES: Add up assigned values for each response; divide by 4 (number of items); subtract 1; multiply by 25.

An optional module score may not be calculated if there are any missing items.

Oswestry Disability Index

Please Read: This questionnaire is designed to enable us to understand how much your low back has affected your ability to manage everyday activities. Please answer each Section by circling the ONE CHOICE that most applies to you. We reali that you may feel that more than one statement may relate to you, but **Please just circle the one choice which closely describes your problem *right now*.**

SECTION 1–Pain Intensity
A. The pain comes and goes and is very mild.
B. The pain is mild and does not vary much.
C. The pain comes and goes and is moderate.
D. The pain is moderate and does not vary much.
E. The pain is severe but comes and goes.
F. The pain is severe and does not vary much.

SECTION 2–Personal Care
A. I would not have to change my way of washing or dressing in order to avoid pain.
B. I do not normally change my way of washing or dressing even though it causes some pain.
C. Washing and dressing increase the pain, but I manage not to change my way of doing it.
D. Washing and dressing increase the pain and I it necessary to change my way of doing it.
E. Because of the pain, I am unable to do any washing and dressing without help.
F. Because of the pain, I am unable to do any washing or dressing without help.

SECTION 3–Lifting
A. I can lift heavy weights without extra pain.
B. I can lift heavy weights, but it causes extra pain.
C. Pain prevents me from lifting heavy weights off the floor.
D. Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently positioned, e.g. on the table.
E. Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned.
F. I can only lift very light weights, at the most.

SECTION 4 –Walking
A. Pain does not prevent me from walking any distance.
B. I have some pain with walking but it does not increase with distance.
C. Pain prevents me from walking more than one mile.
D. Pain prevents me from walking more than 1/2 mile.
E. I can only walk while using a cane or on crutches.
F. I am in bed most of the time and have to crawl to the toilet.

SECTION 5–Sitting
A. I can sit in any chair as long as I like without pain.
B. I can only sit in my favorite chair as long as I like.
C. Pain prevents me from sitting more than one hour.
D. Pain prevents me from sitting more than 1/2 hour.
E. Pain prevents me from sitting more than ten minutes.
F. Pain pevents me from sitting at all.

SECTION 6 – Standing
A I can stand as long as I want without pain
B. I have some pain while standing, but it does not increase with time.
C. I cannot stand for longer than one hour without increasing pain.
D. I cannot stand for longer than 1/2 hour without increasing pain.
E. I can't stand for more than 10 minutes without increasing pain.
F. I avoid standing because it increases pain right away.

SECTION 7–Sleeping
A. I get no pain in bed.
B. I get pain in bed, but it does not prevent me from sleeping.
C. Because of pain, my normal night's sleep is reduced by less tha one-quarter.
D. Because of pain, my normal night's sleep is reduced by less than one-half.
E. Because of pain, my normal night's sleep is reduced by less than three-quarters.
F. Pain prevents me from sleeping at all.

SECTION 8–Social Life
A. My social life is normal and gives me no pain.
B. My social life is normal, but increases the degree of my pain.
C. Pain has no significant effect on my social life apart from limiting my more energetic interests, e.g., dancing, etc.
D. Pain has restricted my social life and I do not go out very often.
E. Pain has restricted my social, life to my home.
F. Pain prevents me from social, life at all.

SECTION 9–Traveling
A. I get no pain while traveling.
B. I get some pain while traveling, but none of my usual forms of travel make it any worse.
C. I get extra pain while traveling, but it does not compel me to seek alternative forms of travel.
D. I get extra pain while traveling which compels me to seek alternative forms of travel.
E. Pain restricts all forms off travel.
F. Pain prevents all forms of travel except that done lying down.

SECTION 10–Changing Degree of Pain
A. My pain is rapidly getting better.
B. My pain fluctuates, but overall is definitely getting better.
C. My pain seems to be getting better, but improvement is slow at present.
D. My pain is neither getting better nor worse.
E. My pain is gradually worsening.
F. My pain is rapidly worsening.

Disability index score:_______ %

Western Ontario and McMaster Universities Osteoarthritis

Index (WOMAC)

The WOMAC is a proprietary use document. Information about the WOMAC can be obtained from the constructor, Professor Nicholas Bellamy at www.womac.org.

APPENDIX B

Electrogoniometer Calibration