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Factors Associated with Musculoskeletal Discomfort in Farmers and Ranchers in the U.S. Central States

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ABSTRACT

Agricultural work involves ergonomic and psychosocial strain, which contribute to musculoskeletal conditions. The aim of this study was to assess if specific ergonomic, psychosocial, and preventive factors are linked to musculoskeletal pain or discomfort symptoms (MSS) in farmers and ranchers. We analyzed data from the Central States Center for Agricultural Safety and Health survey that was conducted in 2018 in a seven-state region of the central United States. MSS were assessed with questions from the Standardized Nordic Questionnaire. The survey included questions on demographic, ergonomic, psychosocial and preventive factors. Farm production variables were added from the Farm Market iD database. We analyzed the data using Generalized Estimating Equations. The overall prevalence of MSS for all body sites combined was 59% among 4,354 farmers and ranchers who responded (19% response rate). After controlling for age, sex, and operator status, three factors (high stress level, sleep deprivation, and exhaustion/fatigue) showed the strongest associations with MSS in any body site, with adjusted odds ratios (OR) ranging from 4.8 to 5.6. Forceful exertions, repetitive tasks, awkward postures, frequent manual labor, and vibration were also significantly associated with MSS, with adjusted ORs ranging from 1.8 to 3.3. Recommended preventive techniques were not protective for MSS. New effective strategies are needed to reduce the high burden of musculoskeletal outcomes among farmers and agricultural workers.

KEYWORDS

Musculoskeletal; symptom; pain; discomfort; agriculture; ergonomic; prevention

Introduction

Agricultural work involves physical and psychosocial strain, which places farmers and farm workers at potential risk for musculoskeletal disorders, including osteoarthritis of the hip and knee, neck and upper limb complaints, hand-arm vibration syndrome, low back pain, etc.[1] Several studies have concluded that musculoskeletal disorders are the most common occupational non-fatal illness for agricultural workers.[2–4] Systematic reviews of epidemiologic studies have identified numerous risk factors for acute injuries in agricultural workers.[5,6] However, fewer studies have investigated risk factors for chronic musculoskeletal conditions among agricultural workers. Working methods and conditions vary greatly by region and type of production, and there is little information on cumulative exposures in different types of agricultural work, ranging from arduous manual labor to highly mechanized and automated sedentary work in modern agriculture.

There is some evidence that ergonomic stressors, including heavy lifting, awkward working postures, forceful exertions, repetitive tasks, insufficient breaks, vibration, etc. may contribute to musculoskeletal conditions in manual agricultural work settings.[7] Individual factors could also contribute, including age, sex, psychological, and social factors.[8]

Psychosocial factors play an essential role in musculoskeletal discomfort. Several studies have reported that work-related stress is a significant risk factor for developing chronic musculoskeletal disorders.[9] Similarly, musculoskeletal discomfort is associated with perceived work fatigue among manual harvesting workers.[10] Further, disrupted sleep is associated with decreased pain threshold, increased musculoskeletal discomfort, and fatigue.[11] Psychological factors,

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such as work strain, high stress level, sleep deprivation, and exhaustion/fatigue, often appear as a cluster of symptoms together with musculoskeletal discomfort.[12] The presence and potential co-occurrence of these symptoms have significance among migrant agricultural workers because they experience long hours of physically arduous work and low pay.[12]

Several studies have focused on the treatment of chronic musculoskeletal pain and musculoskeletal injuries.[13,14] However, few studies have investigated preventive techniques to maintain musculoskeletal health, and much of this work has focused on hired workers doing manual labor. Further studies are needed to identify effective strategies to reduce the incidence of musculoskeletal conditions among self-employed farmers and ranchers doing a mix of manual and technologically advanced agricultural work.

This research used data from an ongoing surveillance program focusing on injury and illness outcomes, exposures, and preventive efforts among self-employed farmers and ranchers in the Central Unites States. The primary aim of this study was to evaluate whether musculoskeletal pain or discomfort symptoms (MSS) among farmers and ranchers are associated with specific ergonomic and psychological factors. The secondary aim was to evaluate the hypothesis that several commonly recommended preventive techniques are protective for MSS.

Methods

Study setting

This study was part of the Central States Center for Agricultural Safety and Health (CS-CASH) surveillance of agricultural injuries and illnesses among farm and ranch operators in seven U.S. states: Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. The population under surveillance included self-employed farmers and ranchers, called "operators" in this study, or "producers" in the most recent Census of Agriculture.[15] The surveillance population excluded salaried agricultural workers and managers that are included in the Bureau of Labor Statistics injury surveillance.

Data collection

The 2018 Farm and Ranch Health and Safety Survey was administered by CS-CASH investigators. CS-CASH collaborated with Farm Market iD (FMiD), which is a commercial agricultural data service provider, primarily used by companies offering products and services to agricultural customers. FMiD covers practically all agricultural operations included in the USDA Census of Agriculture.[15] CS-CASH requested a random sample of farm and ranch operations within the Center's seven-state region, aiming to have at least 2,500 operations per state in the sample, based on prior power calculations. Eligibility criteria for operations were: 1) location in the seven-state region, 2) having an email address, and 3) having at least 5,000 USD of gross farm sales. Email was needed for the online surveys in the first phase of the study, and the sales limitation was used to focus on active (vs. retired, discontinued, etc.) operations. The study flow chart (Figure 1) shows the numbers of operations and operators starting from the total number of operations in the region, progressing to the initial random sample, and further to phase 1 (email and online survey) and phase 2 (mail survey), resulting in the final operator-level dataset of usable responses.

Surveys were sent out through both email and mail in the spring and early summer of 2018 to gather data from operators, focusing on the previous 12-month period. The survey included questions about demographics, injuries, chronic health conditions, exposures, personal protective equipment use, and preventive techniques. The surveys requested information for the principal operator and up to two other operators on each farm or ranch. The final survey dataset was augmented by merging farm production variables from FMiD data at the operation level. The data were entered into the University of Nebraska Medical Center's REDCap system, either directly by operators (online survey) or from survey forms by CS-CASH staff (mail survey).

Dependent variable

The dependent variable, MSS, was measured using questions from the Standardized Nordic

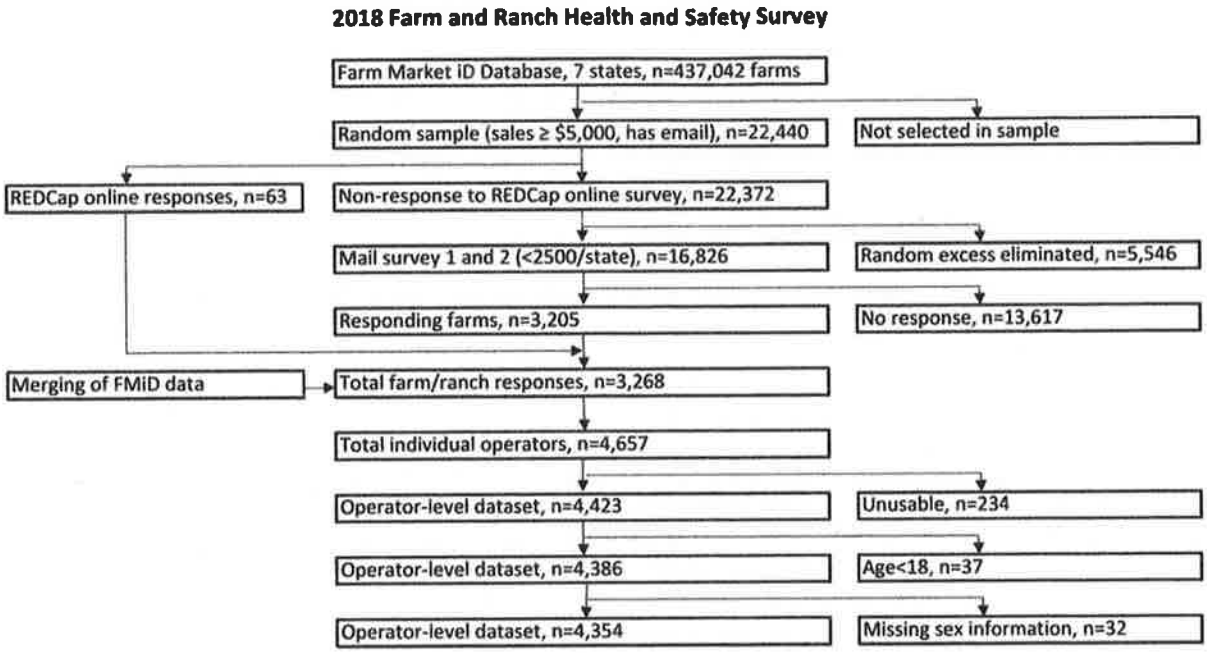

Figure 1. Flow chart depicting the selection procedure for creating the dataset for analyses.

Questionnaire (SNQ).[16] The SNQ is a validated methodology that enables comparison of neck, shoulder, low back, and general musculoskeletal complaints across epidemiological studies using the same methodology.[17] Specifically, MSS was defined using the question: "*Did the operator experience pain or discomfort that affected his/her work in any of the following body areas during the past 12 months? (Mark all that apply.)*" The response options were none, head, cervical, shoulders, chest, elbows, forearms, lumbar, wrist/hands, hip, thighs, knees, legs, ankles/feet. An image of these body sites was included in the survey form. This question was adapted from the SNQ.[16]

We first examined the frequencies of symptoms in each body site as well as associations between demographic variables and body sites. We then created primary and secondary outcome variables. The primary outcome variable, overall MSS in any body region, was considered to be present (yes) if the operator reported experiencing pain or discomfort that affected his/her work in any of the listed body sites and absent (no) if no musculoskeletal pain or discomfort was reported. The secondary outcome variables were MSS in four separate body regions: 1) lumbar, 2) shoulder, 3) "upper limbs", which included elbows, forearms, or wrist/hands, and 4) "lower limbs", which included hip, thighs, knees, legs, and ankles/feet.

Independent variables

Individual-level factors included operator age (categorized as 18–44, 45–64, or 65+ years), sex (male, female), operator status (principal, second, third), primary occupation (farm/ranch work, other), percent of total work time spent on farm/ranch work (0–24%, 25–49%, 50–74%, 75–99%, or 100%), and count of injuries (none, one, two, three or more). Operator status, primary occupation and work time questions were adapted from the Census of Agriculture's questions.[15] Ergonomic factors were measured through the following question: "*Was the operator exposed to any of the following situations at work during the past 12 months? (Mark all that apply.)*" The response options were none, forceful exertions, repetitive tasks, awkward postures, frequent manual labor, vibration, and other. These ergonomic stressors are common in agriculture and the questions were adapted from previous studies.[7,10] Psychological factors were assessed through the following question: "*Did the operator experience extended work periods that resulted in any of the*

following during the past 12 months? (Mark all the apply.)" The response options were none, high-stress level, sleep deprivation, exhaustion/fatigue, and other. These psychological factors are commonly reported by farmers, and the questions were modified from previous studies.[11,12] Preventive factors were measured through the following question: "*Was the operator using any of the following techniques to maintain his/her musculoskeletal health during the past 12 months? (Mark all that apply).*" The response options were none, regular breaks, stretching, exercising, good lifting techniques, mechanizing tasks, and other. These options are based on commonly recommended preventive practices in agriculture and other industries.

Farm-level independent variables included information about the type of operation (farm, ranch), total acres of corn, hay, soy, wheat, vegetables, oil crops, and oats, and numbers of beef, dairy, and other livestock. Continuous variables (acres of crops, heads of livestock) were dichotomized (particular type of production present vs. not) for analyses.

Data analysis

We compared respondent and non-respondent characteristics using key operator and operation variables from the FMiD data to indicate potential biases due to response/n on-response. The age and gender of the listed operator as well as production numbers for several crops and animals were analyzed using the t-test and chi-square test.

We calculated the total count and share of operators who experienced MSS in any body region (main outcome) during the previous year. We also calculated the total count and share of operators reporting MSS by four body regions (secondary outcomes), as well as each technique that operators used to maintain their musculoskeletal health. We tested correlations (continuous variables) and associations (class variables) before conducting regression analyses.

The relationship of the outcomes and potential risk factors was evaluated by logistic regression modeling using the Generalized Estimating Equations (GEE) procedure with exchangeable working correlations, to account for clustering of operators within the same farm. We conducted unadjusted analyses on all independent variables separately at 2-sided $\alpha = 0.05$. We added all statistically significant independent variables from unadjusted models to the adjusted model to control for potential confounding. We converted the continuous variable "age" into the categorical variable age group (18–44, 45–64, 65+) using the same categories as The Burden of Musculoskeletal Diseases in the United States (BMUS) third edition (January 31, 2016). The predictors of musculoskeletal discomfort were measured by odds ratios (OR) and 95% confidence intervals (CI).

We conducted unadjusted and adjusted analyses of risk factors for MSS overall and by four body regions separately. The techniques that farmers and ranchers were using to maintain their musculoskeletal health were also analyzed for overall and region-specific MSS. Farm-level independent variables were also analyzed in the multivariable model. The final adjusted models included age group, sex, and operator number as covariates. Statistical analyses were done using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA).

Ethics review and approval

The study was considered exempt by the University of Nebraska Medical Center's Institutional Review Board (protocol #452-11-EX).

Results

The 2018 Farm and Ranch Health and Safety Survey produced responses from 3,268 agricultural operations and 4,657 individual operators, up to three operators per farm/ranch. The response rate was 0.3% for the email survey and 19% for the mail survey. The farm production characteristics of the responding vs. non-responding operations were similar: any livestock 46/46%; cow calf 16/16%; dairy 5/5%; wheat 40/47%; corn 90/89%; soybeans 86/84%, and hay production 67/69%, respectively.

A total of 4,354 operators, 3,734 (86%) male and 620 (14%) female, from the operator level dataset satisfied our inclusion criteria and were included in the analyses. More than half (n = 2,572, 59%) of the operators reported some MSS (in one or several body sites). The frequency of MSS in any body

region was 2,237 (60%) among males and 335 (54%) among females. Higher frequencies were found among the age group 45 to 64 years of age (n = 1,387; 63%) and operators who spent most (50% or more) of their work time on farm/ranch work (n = 2,212; 61%). The frequency of MSS was lower (56%) among 2,127 operators who did not have an injury in the past 12 months. The odds of MSS (OR: 1.47; 95% CI: 1.28–1.71) and injury (OR: 1.81; 95% CI: 1.35–2.43, not shown in table) were higher among men vs. women. The frequencies are presented in more detail in Table 1. Farm-level independent variables are not included in the table as they did not have statistically significant associations with MSS outcomes.

MSS was reported frequently by those who were exposed to high stress levels, sleep deprivation, exhaustion or fatigue (more than 80% each) and those who were exposed to forceful exertions, repetitive tasks, awkward postures, frequent manual labor, and vibration (about 70% each; Table 2). Contrary to our hypothesis, the frequencies of MSS were higher among those who used preventive techniques (vs. those who did not): 1,303 (63%) who used regular breaks, 1,000 (70%) who used stretching, 771 (64%) who used exercising, 1,365 (65%) who used good lifting techniques, and 1,082 (66%) who used mechanizing tasks as measures to reduce MSS.

Overall, 64% of principal operators, 51% of the second operators, and 39% of the third operators answered that they had experienced MSS in at least one body region (Figure 2). The differences in MSS among operators were the smallest for the lumbar area. After adjusting for age and sex, operator 1 had higher odds (OR: 1.37, 95% CI: 1.02–1.84) of having lumbar pain compared to operator 3. Respectively, operator 2 also had higher odds (OR: 1.16, 95% CI: 0.89–1.54) compared to operator 3. These differences were much larger, especially between operator 1 and 3, for shoulder (OR: 2.26, 95% CI: 1.54–3.31), upper limb (OR: 2.06, 95% CI: 1.36–3.15), and lower limb (OR: 2.03, 95% CI: 1.46–2.81) pain or discomfort. Smaller differences were observed between operator 2 vs. operator 3 for pain or discomfort in the shoulder (OR: 1.41, 95% CI: 0.96–2.08), upper limb (OR: 1.09, 95% CI: 0.72–1.66), and lower limb regions (OR: 1.19, 95% CI: 0.87–1.62).

Multivariable analyses showed that after adjusting for sex, age and operator number, high stress level, sleep deprivation, and exhaustion/fatigue had strong associations with overall MSS, with ORs ranging from 4.8 to 5.6 (Table 3). Forceful exertions, repetitive tasks, awkward postures, frequent manual labor, and vibration were also significantly associated with MSS in any body region, with ORs ranging from 1.8 to 3.3. The hypothesis regarding preventive techniques being protective for musculoskeletal conditions was not confirmed as nearly all preventive techniques had positive (adverse) associations with MSS in specific body regions and in all body regions combined.

Discussion

This study used responses from a survey of farmers and ranchers in a seven-state region in the Central U.S., merged with farm production variables from Farm Market iD (FMiD) database. This region had 437,042 agricultural operations, which is about 20% of all operations in the U.S., according to the 2017 Census of Agriculture.[15] Our study sample was drawn from the Farm Market iD database, which has a similar coverage of farms and ranches as the Census of Agriculture. The smallest operations (Gross Farm Income <$5,000) and operations without email addresses were excluded. The email/online survey produced only 63 usable responses from two rounds of emails to 22,440 operations. Two rounds of mailed surveys yielded 3,205 usable responses, and the overall response rate was 19%, when calculated from the base population of the mail survey. While this rate is low, it could be considered typical for similar surveys in recent years. The demographic and production characteristics of responding and non-responding operations were very similar indicating that the respondents represent fairly well the farmers and ranchers (with email address and sales > $5000) in the region.

Previous research on musculoskeletal conditions and exposures in agriculture has focused on hired workers doing manual labor in the fields, orchards, and vineyards, or repetitive livestock

Table 1. Demographic characteristics and risk of musculoskeletal pain and discomfort among operators (n = 4,354).

	MSS[a] (any body site)		
	Yes[b]	No	
Characteristics	n (%)	n (%)	OR (95% CI)
Total	2,572 (59.1)	1,782 (40.9)	
Sex			
Male	2,237 (59.9)	1,497 (40.1)	1.47 (1.28, 1.71)
Female	335 (54.0)	285 (46.0)	Ref
Age Group			
18–44	379 (44.3)	476 (55.7)	0.44 (0.37, 0.53)
45–64	1,387 (63.3)	805 (36.7)	0.99 (0.86, 1.15)
65+	806 (61.7)	501 (38.3)	Ref
Operation			
Farm	2,081 (59.3)	1,431 (40.8)	Ref
Ranch	301 (63.1)	176 (36.9)	1.21 (0.97, 1.53)
Both	73 (56.2)	57 (43.9)	0.95 (0.62, 1.45)
Missing	117 (49.8)	118 (50.2)	N/A
Main Occupation			
Farm/Ranch work	2,212 (61.1)	1,410 (38.9)	1.74 (1.48, 2.04)
Other	344 (49.6)	349 (50.4)	Ref
Missing	16 (41.0)	23 (59.0)	N/A
Percent work time on farm/ranch			
100%	1,416 (61.5)	886 (38.5)	2.81 (2.13, 3.71)
75–99%	530 (61.8)	327 (38.2)	2.70 (2.01, 3.63)
50–74%	265 (59.7)	179 (40.3)	2.45 (1.77, 3.38)
25–49%	254 (56.1)	199 (43.9)	1.96 (1.42, 2.70)
0–24%	96 (37.9)	157 (62.1)	Ref
Missing	11 (24.4)	34 (75.6)	N/A
Injury			
None	2,127 (55.9)	1,676 (44.1)	Ref
One	361 (80.0)	90 (20.0)	3.27 (2.55, 4.19)
Two	63 (87.5)	9 (12.5)	5.86 (2.86, 12.00)
Three or more	21 (95.5)	1 (4.5)	17.61 (1.76, 176.10)
Missing	0 (0.0)	6 (100.0)	N/A
State[c]			
IA	440 (56.8)	335 (43.2)	
KS	297 (56.8)	226 (43.2)	
MN	365 (58.6)	258 (41.4)	
MO	232 (63.6)	133 (36.4)	
NE	564 (58.5)	401 (41.5)	
ND	294 (58.3)	210 (41.7)	
SD	380 (63.4)	219 (36.6)	

a. MSS – Musculoskeletal pain or discomfort symptoms.
b. The participant had at least one musculoskeletal pain or discomfort in any body site. The table includes the data for all three operators.
c. IA – Iowa, KS – Kansas, MN – Minnesota, MO – Missouri, NE – Nebraska, ND – North Dakota, SD – South Dakota

production work, such as milking.[7–10] Musculoskeletal problems are highly relevant in states and regions with strong fruit, nut, and vegetable production. The Central States region is dominated by row crop production and large-scale production of beef, pork and poultry.[15] In this region, most agricultural work is done by owner-operator farmers and their family mem bers. Much of the field and livestock work is highly mechanized; e.g. driving tractors, combines, trucks and equipment, and monitoring automated storage, handling, and processing equipment. Ergonomic problems differ greatly between manual labor and mechanized/automated agriculture. The current study focused on self-employed farmers and their close family members, addressing musculoskeletal issues in this agricultural working population.

Overall, the results of this study indicate that farmers and ranchers have a high prevalence of musculoskeletal pain and discomfort. Psycho logical strain symptoms and ergonomic factors were strongly and positively associated with MSS in all body regions. Contrary to our initial hypothesis, all preventive techniques were also positively (adversely) associated with MSS in all body regions.

Table 2. Crude association of psychological, ergonomic, and preventive factors with musculoskeletal discomfort in any body site (n = 4,354).

Factors	MSS[a] (any body site)		
	Yes	No	
	n (%)	n (%)	OR (95% CI)[b]
Total	2,572 (59.1)	1,782 (40.9)	
Psychological strain			
High stress level			
Yes	1,045 (84.1)	198 (15.9)	5.47 (4.63, 6.47)
No	1,527 (49.1)	1,584 (50.9)	
Sleep deprivation			
Yes	879 (83.9)	169 (16.1)	4.96 (4.15, 5.92)
No	1,693 (51.2)	1,613 (48.8)	
Exhaustion/fatigue			
Yes	1,070 (84.5)	197 (15.5)	5.73 (4.85, 6.78)
No	1,502 (48.7)	1,585 (51.3)	
Ergonomic factors			
Forceful exertions			
Yes	1,479 (71.5)	591 (28.5)	2.73 (2.40, 3.09)
No	1,093 (47.9)	1,191 (52.1)	
Repetitive tasks			
Yes	1,600 (71.3)	645 (28.7)	2.90 (2.56, 3.29)
No	972 (46.1)	1,137 (53.9)	
Awkward postures			
Yes	1,561 (72.7)	585 (27.3)	3.16 (2.78, 3.59)
No	1,011 (45.8)	1,197 (54.2)	
Frequent manual labor			
Yes	1,853 (68.6)	850 (31.4)	2.83 (2.49, 3.21)
No	719 (43.6)	932 (56.4)	
Vibration			
Yes	1,145 (70.9)	469 (29.1)	2.25 (1.97, 2.56)
No	1,427 (52.1)	1,313 (47.9)	
Preventive techniques			
Regular breaks			
Yes	1,303 (62.6)	778 (37.4)	1.33 (1.17, 1.50)
No	1,269 (55.8)	1,004 (44.2)	
Stretching			
Yes	1,000 (70.1)	426 (29.9)	2.02 (1.77, 2.32)
No	1,572 (53.7)	1,356 (46.3)	
Exercising			
Yes	771 (63.8)	438 (36.2)	1.31 (1.25, 1.51)
No	1,801 (57.3)	1,344 (42.7)	
Good lifting techniques			
Yes	1,365 (65.0)	736 (35.0)	1.61 (1.42, 1.82)
No	1,207 (53.6)	1,046 (46.4)	
Mechanizing tasks			
Yes	1,082 (65.8)	563 (34.2)	1.57 (1.38, 1.79)
No	1,490 (55.0)	1,219 (45.0)	

a. MSS – Musculoskeletal pain or discomfort symptoms.
b. The odds ratio is crude odds ratio without considering correlation between operators on the same farm/ranch.

Prevalence of musculoskeletal discomfort

Musculoskeletal discomfort is a common health problem among agricultural workers. Overall, our study found a high one-year period prevalence of MSS among farmers and ranchers. Three out of five operators (59%) reported musculoskeletal discomfort in at least one body site: lower limbs 35%, lumbar 26%, shoulder 23%, and upper limbs 17%. Similar results have been found in other studies using the Nordic questionnaire among North American farmers. A study of Saskatchewan farmers reported the highest prevalences; 86% reported musculoskeletal pain in at least one body area, and high prevalences were reported for lower back (58%), shoulders (44%), and neck (40%).[18] A study of Iowa dairy farmers also showed a higher prevalence of musculoskeletal symptoms:

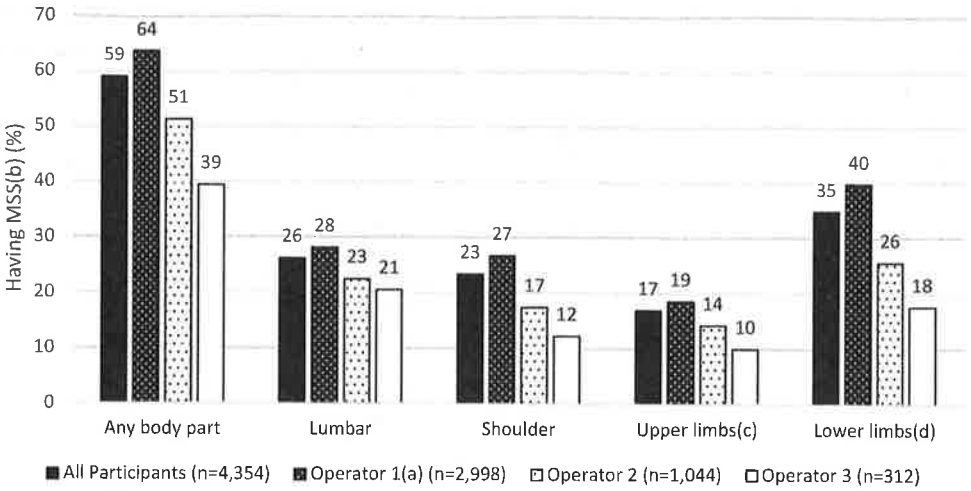

Figure 2. Prevalence of musculoskeletal pain or discomfort by operator number and body part.
(a). Operator 1 – principal operator. (b). MSS – Musculoskeletal pain or discomfort symptoms. (c). Upper limbs include elbows, forearms, and wrist/hands. (d). Lower limbs include hips, thighs, knees, legs, and ankles/feet.

75% at any site, 54% in shoulders, and 45% in two or more body areas.[19] Rosecrance et al. reported rates among Southeast Kansas farmers that were similar to ours.[20] In their study, about 60% of the farmers reported farm work-related MSS in at least one body area. The highest frequencies were reported for low back (38%), shoulders (26%), knees (24%), and neck (23%). Studies using different methodologies have reported lower rates. For example, the National Agricultural Workers Survey (NAWS) 2013–2014 reported a 17% prevalence in the U.S. overall; although some subpopulations had higher prevalence: 35% among agricultural workers in North Carolina, and 54% among agricultural workers aged 10–17 years.[21] The National Health Interview Survey reported monthly prevalences for joint pain: 17.0% for hips/knees, 9.5% for wrists/hands, 5.4% for elbows, and 4.7% for ankles/toes among agricultural workers in the U.S. between 2004 and 2008.[22]

Risk factors for musculoskeletal discomfort

Most study participants were male. About 60% of them reported MSS in any body area, which was higher than the percentage for females (54%). The Saskatchewan study found similar frequencies for farmers (most often male) and spouses, while gender differences were not addressed in the Iowa and Kansas studies. Musculoskeletal conditions influence workability, and one study of Finnish farmers concluded that self-reported workability declined much faster with age among female farmers compared to male farmers.[23] Injury risk factor research indicates that males have a much higher risk of injuries.[6] However, if given the same work task exposure time, there may be no difference in the risk of injuries between genders.[24] The contribution of work (vs. non-work) influence on musculoskeletal conditions is difficult to ascertain from the current study as the ergonomic factors increased the risk of MSS but the farm-level variables were not significantly associated with MSS outcomes.

The age group 45–64 reported the highest 12-month prevalence of MSS in our study (63%). The effect of aging on the musculoskeletal system has been addressed in several studies.[25,26] The joints and muscle tissues are both affected by aging resulting in greater prevalence of MSS at later age.

Up to three operators were included in this study on each responding farm or ranch. There were clear age and gender differences between operators. The first operators were the oldest and primarily male, the second operators were younger and more evenly divided between genders, and the third operators were the youngest and primarily male. MSS in any body region was most prevalent among principal operators and least prevalent

Table 3. Multivariable analysis of the associations of psychological, ergonomic, and preventive factors with musculoskeletal pain or discomfort.

	Musculoskeletal pain or discomfort symptoms				
	Any body site	Lumbar	Shoulders	Upper limbs	Lower limbs
	OR (95% CI)[a]	OR (95% CI)[a]	OR (95% CI)[a]	OR (95% CI)[a]	OR (95% CI)[a]
Psychological strain[b]					
High stress level					
Yes	5.55 (4.65, 6.61)	2.62 (2.25, 3.04)	3.09 (2.64, 3.61)	3.45 (2.89, 4.12)	3.53 (3.03, 4.11)
No	Reference	Reference	Reference	Reference	Reference
Sleep deprivation					
Yes	4.76 (3.96, 5.72)	2.68 (2.28, 3.14)	2.76 (2.34, 3.25)	3.93 (3.28, 4.70)	3.48 (2.97, 4.07)
No	Reference	Reference	Reference	Reference	Reference
Exhaustion/fatigue					
Yes	5.52 (4.61, 6.60)	2.80 (2.41, 3.25)	3.32 (2.83, 3.90)	3.68 (3.09, 4.38)	4.01 (3.45, 4.66)
No	Reference	Reference	Reference	Reference	Reference
Ergonomic factors[c]					
Forceful exertions					
Yes	2.82 (2.45, 3.24)	2.31 (1.99, 2.68)	2.42 (2.06, 2.83)	2.57 (2.04, 2.94)	2.08 (1.81, 2.39)
No	Reference	Reference	Reference	Reference	Reference
Repetitive tasks					
Yes	3.00 (2.61, 3.45)	2.27 (1.95, 2.64)	2.29 (1.96, 2.67)	2.95 (2.45, 3.55)	2.35 (2.04, 2.70)
No	Reference	Reference	Reference	Reference	Reference
Awkward postures					
Yes	3.27 (2.85, 3.76)	2.69 (2.31, 3.13)	2.62 (2.24, 3.06)	3.01 (2.51, 3.61)	2.47 (2.15, 2.84)
No	Reference	Reference	Reference	Reference	Reference
Frequent manual labor					
Yes	2.81 (2.44, 3.24)	2.00 (1.70, 2.34)	2.19 (1.85, 2.59)	2.56 (2.10, 3.13)	2.52 (2.17, 2.92)
No	Reference	Reference	Reference	Reference	Reference
Vibration					
Yes	2.30 (1.99, 2.66)	1.88 (1.62, 2.19)	2.19 (1.87, 2.55)	2.58 (2.17, 3.06)	2.20 (1.91, 2.53)
No	Reference	Reference	Reference	Reference	Reference
Preventive techniques[d]					
Regular breaks					
Yes	1.35 (1.19, 1.55)	1.09 (0.94, 1.26)	1.12 (0.97, 1.30)	1.01 (0.85, 1.19)	1.32 (1.16, 1.51)
No	Reference	Reference	Reference	Reference	Reference
Stretching					
Yes	1.99 (1.72, 2.29)	1.81 (1.56, 2.09)	1.70 (1.46, 1.98)	1.62 (1.36, 1.92)	1.52 (1.32, 1.75)
No	Reference	Reference	Reference	Reference	Reference
Exercising					
Yes	1.35 (1.17, 1.55)	1.22 (1.04, 1.42)	1.23 (1.05, 1.45)	1.30 (1.09, 1.55)	1.21 (1.04, 1.39)
No	Reference	Reference	Reference	Reference	Reference
Good lifting techniques					
Yes	1.61 (1.41, 1.84)	1.40 (1.22, 1.63)	1.34 (1.15, 1.56)	1.45 (1.23, 1.71)	1.32 (1.16, 1.51)
No	Reference	Reference	Reference	Reference	Reference
Mechanizing tasks					
Yes	1.55 (1.35, 1.78)	1.56 (1.34, 1.82)	1.32 (1.13, 1.55)	1.69 (1.42, 2.01)	1.46 (1.27, 1.68)
No	Reference	Reference	Reference	Reference	Reference

a. Generalized estimating equation (GEE) analysis was performed, adjusted by sex, age, operator number; CI, confidence interval; OR, odds ratio.
b. Psychological strain (Yes) – operator experienced at least one work strain symptom.
c. Ergonomic factors (Yes) – operator exposed to at least one ergonomic factor.
d. Preventive techniques (Yes) – operator used at least one technique to maintain his/her musculoskeletal health.

among third operators. This may be partially due to the age differences and work responsibilities on the operations. Principal (male) operators are more likely to be exposed to heavy manual labor on the farm/ranch.[24] MSS in the lumbar region were common and fairly evenly distributed between operators while MSS in the shoulder, upper limbs, and lower limbs were less common among second and third operators compared to principal operators. This evidence suggests that ergonomic exposures may have a greater effect on shoulder, upper limb, and lower limb symptoms while MSS in the lumbar region are less affected by work exposures.

Several studies have shown that musculoskeletal discomfort is associated with physical work

hazards.[27–30] Five ergonomic factors were included in our study: forceful exertions, repetitive tasks, awkward postures, frequent manual labor, and vibration. All ergonomic factors were positively (adversely) associated with MSS overall and by body region. Upper limbs were most strongly affected by ergonomic strain indicator variables.

We asked three questions about psychological strain, i.e. high stress levels, sleep deprivation, and exhaustion/fatigue. We did not differentiate whether the strain was related or unrelated to work. All three strain symptoms were strongly associated with MSS overall (odds ratios 4.8–5.6) and in individual body regions separately (odds ratios 2.6–4.0). Other studies have reported similar associations between psychological strain and musculoskeletal conditions.[31–33]

Preventive techniques

The techniques that operators used to maintain their musculoskeletal health included five categories, i.e. regular breaks, stretching, exercising, good lifting techniques, and mechanizing tasks. These techniques are commonly recommended interventions to prevent musculoskeletal discomfort. Contrary to our hypothesis, all techniques were positively (adversely) associated with MSS overall and by body region. Evidence on successful interventions to reduce musculoskeletal pain and discomfort is scarce. For instance, a recent systematic review found that work break interventions did not reduce musculoskeletal disorders.[34] Supplementary breaks were more effective than a conventional break schedule in reducing the intensity of musculoskeletal symptoms.[35] The evidence on exercise interventions has been mixed; most studies (among non-agricultural populations) showed positive effects while some showed no effects, or negative effects.[36] Mechanization, in its broadest sense, has great potential to increase productivity and improve livelihoods, but it has also been linked as an etiological pathway to overweight and obesity.[37,38]

Strengths and limitations

The strengths of this study include relatively large sample size (over 3,000 farms and ranches), enabling precise estimates of MSS determinants. The validated Standardized Nordic Questionnaire provided an opportunity to compare results with other studies using the same method in different agricultural populations.[18–20] Having access to demographic and farm production variables from Farm Market iD (FMiD) database enabled using a shorter survey when existing data could be merged to survey responses. FMiD data also enabled comparing responding and non-responding operations.

The limitations of this study include the compromise between the length and depth of the survey vs. response rate and mailing costs. Given the space, five pages plus cover sheet (on one 25.5-inch wide trifold sheet), we had to limit and condense the questions. Yet, the response rate was relatively low. Comparison of principal operator demographics and farm production characteristics showed very small differences, which could indicate that response biases might not be a major concern in this study. However, this comparison could not reveal potential response biases related to the health outcomes. Those with injuries and health conditions could be more interested in responding than "healthy" farmers and ranchers. This type of bias would result in over-estimation of the health outcome frequencies in question.

Injuries and MSDs were strongly associated, although we do not know whether injuries were partially caused by musculoskeletal discomfort, or if musculoskeletal pain/discomfort lead to injuries in some cases. It is also possible that farmers and ranchers started using preventive techniques after experiencing MSS rather than to prevent them, which may explain the positive association found in this study between these factors. We recognize that there are much overlap and potential confounding between the different types of outcomes, exposures, and preventive measures.

Finally, for prevention, it would be important to know which MSS were related to work vs. non-work exposures. However, such determination is challenging even in medical and exposure evaluations, and not feasible to evaluate in this survey study.

Conclusion

A high prevalence of musculoskeletal discomfort (59%) was reported at all body areas combined.

High stress level, sleep deprivation, and exhaustion/fatigue showed the strongest associations with (any) musculoskeletal discomfort with adjusted ORs ranging from 4.8 to 5.6. Forceful exertions, repetitive tasks, awkward postures, frequent manual labor, and vibration were also significantly associated with MSS in any body region, with ORs ranging from 1.8 to 3.3. Recommended preventive techniques were not protective for adverse musculoskeletal outcomes. New effective strategies are needed to reduce the high burden of musculoskeletal outcomes among agricultural workers. These may include interventions related to lifestyle and work exposures.

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Authors' contributions

Yi Du (ORCID ID: 0000-0003-4044-1989) participated in the design of the research methodology, data analysis/interpretation, and drafted and finalized the manuscript. Lorena Baccaglini (ORCID ID: 0000-0003-3548-4802) participated in the design of the research methodology, developing statistical models/interpretation, and critically evaluating the draft. Risto H Rautiainen (ORCID ID: 0000-0001-7295-5277) participated in the design of the research methodology, data collection, developing statistical models, and critically evaluating the draft. Anthony Johnson Jr (ORCID ID: 0000-0003-3478-8214) participated in the design of the research methodology, and critically evaluating the draft. Jagadeesh Puvvula (ORCID ID: 0000-0002-4927-3507) participated in the design of the research methodology, and critically evaluating the draft. Kaeli Samson prepared datasets for analyses.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Institution and Ethics approval and informed consent

University of Nebraska Medical Center Institutional Review Board approved this study protocol as exempt (#452-11-EX).

References

1. Walker-Bone K, Palmer KT. Musculoskeletal disorders in farmers and farm workers. *Occup Med (Lond).* 2002;52(8):441–450. doi:10.1093/occmed/52.8.441.
2. Fathallah FA. Musculoskeletal disorders in labor-intensive agriculture. *Appl Ergon.* 2010;41(6):738–743. doi:10.1016/j.apergo.2010.03.003.
3. Karttunen JP, Rautiainen RH, Leppala J. Characteristics and costs of disability pensions in Finnish agriculture based on 5-year insurance records. *J Agromed.* 2015;20(3):282–291. doi:10.1080/1059924X.2015.1042179.
4. Kirkhorn SR, Earle-Richardson G, Banks RJ. Ergonomic risks and musculoskeletal disorders in production agriculture: recommendations for effective research to practice. *J Agromed.* 2010;15(3):281–299. doi:10.1080/1059924X.2010.488618.
5. Jadhav R, Achutan C, Haynatzki G, Rajaram S, Rautiainen R. Risk factors for agricultural injury: A systematic review and meta-analysis. *J Agromed.* 2015;20(4):434–449. doi:10.1080/1059924X.2015.1075450.
6. Jadhav R, Achutan C, Haynatzki G, Rajaram S, Rautiainen R. Review and meta-analysis of emerging risk factors for agricultural injury. *J Agromed.* 2016;21(3):284–297. doi:10.1080/1059924X.2016.1179611.
7. Xiao H, McCurdy SA, Stoecklin-Marois MT, Li CS, Schenker MB. Agricultural work and chronic musculoskeletal pain among Latino farm workers: the MICASA study. *Am J Ind Med.* 2013;56(2):216–225. doi:10.1002/ajim.22118.
8. Bhattacharyya N, Chakrabarti D. Ergonomic basket design to reduce cumulative trauma disorders in tea leaf plucking operation. *Work.* 2012;41(Suppl 1):1234–1238. doi:10.3233/WOR-2012-0308-1234.
9. Buscemi V, Chang WJ, Liston MB, McAuley JH, Schabrun S. The role of psychosocial stress in the development of chronic musculoskeletal pain disorders: protocol for a systematic review and meta-analysis. *Syst Rev.* 2017;6(1):224. doi:10.1186/s13643-017-0618-0.
10. Jain R, Meena ML, Dangayach GS, Bhardwaj AK. Risk factors for musculoskeletal disorders in manual

harvesting farmers of Rajasthan. *Ind Health.* 2018;56 (3):241–248. doi:10.2486/indhealth.2016-0084.
11. Huntley ED, Campo JV, Dahl RE, Lewin DS. Sleep characteristics of youth with functional abdominal pain and a healthy comparison group. *J Pediatr Psychol.* 2007;32(8):938–949. doi:10.1093/jpepsy/jsm032.
12. Sandberg JC, Grzywacz JG, Talton JW, et al. A cross-sectional exploration of excessive daytime sleepiness, depression, and musculoskeletal pain among migrant farmworkers. *J Agromed.* 2012;17(1):70–80. doi:10.1080/1059924X.2012.626750.
13. Costa ML, Achten J, Bruce J, et al. Negative-pressure wound therapy versus standard dressings for adults with an open lower limb fracture: the WOLLF RCT. *Health Technol Assess.* 2018;22(73):1–162.doi:10.3310/hta22730.
14. Kravitz RL, Schmid CH, Marois M, et al. Effect of mobile device-supported single-patient multi-crossover trials on treatment of chronic musculoskeletal pain: A randomized clinical trial. *JAMA Intern Med.* 2018;178(10):1368–1377.doi:10.1001/jamainternmed.2018.3981.
15. USDA. 2017. *Census of agriculture. United States. Summary and state data.* Volume 1. Geographic Area Series. Part 51. https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf
16. Kuorinka I, Jonsson B, Kilbom A, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon.* 1987;18(3):233–237. doi:10.1016/0003-6870(87)90010-X.
17. Descatha A, Roquelaure Y, Chastang JF, et al. Validity of Nordic-style questionnaires in the surveillance of upper-limb work-related musculoskeletal disorders. *Scand J Work Environ Health.* 2007;33(1):58–65. doi:10.5271/sjweh.1065.
18. McMillan M, Trask C, Dosman J, Hagel L, Pickett W, The Saskatchewan Farm Injury Co F. Saskatchewan farm injury cohort study T. Prevalence of musculoskeletal disorders among Saskatchewan farmers. *J Agromed.* 2015;20(3):292–301. doi:10.1080/1059924X.2015.1042611.
19. Nonnenmann MW, Anton D, Gerr F, Merlino L, Donham K. Musculoskeletal symptoms of the neck and upper extremities among Iowa dairy farmers. *Am J Ind Med.* 2008;51(6):443–451. doi:10.1002/ajim.20582.
20. Rosecrance J, Rodgers G, Merlino L. Low back pain and musculoskeletal symptoms among Kansas farmers. *Am J Ind Med.* 2006;49(7):547–556. doi:10.1002/ajim.20324.
21. National Center for Farmworker Health I. Agricultural worker occupational health & safety. 2015; Available at: https://www.ncfh.org/uploads/3/8/6/8/38685499/fs-occ_health.pdf. Accessed December 14, 2020.
22. Lee SJ, Tak S, Alterman T, Calvert GM. Prevalence of musculoskeletal symptoms among agricultural workers in the United States: an analysis of the national health interview survey, 2004-2008. *J Agromed.* 2014;19 (3):268–280. doi:10.1080/1059924X.2014.916642.
23. Karttunen JP, Rautiainen RH. Work ability index among Finnish dairy farmers. *J Agric Saf Health.* 2009;15(4):353–364. doi:10.13031/2013.28889.
24. Karttunen JP, Rautiainen RH, Quendler E. Gender division of farm work and occupational injuries. *J Agric Saf Health.* 2019;25(3):117–127. doi:10.13031/jash.13177.
25. Collins J. Letter from the editor: effects of aging on the musculoskeletal system. *Semin Roentgenol.* 2013;48 (2):105–106. doi:10.1053/j.ro.2012.04.002.
26. Valdez G. Effects of disease-afflicted and aging neurons on the musculoskeletal system. *Bone.* 2019;122:31–37. doi:10.1016/j.bone.2019.01.023.
27. Arokoski JP, Juntunen M, Luikku J. Use of health-care services, work absenteeism, leisure-time physical activity, musculoskeletal symptoms and physical performance after vocationally oriented medical rehabilitation-description of the courses and a one-and-a-half-year follow-up study with farmers, loggers, police officers and hairdressers. *Int J Rehabil Res.* 2002;25(2):119–131. doi:10.1097/00004356-200206000-00005.
28. Bartels S, Niederman B, Waters TR. Job hazards for musculoskeletal disorders for youth working on farms. *J Agric Saf Health.* 2000;6(3):191–201. doi:10.13031/2013.1913.
29. Holmberg S, Thelin A, Stiernstrom E, Svardsudd K. The impact of physical work exposure on musculoskeletal symptoms among farmers and rural non-farmers. *Ann Agric Environ Med.* 2003;10(2):179–184. doi:10.1016/S1474-8177(03)03022-5.
30. Kearney GD, Allen DL, Balanay JA, Barry P. A descriptive study of body pain and work-related musculoskeletal disorders among Latino farmworkers working on sweet potato farms in eastern North Carolina. *J Agromed.* 2016;21(3):234–243. doi:10.1080/1059924X.2016.1178613.
31. Lachowski S, Choina P, Florek-Luszczki M, Gozdziewska M, Jezior J. Dissatisfaction with work as a risk factor of musculoskeletal complaints among foresters in Poland. *Ann Agric Environ Med.* 2017;24 (4):706–711. doi:10.26444/aaem/80985.
32. Telaprolu N, Anne SD. Physical and psychological work demands as potential risk factors for musculoskeletal disorders among workers in weaving operations. *Indian J Occup Environ Med.* 2014;18(3):129–134. doi:10.4103/0019-5278.146910.
33. Tribble AG, Summers P, Chen H, Quandt SA, Arcury TA. Musculoskeletal pain, depression, and stress among Latino manual laborers in North Carolina. *Arch Environ Occup Health.* 2016;71 (6):309–316. doi:10.1080/19338244.2015.1100104.
34. Luger T, Maher CG, Rieger MA, Steinhilber B. Work-break schedules for preventing musculoskeletal symptoms and disorders in healthy workers. *Cochrane*

Database Syst Rev. 2019;7:CD012886. doi:10.1002/14651858.CD012886.pub2.

35. Stock SR, Nicolakakis N, Vézina N, Vézina M, Gilbert L, Turcot A, Sultan-Taïeb H, Sinden K, Denis M-A, Delga C, Beaucage C. Are work organization interventions effective in preventing or reducing work-related musculoskeletal disorders? A systematic review of the literature. Scand J Work Environ Health. 2018;44 (2):113-133. doi:10.5271/sjweh.3696. Are work organization interventions effective in preventing or reducing work-related musculoskeletal disorders? A systematic review of the literature. *ScandJ Work Environ Health.* 2018;44(2):113–133. doi:10.5271/sjweh.3696.
36. Martin-Diener E, Hartmann F, van Mechelen W, Kahlmeier S. Effectiveness of exercise-based interventions aimed at reducing injuries and musculo
skeletal disorders in workers in forestry and other strenuous jobs: an overview of the literature: report for the Swiss federal office for the environment FOEN.: Zürich: Universität Zürich, Epidemiology, Biostatistics and Prevention Institute.; 31 January 2018 2018. doi:10.5167/uzh-152005.
37. Sims B, Kienzle J. Sustainable agricultural mechanization for smallholders: what is it and how can we im plement it? Agriculture. 2017;7(6):50. doi:10.3390/agriculture7060050.
38. Pickett W, King N, Lawson J. et al. Farmers, mechanized work, and links to obesity. *Prev Med.* 2015;70:59–63. doi:10.1016/j.ypmed.2014.11.012.