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Work-related musculoskeletal symptoms and job factors among dairy milkers

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Abstract

Dairy production in the United States is moving towards large-herd milking operations, resulting in an increase in task specialization and work demands. The objective of this project was to provide preliminary evidence of the association of a number of specific job conditions that commonly characterize large-herd parlor milking operations with work-related musculoskeletal symptoms (MSS). A modified version of the Standardized Nordic Questionnaire was administered to assess MSS prevalence among 450 US large-herd parlor workers. Worker demographics and MSS prevalences were generated. Prevalence ratios were also generated to determine associations of a number of specific job conditions that commonly characterize large-herd parlor milking operations with work-related MSS. Work-related MSS are prevalent among large-herd parlor workers, since nearly 80% report 12-month prevalences of one or more symptoms, which are primarily located in the upper extremities, specifically shoulders and wrist/hand. Specific large-herd milking parlor job conditions are associated with MSS in multiple body regions, including performing the same task repeatedly, insufficient rest breaks, working when injured, static postures, adverse environmental conditions, and reaching overhead. These findings support the need for administrative and engineering solutions aimed at reducing exposure to job risk factors for work-related MSS among large-herd parlor workers.

Keywords

Agriculture workers; dairy; ergonomics; farm; injury; musculoskeletal; public health; safety

Introduction

The United States (US) dairy industry continues to shift to a large-herd production model due to economies of scale. According to the US Department of Agriculture, smaller dairy farms have higher costs per cow, thus resulting in limited profit. As a result, investments have concentrated in large-herd dairy operations, leading to larger herd sizes and further

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consolidation of US milk production.[1] Although the number of dairy operations has dramatically decreased to around 58,000 in 2011 (33% less than 2001 and 91% less than in 1970), milk production and herd sizes have increased. In 2012, large-herd operations (>500 head) produced 63% of US milk, up from 35% in 2001; and operations with 2,000 head or more accounted for 35% of the production, up from 12% in 2001.[2] Production costs of larger herd dairies favor milking in parlor systems (i.e., loose- or free-stall housing where cows are directed into a dedicated milking facility) versus stanchion systems (i.e., conventional housings where cows are milked while tethered in stalls).[3] In 2006, all large-herd farms utilized milking parlor systems, and 78% of all US dairy cows were milked in parlors.[4]

The majority of peer-reviewed literature addressing musculoskeletal outcomes among dairy workers and exposure to physical risk factors during dairy work involves European smaller-herd operations.[5,6] Differences between US and European parlor systems, herd sizes, milking methods, and labor staffing strategies make extrapolations of findings from European studies to the United States difficult. Large-herd dairy farms in the United States are unique in that workers are assigned to specific farm operations such as milking, cow or calf-care, feeding, or maintenance. Parlor workers perform specific milking tasks throughout an entire work shift and have no other job responsibilities on the farm. The US industry trend toward a large-herd production model could lead to an increased risk of work-related musculoskeletal outcomes among parlor workers due to task specialization and greater work demands due to higher cow volumes. A small but growing literature in the United States indicates that working on large dairy operations is associated with an increased risk for injury,[7–9] but no prior study has investigated the association of work-related musculoskeletal symptoms (MSS) among parlor workers and specific job conditions that characterize large-herd milking parlors.

Taking advantage of a recent 4-year investigation of MSS among US large-herd parlor workers, the purpose of this study is to provide preliminary evidence of the association of a number of specific job conditions that commonly characterize large-herd milking parlor operations with work-related musculoskeletal symptoms.

Methods

Study design, sample, and procedures

Parlor workers (i.e., milkers) were recruited from 32 large-herd dairy farms in five western US states with herd sizes between 680 and 6,000 (mean = 2,673; *SD* = 1,338). Dairy owners provided consent after being informed about the study purpose and procedures. All parlor workers aged 18 years or older were invited to participate. A total of 452 (99.6% of eligible parlor workers), an average of 14 workers per dairy, agreed to participate upon providing written consent. Each worker received $20 in appreciation for their time. The University of Texas Health Science Center at Houston Committee for the Protection of Human Subjects approved the study.

Data for the study were collected with a questionnaire administered by a bilingual (English/Spanish) member of the research team to ensure that respondents understood questions, thus

preventing reading literacy from affecting survey responses. Questionnaire administration took about 30 minutes per person, and managers or owners were not present during the administration. In each parlor we sampled two shifts of workers: the morning shift after they finished their work shift, and the evening shift before they began their work shift. The questionnaire asked about the following characteristics: demographic (i.e., age, gender), anthropometric (i.e., grip reach, height), health-related (i.e., smoking and body mass index), work-related (i.e., time working in the parlor, work shift, having other nondairy job), MSS, and job conditions that characterize large-herd parlor milking operations.

Musculoskeletal symptoms

Details of the assessment of work-related MSS among parlor workers was previously reported.[10] Work-related MSS were assessed with a modified version of the Standardized Nordic Questionnaire,[11] a widely used tool with good test-retest reliability and validity.[5,12–18] For nine anatomical sites (neck, shoulder, upper back, lower back, elbow, wrist/hand, hip/thigh, knee, feet), the questionnaire asks if, during the last 12-months, the respondent (1) had a work-related ache, pain, or discomfort that (2) had prevented the respondent from doing the day's work, and (3) if the respondent had seen a medical doctor, osteopath, or chiropractor about the reported symptom. Due to small numbers, questions related to having been prevented from doing work and having seen a physician were not analyzed. For each site, a dichotomous variable was created to indicate whether a worker had experienced MSS or not, and a summary variable was created to indicate if participants had experienced MSS in any body part. To maximize statistical power, we examined MSS by grouping sites into four anatomical regions (i.e., neck and upper back, lower back, upper extremities [shoulder, elbow, and wrist/hand], and lower extremities [hip/thigh, knee, and feet]) and an additional category of any body part.

Characterizing working in large-herd parlor milking operations

Using elements from a previously developed job questionnaire used in ergonomics research,[17] participants were asked to indicate how much of a problem, on a scale from 0 (no problem) to 10 (major problem), they have with a list of 14 job common conditions in parlor milking. The 14 items were grouped into organizational (performing the same task over and over; working very fast, for short periods; insufficient breaks during the work day), work scheduling (overtime, length or workday; continuing to work when injured or hurt), ergonomic/physical (working in awkward or cramped conditions; working in the same position for long periods; bending/twisting back in an awkward way; working at or near physical limits; reaching/working over head or away from body; hot cold, humid, wet conditions), and handling equipment (having to handle or grasp small objects; carrying/lifting/moving heavy materials or equipment; using milking equipment). Given their limited distribution, all items were dichotomized by grouping all answers greater than 0 into 1, indicating the respondent had some problems performing the job under that specific job condition.

Statistical analysis

First, the prevalence of work-related MSS during the last 12 months for each body region, as well as an overall indicator of MSS in any body part, was estimated by milking parlor

working conditions. Second, crude and adjusted prevalence ratios (PRs), and corresponding 95% confidence intervals (95% CIs), were calculated using Poisson regression models.[19] Models were clustered by parlor to account for participants within the same parlor sharing some characteristics. We did not cluster our analysis by location of dairy farm (US state), since there are no differences in the way dairy parlors operate in the states we sampled. In the adjusted models, we controlled for gender, height, arm length, shift, having been kicked, and hours worked per day, which were variables that had statistically significant associations with MSS in preliminary bivariate models. For consistency and comparability, all models included the same covariates. Statistical significance was declared at the .05 level. Statistical analysis was performed with Stata/MP 13 (StataCorp, College Station, TX).

Results

Overall sample characteristics for participants who responded to both the MSS and job conditions items are shown in Table 1. Two participants did not complete the job condition questionnaire, which resulted in a total sample size of 450. Participants were mostly young (mean = 30 years, SD = 9.0 years); mostly male (89%), Hispanic (97%), and right-hand dominant (97%). Mean anthropometric measurements were about 68 cm of grip reach, 167 cm of height, and 73 kg body mass, with 55% of participants being overweight or obese. Participants worked an average of 9 hours per day, 6 days per week, and 50 weeks per year and had worked over 4 years in a dairy parlor, with 98% reporting not having another job. About 42% reported as having experience working all shifts, and near 85% declared having been kicked or stepped on by a cow.

Overall (Table 2), more than 50% of the respondents reported having a problem performing their job under all but two conditions: performing the same task over and over (43%), and having to handle or grasp small objects (36%). Two conditions were reported as problematic by most workers (82%): working under hot, cold, humid, and wet conditions, and continuing to work when injured or hurt. More than 80% of the respondents reported experiencing work-related MSS in any anatomical site in the prior 12-month period. The highest prevalences of MSS (over 60%) were reported in the upper extremity region, followed by lower extremity (near 60%, on average), neck and upper back (around 50%), and lower back (over 30%).

Regarding MSS prevalences by job condition, the highest reported prevalences were in the upper extremity across all organizational working conditions, ranging from 58% for continuing to work when injured or hurt, to 63% for performing the same task over and over. Similar findings, with the upper extremity locations having the highest prevalences, were observed for ergonomic/physical working conditions: reaching/working overhead or away from body (63%), followed by working in awkward or cramped conditions (60%) and working at or near physical limits (59%). The highest MSS prevalences among conditions related to equipment handling was noted in the upper extremity, with using milking equipment having the highest MSS prevalence (62%).

Table 3 shows prevalence ratios associated with milking parlor working conditions and work-related MSS. In the adjusted models, significant prevalence ratios indicated higher

prevalence of having problems performing the job across all milking parlor working conditions and having MSS in any body location. For each body region, there were statistically significant ($P < .05$) prevalence ratios involving at least three milking parlor conditions and MSS, except for the lower back, which had no statistically significant prevalence ratios associated with any parlor condition. By type of working conditions, the greatest prevalence ratio regarding organizational conditions was observed for continuing to work when injured or hurt, which was associated with MSS in the neck and upper back (PR = 2.07, 95% CI: 1.28–3.35). The greatest associations regarding ergonomic/physical conditions were observed for reaching/working over head or away from body (PR = 1.85, 95% CI: 1.35–2.53) as well as working under hot, cold, humid, wet conditions (PR = 1.84, 95% CI: 1.40–2.41), both associated with MSS in the neck and upper back. The greatest prevalence ratio regarding handling equipment was observed for using milking equipment (PR = 1.39, 95% CI: 1.15–1.67), which was also associated with MSS in the neck and upper back.

Discussion

To our knowledge, this cross-sectional study is the first to estimate the associations of prevalences of work-related MSS with problems performing the job under working conditions in three domains (i.e., organizational, ergonomic/physical, and equipment-related) commonly observed among US large-herd dairy parlor workers. We previously reported that MSS are prevalent among large-herd parlor workers. Nearly 80% of large-herd parlor workers report 12-month prevalences of one or more symptoms, mostly located in the upper extremity.[10] However, the present study adds to the literature on work-related musculoskeletal outcomes by showing that MSS and reporting having problems performing the job under common milking parlor working conditions are related, particularly with MSS in the neck and upper back and upper extremities. This will help guide future intervention efforts, which may include both administrative and engineering controls.

Except for the lower back, workers who reported MSS in all other body regions also reported having problems with typical organizational conditions in milking parlors. Modern large-herd milking parlors operate continuously on a 24-hour basis every day of the week, often milking each cow on a farm two to three times per day. Participants in our study worked an average of 9 hours per day, 6 days per week, and 50 weeks a year.[10] Also, given the typical work scheduling and organization of the milking routine, parlor workers rarely take breaks during the work shift, and there is limited opportunity for task variability.[20,21] Our findings suggest that large-herd parlor milking is a fast-paced, repetitive, and physically demanding job that is associated with prevalent MSS. Importantly, most workers report having to continue to work despite their health issues. These findings should direct interventional research efforts towards the development of cost-effective administrative controls such as, to the extent possible, increase worker staffing scheduling, work-rest scheduling, or include task variation strategies.

Ergonomic/physical job factors were reported as creating problems to perform the job and associated with MSS in the neck and upper back, upper extremities, as well as lower extremities. Working in the same position for long periods, bending/twisting the back, and

working at or near physical limits were all problematic for workers reporting MSS in the neck and upper back, as well as lower extremities. Reaching/working overhead or away from body was problematic for those reporting MSS in the neck and upper back, upper extremities, as well as lower extremities. The milking "workstation" can be described as the worker operating in a pit, below a milking platform where each cow stands. Milkers perform repetitive milking tasks while reaching forward to access the cow's udder (Figure 1). Workers are often spraying water to clean the milking floor, walls, and equipment. This creates a humid environment. Lastly, since parlors have open access to outside elements, seasonal weather extremes can create extremely hot conditions in the summer or cold conditions in the winter. Large-herd parlor milking involves exposure to physical risk factors such as awkward postures, repetitive motions, high muscle loads, minimal opportunity for rest, and harsh environmental conditions that may increase the risk for development of work-related MSS.[22] Our findings suggest that future interventional efforts should be directed at parlor configuration redesigns such as pit heights to accommodate a predominantly Hispanic workforce of shorter stature and arm reach. Additionally, milking equipment and parlor designs should ensure that each cow is directed as close to the milking pit as possible to minimize the reach distance for the worker. Parlor designs should incorporate adequate cross-ventilation strategies to provide airflow to reduce heat stress to both worker and cow.

Drawing comparisons of our findings with previous studies is made difficult by the fact that most previous studies have evaluated associations between musculoskeletal outcomes and job factors among dairy farmers.[16,23–27] Dairy farmers included in these studies often perform a multitude of farm tasks with differing health risk exposures as compared with those experienced by hired workers. Our literature search produced only two prior studies that reported having sampled dairy workers.[23,28] However, due to smaller-herd sizes and limited job specialization, these workers may also perform other tasks outside of the milking parlor and may be exposed to a broader array of musculoskeletal risk factors. In comparison, US large-herd parlor workers perform only milking tasks and have no other job responsibilities in other areas on the farm.

Using questionnaires, Lunner Kolstrup[23] compared work-related MSS and ergonomic work factors among 37 employed Swedish dairy workers. Participants milked an average of 19 hours per week and represented dairy farms with a mean herd size of 119 head. Milking was perceived as a physically demanding work task, and repetitive and monotonous work in milking parlors was the ergonomic work factor most frequently (32%) reported as causing physical discomfort, followed by lifting heavy objects (27%). Female workers reported higher levels of discomfort from repetitive and monotonous work than their male counterparts. In another study, Kolstrup et al.[28] investigated prevalences of work-related MSS and job factors among 42 Swedish dairy workers representing dairy farms with more than 300 head. Repetitive work, working in awkward postures, and being exposed to dust were significant risk factors in experiencing adverse musculoskeletal health outcomes. Our study supports these findings[23,28] in that repetitive work and awkward postures are two milking parlor job factors associated with the development of adverse musculoskeletal health outcomes.

Expanding our discussion to include studies that investigated working conditions and health among dairy farmers, a common finding across studies is that milking tasks are among the most physically demanding. In a 14-year follow-up of Swedish dairy farmers, Pinzke[5] reported silage handling and milking tasks being among the most strenuous. Lower et al.[24] reported that milking was among activities associated with the occurrence of back trouble among 138 Australian dairy farmers, and Innes and Walsh[25] reported that routine tasks performed repetitively caused more musculoskeletal discomfort among a total of 433 Australian dairy farmers.

Lastly, participants in our study who reported MSS in the neck and upper back as well as upper extremity reported using milking equipment as being problematic. Milking tasks involve the worker reaching forward, between the hind legs of a cow, to access the cow's udder, as well as repeated lifting and attachment of a milking unit, which can weigh up to 3.5 kg.[6] Constrained work involving repetitive movements of hands and static muscle loading of the neck and shoulder have been shown to be risk factors for neck/shoulder musculoskeletal pathology.[29,30] A limited number of studies have evaluated milking equipment controls and their effectiveness in reducing musculoskeletal burden. Stål et al.[31] evaluated a prototype support arm designed to facilitate milking unit attachment. The authors demonstrated a minimal decrease in muscle activity and minimal change in wrist posture while using the support arm. Pinzke et al.[32] evaluated lightweight milk tubes, and Jakob et al.[33] investigated the effects of a quarter-individual milking unit on muscle activity and posture. Results suggested that this alternative milking unit design has the potential to reduce muscle activity and non-neutral postures among parlor workers. Future interventional efforts could be directed at the redesign of milking clusters. Lighter-weight composite materials could be used in the manufacture of milking clusters to potentially reduce the lifting load, as well as new designs to accommodate smaller hand spans that characterize the Hispanic workforce. Other studies have evaluated engineering control strategies and their effectiveness in reducing musculoskeletal burden. Prior studies have demonstrated that parlor pit height may influence upper extremity muscular activity during parlor milking,[34,35] as well as milking stall rail height.[36]

Future intervention strategies, in the form of administrative and engineering controls, may not only improve worker health and safety, but also worker performance and parlor productivity. An ongoing operational challenge in large-herd milking parlors is milking procedure consistency. Parlor productivity and cow health are dependent on consistent milker performance, and a minimization of milking process drift. As workers fatigue or experience discomfort over long milking shifts or multiple days of milking, their performance may decline as a result. Consequently, parlor production and cow health could decline. Therefore, effective engineering control strategies addressing worker health should positively influence productivity and cow health, as well as withstand the rigors of large-volume parlor milking. Future occupational health interventional studies should integrate parlor productivity and cow health variables.

Study limitations

Several methodological issues must be considered when interpreting our findings. First and foremost, our study design was cross-sectional in nature with the intent of investigating associations between large-herd milking parlor job factors and musculoskeletal outcomes. Each parlor worker was surveyed at a single time point, which prevents any inference of causality. Our study does not enable the determination if reported MSS was the result of problems with usual milking parlor working conditions, or if these conditions were the result of having MSS (reverse causality). Nevertheless, conducting longitudinal occupational health and safety research in dairy farm settings remains an extremely difficult undertaking given the need to gain support and permission from dairy owners to conduct research on farms, the dynamic and often unpredictable nature of the US dairy industry, and a workforce comprised predominantly of immigrant workers. Additionally, remote locations of dairy farms and high employee turnover often limit the ability of researchers to access newly hired workers in a timely fashion, or to follow workers in a prospective fashion over a longer period of time. Because of these challenges, less than desirable cross-sectional designs remain an often-used strategy to investigate work-related musculoskeletal outcomes among workers in US agriculture settings. Despite the limitations of cross-sectional research, it still has some inferential capabilities. As utilized in the present study, the prevalence ratio is a conservative, consistent, and interpretable effect measure that is appropriate in the analysis of cross-sectional data.[19]

Second, our findings may have been influenced by reporting bias. Period prevalence rates were based on self-reported MSS, which may be biased in comparison with clinical diagnosis established via medical examination. However, in this study, the Nordic Musculoskeletal Questionnaire for the assessment of MSS was used. This is a standardized, validated, and widely used tool that has proven useful for studying the prevalence of reported MSS in across a wide range of occupations.[37–41] Third, almost all participants in our study were Hispanic (97.1%) and male (89.4%). We did not assess immigration status but prior research suggests that Hispanic immigrant men in the United States, particularly those with lower education levels, illiteracy, and limited English proficiency, tend to occupy lower-wage, higher-hazard jobs. Additionally, these workers experience higher rates of work-related injuries and illnesses than US-born Hispanic and other non-Hispanic male groups.[42] Thus, our findings may reflect the overall higher prevalence of health conditions among Hispanics in the United States. Although possible, we consider unlikely survey responses were affected by low literacy levels, since data collection was administered by an interviewer, and in Spanish when needed.

Conclusions

In summary, dairy farming is a very physically demanding occupation, and MSS are prevalent among US large-herd parlor workers. Symptoms primarily involve the neck, upper back, and upper extremity. Results from this study suggest that specific large-herd milking parlor job factors are associated with MSS in multiple body regions. These findings support the need for administrative and engineering solutions aimed at reducing exposure to job risk factors for work-related MSS among parlor workers, while simultaneously improving

worker efficiency, productivity, and ease of work. Researchers should engage and partner with dairy owners and workers to generate cost-effective injury prevention strategies.

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Figure 1.
Dairy parlor worker performing milking task.

Table 1.

Sample characteristics of US large-herd dairy parlor workers ($N = 450$).

Characteristic	% (n) or Mean (SD)
Age (in years) [Mean(SD)]	30.3 (9.0)
Gender	
Female	10.6 (48)
Male	89.3 (402)
Hispanic	
No	2.9 (13)
Yes	97.1 (437)
Dominant hand	
Right	96.7 (435)
Left	3.3 (15)
Grip reach (in cm) [Mean(SD)]	67.6 (6.74)
Height (in cm) [Mean(SD)]	166.6 (12.0)
Weight (in kg) [Mean(SD)]	73.3 (13.4)
Body Mass Index	
Underweight	2.5 (11)
Normal	42.2 (189)
Overweight & obese	55.4 (248)
Time working in dairy parlor	
Hours per day [Mean(SD)]	9.1 (1.8)
Days per week [Mean(SD)]	5.9 (0.6)
Weeks per year [Mean(SD)]	49.7 (8.0)
Years [Mean(SD)]	4.2 (4.3)
Other Job	
Yes	2.0 (9)
No	98.0 (441)
Usual work shift	
Morning, afternoon/evening or night	58.2 (262)
All	41.8 (188)
Ever kicked/stepped on by cow	
No	15.1 (68)
Yes	84.9 (382)
Total	**100.0 (450)**

Table 2.

Prevalence (%) of work-related MSS among milkers by parlor working conditions ($N = 450$).

		Musculoskeletal Symptoms				
		Neck & Upper back	Lower back	Upper extremities	Lower extremities	Any
Milking parlor working conditions	**% (n)**	**%**	**%**	**%**	**%**	**%**
ORGANIZATIONAL						
Performing the same task over and over						
No	57.2 (257)	37.9	25.6	48.6	46.8	70.8
Yes	42.8 (192)	57.8	35.6	63.4	58.4	83.8
Working very fast, for short periods						
No	46.4 (205)	40.6	25.6	46.7	42.5	67.8
Yes	53.6 (237)	51.1	33.9	61.6	60.2	83.5
Insufficient breaks during the work day						
No	38.2 (169)	34.1	24.2	41.8	36.0	62.7
Yes	61.9 (274)	54.2	33.6	63.2	61.2	84.7
Work scheduling (overtime, length or workday)						
No	46.1 (202)	38.2	26.4	47.7	46.4	66.3
Yes	53.9 (236)	54.2	32.9	61.7	57.6	86.4
Continuing to work when injured or hurt						
No	18.4 (81)	25.0	25.0	44.3	33.3	54.3
Yes	81.6 (359)	51.5	31.4	57.8	56.6	82.2
ERGONOMIC/PHYSICAL						
Working in awkward or cramped conditions						
No	39.3 (174)	40.1	28.3	47.9	42.4	65.5
Yes	60.7 (269)	50.0	31.2	60.1	57.3	83.3
Working in the same position for long periods						
No	29.5 (129)	31.8	25.4	46.4	37.3	64.3
Yes	70.6 (309)	52.8	32.1	58.6	58.5	82.2
Bending/twisting back in an awkward way						
No	30.2 (134)	33.6	22.2	49.2	38.0	64.2
Yes	69.8 (310)	51.9	33.6	57.8	57.6	81.6
Working at or near physical limits						
No	32.7 (145)	34.5	25.7	46.4	37.1	60.0
Yes	67.3 (298)	52.4	32.4	59.3	58.9	84.6
Reaching/working over head or away from body						
No	32.5 (143)	28.6	25.7	37.4	38.6	60.8
Yes	67.5 (297)	55.6	32.4	62.7	58.8	83.8
Hot cold, humid, wet conditions						

		Musculoskeletal Symptoms				
		Neck & Upper back	Lower back	Upper extremities	Lower extremities	Any
Milking parlor working conditions	**% (n)**	**%**	**%**	**%**	**%**	**%**
No	18.5 (82)	27.9	23.4	39.7	36.3	57.3
Yes	81.5 (362)	50.6	31.2	58.1	55.6	80.7
HANDLING EQUIPMENT						
Having to handle or grasp small objects						
No	63.5 (278)	43.3	30.6	51.8	49.5	73.7
Yes	36.5 (160)	51.3	28.9	60.0	56.0	80.6
Carrying/lifting/moving heavy materials or equipment						
No	33.4(148)	35.2	25.7	51.4	43.5	65.5
Yes	66.6 (295)	51.9	31.9	56.0	56.2	81.4
Using milking equipment						
No	49.4 (219)	38.4	28.3	47.7	44.4	67.6
Yes	50.6 (224)	54.5	31.4	62.3	58.7	85.3
OTHER						
Training on how to do the job						
No	77.9 (346)	47.2	32.9	54.8	54.7	78.0
Yes	22.1 (98)	44.9	18.3	56.7	42.7	71.4

Table 3.

Prevalence ratios* (95% confidence intervals) of working conditions and work-related musculoskeletal symptoms during the last 12 months.

	Musculoskeletal Symptoms				
	Neck & Upper back	Lower back	Upper extremities	Lower extremities	Any
Milking parlor working conditions	**PR (95%CI)**	**PR (95%CI)**	**PR (95%CI)**	**PR (95%CI)**	**PR (95%CI)**
ORGANIZATIONAL					
Performing the same task over and over					
Crude	1.52 (1.21-1.92)	1.39 (0.94-2.06)	1.30 (1.02-1.67)	1.25 (1.00-1.56)	1.18 (1.03-1.37)
Adjusted**	1.46 (1.17-1.83)	1.36 (0.93-1.99)	1.26 (1.00-1.59)	1.24 (1.02-1.50)	1.17 (1.03-1.32)
Working very fast, for short periods					
Crude	1.26 (1.03-1.54)	1.32 (0.94-1.86)	1.32 (1.05-1.65)	1.42 (1.06-1.89)	1.23 (1.10-1.41)
Adjusted*	1.20 (1.01-1.43)	1.24 (0.88-1.73)	1.27 (1.02-1.58)	1.36 (1.03-1.79)	1.20 (1.10-1.37)
Insufficient breaks/pauses during the work day					
Crude	1.59 (1.23-2.06)	1.39 (0.97-1.97)	1.51 (1.15-1.99)	1.70 (1.22-2.38)	1.35 (1.12-1.63)
Adjusted*	1.50 (1.15-1.92)	1.22 (0.86-1.73)	1.43 (1.10-1.86)	1.60 (1.15-2.23)	1.31 (1.09-1.57)
Work scheduling (overtime, length or workday)					
Crude	1.42 (1.16-1.73)	1.25 (0.82-1.90)	1.29 (1.02-1.65)	1.24 (0.94-1.65)	1.30 (1.11-1.53)
Adjusted*	1.39 (1.16-1.65)	1.18 (0.81-1.72)	1.27 (1.02-1.58)	1.23 (0.94-1.60)	1.30 (1.11-1.52)
Continuing to work when injured or hurt					
Crude	2.06 (1.21-3.01)	1.25 (0.61-2.56)	1.30 (0.89-1.91)	1.70 (0.94-3.05)	1.51 (1.07-2.14)
Adjusted*	2.07 (1.28-3.35)	1.16 (0.67-1.95)	1.29 (0.95-1.76)	1.69 (1.04-2.74)	1.53 (1.15-2.02)
ERGONOMIC/PHYSICAL					
Working in awkward or cramped conditions					
Crude	1.25 (0.97-1.60)	1.10 (0.74-1.64)	1.25 (0.99-1.59)	1.35 (1.00-1.82)	1.27 (1.06-1.52)
Adjusted*	1.21 (0.95-1.53)	1.05 (0.72-1.53)	1.23 (0.99-1.54)	1.36 (1.02-1.82)	1.26 (1.06-1.49)
Working in the same position for long periods					
Crude	1.66 (1.21-2.28)	1.26 (0.69-2.31)	1.26 (0.93-1.72)	1.57 (1.12-2.19)	1.28 (1.06-1.54)
Adjusted*	1.57 (1.17-2.10)	1.17 (0.69-1.97)	1.21 (0.94-1.56)	1.52 (1.13-2.04)	1.25 (1.08-1.45)
Bending/twisting back in an awkward way					
Crude	1.55 (1.22-1.96)	1.51 (0.82-2.77)	1.17 (0.88-1.56)	1.52 (1.01-2.27)	1.27 (1.03-1.57)
Adjusted*	1.48 (1.17-1.88)	1.44 (0.87-2.37)	1.14 (0.90-1.45)	1.52 (1.07-2.16)	1.26 (1.06-1.50)
Working at or near physical limits					
Crude	1.52 (1.13-2.04)	1.26 (0.75-2.13)	1.28 (0.91-1.79)	1.59 (1.06-2.38)	1.41 (1.11-1.79)

	Musculoskeletal Symptoms				
	Neck & Upper back	Lower back	Upper extremities	Lower extremities	Any
Milking parlor working conditions	**PR (95%CI)**	**PR (95%CI)**	**PR (95%CI)**	**PR (95%CI)**	**PR (95%CI)**
Adjusted *	1.47 (1.10-1.95)	1.19 (0.78-1.82)	1.24 (0.92-1.67)	1.56 (1.11-2.21)	1.40 (1.14-1.73)
Reaching/working over head or away from body					
Crude	1.94 (1.38-2.73)	1.26 (0.78-2.02)	1.68 (1.16-2.43)	1.53 (1.06-2.20)	1.38 (1.12-1.70)
Adjusted *	1.85 (1.35-2.53)	1.20 (0.81-1.76)	1.64 (1.18-2.27)	1.51 (1.10-2.08)	1.37 (1.14-1.64)
Hot cold, humid, wet conditions					
Crude	1.82 (1.33-2.47)	1.33 (0.64-2.79)	1.46 (1.00-2.13)	1.53 (0.96-2.25)	1.41 (1.00-1.97)
Adjusted *	1.84 (1.40-2.41)	1.30 (0.76-2.23)	1.48 (1.10-1.98)	1.56 (1.05-2.32)	1.45 (1.08-1.93)
HANDLING EQUIPMENT					
Having to handle/grasp small objects					
Crude	1.18 (0.95-1.47)	0.94 (0.66-1.35)	1.16 (0.95-1.41)	1.13 (0.91-1.41)	1.09 (0.95-1.25)
Adjusted *	1.14 (0.94-1.39)	0.92 (0.65-1.30)	1.13 (0.94-1.36)	1.14 (0.92-1.42)	1.08 (0.95-1.23)
Carrying/lifting/moving heavy materials or equipment					
Crude	1.47 (1.15-1.87)	1.24 (0.68-2.26)	1.10 (0.80-1.47)	1.29 (0.91-1.84)	1.24 (0.98-1.57)
Adjusted *	1.40 (1.12-1.75)	1.19 (0.70-2.01)	1.04 (0.81-1.36)	1.27 (0.93-1.73)	1.23 (1.01-1.51)
Using milking equipment					
Crude	1.42 (1.16-1.73)	1.11 (0.79-1.55)	1.31 (1.04-1.65)	1.32 (1.03-1.70)	1.26 (1.09-1.47)
Adjusted *	1.39 (1.15-1.67)	1.08 (0.76-1.54)	1.29 (1.03-1.61)	1.30 (1.03-1.65)	1.26 (1.09-1.46)
OTHER					
Training on how to do the job					
Crude	0.95 (0.76-1.19)	0.55 (0.36-0.85)	1.03 (0.81-1.31)	0.78 (0.61-1.00)	0.92 (0.80-1.05)
Adjusted *	0.96 (0.78-1.19)	0.59 (0.39-0.91)	1.05 (0.85-1.31)	0.83 (0.65-1.06)	0.93 (0.82-1.06)

* Adjusted for gender, height, arm length, shift, having been kick, and hours worked per day.