

Musculoskeletal Pain Among Midwest Farmers and Associations With Agricultural Activities

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Background Although agricultural workers experience a high prevalence of musculoskeletal pain, associations between specific agricultural activities and musculoskeletal pain are not well characterized.

Methods Among 518 regional farmers, responses to a mailed questionnaire were used to estimate (i) the 2-week prevalence of low back, neck/shoulder, and elbow/wrist/hand pain, and (ii) associations between the average hours per week performing common agricultural activities and musculoskeletal pain.

Results The low back was the most common location of musculoskeletal pain (33.2%), followed by the neck/shoulder (30.8%) and elbow/wrist/hand (21.6%). Statistically significant adjusted associations were observed between performing equipment repair and maintenance and low back pain; milking animals and neck/shoulder pain; and manual material handling and elbow/wrist/hand pain, among others.

Conclusions The observed prevalence estimates are consistent with previous literature, and the associations between agricultural activities and musculoskeletal pain provide an initial basis for targeted intervention research. *Am. J. Ind. Med.* 58:319–330, 2015.

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INTRODUCTION

Agricultural workers are at increased risk for a wide range of adverse health outcomes. Several population-based studies have highlighted the potential for adverse musculoskeletal health outcomes among such workers, especially in comparison to workers in other industries [Leigh and Sheetz, 1989; Morse et al., 2007] or in comparison to referent groups of persons not engaged in agriculture [Park

et al., 2001; Holmberg et al., 2005]. However, studies exploring specific risk factors for musculoskeletal health outcomes among agricultural workers, themselves, are less common.

Ultimately, one purpose of characterizing exposure-effect associations is to provide an empirical basis for future intervention. While identification of industries with elevated rates of musculoskeletal health outcomes may be useful to identify populations for additional study, it does not provide information of sufficient detail to permit the design of specific interventions. For example, a study of back pain among agricultural workers in Iowa categorized “major farm activities” as either crop production alone or crop production with livestock [Park et al., 2001]. No task-level exposure information was collected. Similarly, Xiang et al. [1999] characterized agricultural activities by creating three cash crop categories. Again, no task-level information was collected.

Only a few studies among agricultural workers in the United States have examined associations between specific tasks and musculoskeletal health outcomes, and they have

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tended to be commodity-specific. For example, Nonnenmann et al. [2008] reported associations between categories of time spent manually feeding animals, tractor use, and manually cleaning stalls, and the average number of cows milked per day with a range of musculoskeletal health outcomes among dairy farmers. Similarly, Douphrate et al. [2014] examined the effect of dairy parlor configuration (herringbone, parallel, and rotary) and several dairy-specific tasks on the musculoskeletal health status of dairy farm workers. Xiao et al. [2013] recently reported the proportion of Latino farm workers engaging in a variety of tasks (e.g., packing/sorting, planting, and machine operation) and associations between the hours per week exposed to several postural risk factors (e.g., stooped and kneeling or crawling) and musculoskeletal pain. Because agriculture is a highly heterogeneous industrial sector, observations among dairy farmers and Latino farm workers may not be generalizable to the large population of agricultural workers in the Midwest region of the United States.

To address this and other methodological limitations of the existing literature, we are conducting an ongoing prospective epidemiological study affiliated with the Great Plains Center for Agricultural Health (GPCAH) at the University of Iowa. The objectives of the study are to (i) examine seasonal trends of musculoskeletal health outcomes among a cohort of agricultural workers in nine states in the Midwest region of the United States, (ii) characterize exposure to physical risk factors for musculoskeletal health outcomes during common agricultural activities, and (iii) estimate associations between physical risk factors and musculoskeletal health outcomes. Information about musculoskeletal health outcomes, the average hours per week engaged in common agricultural activities, and potential covariates is obtained semi-annually from all participants using a self-administered set of questionnaires. In addition, a subset of participants contributes to on-farm assessment of exposure to physical risk factors using direct measures of muscle activity, posture, and whole-body vibration.

Recruitment and enrollment began in February 2012 and the maximum duration of observation will be 3.5 years. On-farm assessments of exposure to physical risk factors are in progress. The purpose of the current paper is to report demographic and personal health characteristics of the participants, characteristics of their farm operations, information about musculoskeletal health outcomes and potential covariates at the time of enrollment, and baseline (cross-sectional) associations between self-reported average weekly hours engaged in common agricultural activities and musculoskeletal pain.

METHODS

Study Participants

Names and addresses of randomly selected farm operators from the nine states served by the GPCAH (Illinois,

Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin) were obtained from a commercial agricultural marketing database (FarmReach, Baitinger Consulting, Urbandale, IA). The sampling frame for potential participants was regionally distributed in proportion to the number of farms in each of the nine states. Participants were recruited and enrolled during two periods: February 2012 and August 2012. In February 2012, invitations (including a letter containing all required elements of informed consent) and baseline questionnaires were mailed to 3,207 potential participants. The mailing included a postage-paid envelope in which to return the questionnaires, or optionally, instructions for completing the questionnaires using a secure website. A reminder postcard was sent to non-responders 3 weeks after the initial mailing. The same process was used to identify an additional 3,208 potential participants. In August 2012, invitations and the baseline questionnaires were mailed to both the second set of 3,208 potential participants and to the non-responders from the initial set of 3,207 potential participants. For both rounds of enrollment, study invitations specified that the person completing the questionnaires should (i) be at least 18 years of age and (ii) perform the majority of the work on the farm. Participants enrolled in February 2012 (group "A" hereafter) and participants enrolled in August 2012 (group "B" hereafter) formed the full study cohort. Upon receipt of the completed questionnaires, participants were compensated (\$25 USD) and became eligible to receive a lottery prize (\$100 USD). The University of Iowa Institutional Review Board approved all study procedures and authorized the consideration of participants' return of completed questionnaires as the equivalent of written informed consent.

Questionnaires and Study Variables

The self-administered questionnaires collected information about (i) demographics and personal health, (ii) characteristics of the farm operation, (iii) musculoskeletal health outcomes, (iv) the average hours per week engaged on common agricultural activities, (v) occupational psychosocial stress, and (vi) affectivity. Each questionnaire and the variables extracted for the current analyses are described below.

Demographics and personal health

Demographic information included gender; date of birth, from which age was calculated; height and weight, from which body mass index was calculated in kg/m²; education level, categorized as "up to, and including, a high school diploma," "technical school, trade school, or community college," and "university degree;" ethnicity, dichotomized as "Caucasian" and "all others;" the current position on the farm, categorized as "owner," "co-owner," and "other;" the number

of years in the current position on the farm; a dichotomous variable to indicate whether or not the participant performs the majority of the work on the farm; a dichotomous variable to indicate whether or not the participant reported farming as his/her primary occupation; and a dichotomous variable indicating whether or not the participant maintained a second, labor-intensive job outside the farm. Second jobs were classified as labor-intensive based on the industry (e.g., construction and manufacturing) or the job description (e.g., welder and mechanic).

Personal health information included tobacco use, categorized as “current,” “previous,” and “never;” alcohol use, dichotomized as no alcoholic beverages consumed per week or any alcoholic beverages consumed per week; and dichotomous variables to indicate previous diagnoses of musculoskeletal conditions or systemic autoimmune conditions (e.g., rheumatoid arthritis).

Farm operation characteristics

Characteristics of the farm operation included gross agricultural sales during the previous year (in USD), categorized as “<\$10,000,” “\$10,000–\$49,999,” “\$50,000–\$99,999,” and “≥\$100,000;” commodities produced and the proportion of annual revenue attributable to each commodity produced; and the average number of acres in production or number of animals for each commodity produced during the previous 5 years. All variables selected for inclusion in the farm operation characteristics questionnaire were obtained from analogous items used in the US Census of Agriculture [NASS, 2014]. The proportion of revenue responses were used to construct a variable to indicate the *primary* source of agricultural sales, categorized as “grain or field crops only,” “beef cattle only,” “hogs only,” “dairy only,” “specialty commodities,” “two commodities” (e.g., 50% of revenue from grain and 50% of revenue from beef cattle), “three or more commodities,” and “other.”

Musculoskeletal health outcomes

Musculoskeletal health outcomes of the low back, neck/shoulder, and elbow/wrist/hand were assessed separately. Participants who reported musculoskeletal pain of 60 min or more in total duration during the previous 2 weeks were classified as symptom positive. The maximum severity of low/back, neck/shoulder, and elbow/wrist/hand pain during the previous 2 weeks was assessed with a separate 10 cm visual analog scale for each body region. In addition, participants reported the number of days during the previous 2 weeks that low back, neck/shoulder, or elbow/wrist/hand pain affected their ability to perform their usual agricultural activities. Musculoskeletal health outcomes questionnaire items were selected from among several widely used and well-validated instruments [McDowell, 2006].

Weekly hours engaged in agricultural activities

Participants reported the average hours per week performing a variety of common agricultural activities during the 3-month period prior to enrollment (November 1, 2011 to January 31, 2012 for group A; May 1, 2012 to July 31, 2012 for group B). Agricultural activities were adapted from the Agriculture, Forestry, and Fishing industry sector agenda of the National Institute for Occupational Safety and Health (NIOSH) National Occupational Research Agenda [NORA AgFF Sector Council, 2008, pp. 76–77] and included: field work with a self-powered vehicle (e.g., combine or tractor); equipment maintenance and repair; building and structure service and repair; handling or storing harvested crop; manual handling of containers and bags (i.e., manual material handling); powered handling of containers and bags (i.e., powered material handling); feeding animals; moving, loading, or sorting animals; treating, or tagging animals; milking animals; paper work, and business duties related to the farm operation; and other (unspecified) activities.

Occupational psychosocial stress

The psychological job demands (“demand”) and decision latitude (“control”) subscales of the Job Content Questionnaire (JCQ; [Karasek et al., 1998]) were used to collect information about occupational psychosocial stress. For each participant, we calculated a “job strain ratio” by dividing the response to the decision latitude subscale by the response to the psychological job demands subscale [Landsbergis et al., 1994].

Negative affectivity

The positive and negative affectivity scale (PANAS; [Watson et al., 1988]) was used to assess negative affectivity. The PANAS scale includes 20 words conveying emotional states (e.g., interested, alert, nervous, and hostile) and, for each word, participants provide a rating of the extent they have felt that way using a five-item Likert scale (1 = “very slightly or not at all;” 5 = “extremely”). The negative affectivity score was calculated as the numerical sum of the Likert scale ratings from the 10 words associated with negative emotional states, and ranged from a score of 10 to a score of 50.

Data Analysis

The distributions of all categorical variables were summarized using observation frequencies and proportions, and the distributions of all continuous variables were summarized using means and standard deviations. Demographic and farm operation characteristics of the participants

were compared with data from each of the nine states comprising the GPCAH region reported in the 2012 Census of Agriculture [NASS, 2014]. Since participant groups A and B were enrolled during different time periods, differences between groups A and B were assessed using chi-square tests (categorical variables) or two-sample independent *t*-tests (continuous variables) to ensure the pooling of the two enrollment groups would not bias the observed associations between the exposure and outcome variables.

Unadjusted associations between (i) all demographic, personal health, farm operation characteristics, occupational psychosocial stress, and affectivity variables (i.e., all potential confounders) and (ii) the average number of weekly hours engaged in agricultural activities (i.e., the exposure variables in the current analysis), and musculoskeletal pain of the low back, neck/shoulder, and elbow/wrist/hand were estimated using logistic regression. We included an interaction term in each univariate logistic regression model to examine modification of the effect of each variable by participant group [e.g., low back pain status = age + group + (age × group)].

Multivariable logistic regression models were then developed to estimate associations between the average number of weekly hours engaged in agricultural activities and musculoskeletal pain of the low back, neck/shoulder, and elbow/wrist/hand. Separate models were constructed for each combination of agricultural activity and pain location. Each initial multivariable model included an agricultural activity and any covariate associated with pain with $P \leq 0.2$ in the univariate logistic regression analyses (alone or as a result of an interaction with enrollment group). A backward elimination procedure was then used to obtain a final multivariable logistic regression model for each body region [Kleinbaum et al., 1982]. All analyses were performed using SAS (version 9.3, SAS Institute, Inc., Cary, North Carolina).

RESULTS

Participation Rate and Study Sample

We received 654 responses from among the 6,415 randomly selected farm operators to whom invitations and baseline questionnaires were distributed. Of these, 136 indicated that either the farm was no longer in operation or the potential participant (to whom the invitation and questionnaires were addressed) was deceased, or were returned as not-deliverable. These 136 potential participants were deemed ineligible and, therefore, the study cohort included 518 participants of whom 246 were enrolled in February 2012 (group A) and 272 were enrolled in August 2012 (group B). The estimated participation rate was 8.2%.

Few statistically significant differences in demographic and personal health characteristics were observed between the two enrollment groups (Table I). Compared to group B

participants, group A participants were younger (mean age 58.4 years vs. 63.6 years, $P < 0.01$), more frequently male (98.0% vs. 90.4%, $P < 0.01$), and reported first working on a farm at a younger age (mean age first worked on a farm 15.8 years vs. 18.2 years, $P < 0.01$). Slightly more than one-third of the participants reported earning a degree from a 4-year university. About 80% of participants reported owning the farm operation on which they worked and more than 70% reported farming as their primary occupation.

Participants were enrolled from all nine states in the GPCAH region, although we enrolled proportionally more participants from Iowa, Minnesota, Nebraska, and North Dakota in group A compared to group B, and proportionally more participants from Illinois in group B compared to group A (Table II). Based on the 2012 Census of Agriculture (data not shown) and in comparison to the general population of farm owner/operators in the GPCAH region, study participants were somewhat older (overall mean age of 60.3 years vs. 56.2 years) and proportionally fewer reported gross annual agricultural sales of less than \$100,000 (47.4% vs. 63.5%). The difference in gross annual sales was most pronounced for operations reporting less than \$10,000 in annual sales (13.8% vs. 41.7%). Participants produced a wide range of commodities (Table III), most commonly grain (67.8%), beef cattle (25.7%), and field crops (24.5%). The gender distribution of the study sample (6% female) was similar to the gender distribution of the general population of farm owner/operators in the GPCAH region (6.3% of operations with female principal operators). No participants reported hogs as the primary source of agricultural sales, although several participants produced hogs in combination with at least one other commodity.

Occupational Psychosocial Stress and Affectivity

The mean score of the psychological job demands subscale of the JCQ among group A participants was slightly greater than among group B participants (24.1 vs. 23.2, $P = 0.05$; Table IV). However, mean job strain ratio (the ratio of the decision latitude subscale score to the psychological job demands subscale score) among group B participants was slightly greater than among group A participants (3.4 vs. 3.3, $P = 0.05$). Although not statistically significant, the mean negative affectivity score was slightly greater among group A participants than among group B participants.

Musculoskeletal Health Outcomes

Among all participants, the 2-week prevalence of low back pain was 33.2% (172/518), of neck/shoulder pain was 30.8% (160/518), and of elbow/wrist/hand pain was 21.6% (112/518). Among participants reporting musculoskeletal

TABLE I. Demographic and Personal Health Characteristics, by Enrollment Group

	Group A (n = 246)		Group B (n = 272)		P-value
	N (%)	Mean (SD)	N (%)	Mean (SD)	
Age in years		58.4 (13.4)		63.6 (11.7)	<0.01
Male gender	241 (98.0)		246 (90.4)		<0.01
Body mass index (kg/m ²)		29.0 (5.0)		29.1 (4.9)	0.84
Caucasian ethnicity	245 (99.6)		271 (99.6)		0.94
Education					0.79
Up to and incl. high school diploma	94 (38.2)		96 (35.3)		
Tech/trade/comm. college	64 (26.0)		82 (30.1)		
University degree	88 (35.8)		90 (33.1)		
Tobacco use					0.28
Currently use tobacco	34 (13.8)		26 (9.6)		
Never used tobacco	147 (59.8)		164 (60.5)		
Previously used tobacco	65 (26.4)		81 (29.9)		
Currently drink alcoholic beverages	140 (56.9)		139 (51.1)		0.19
Farm ownership status					0.91
Owner	199 (80.9)		216 (79.4)		
Co-owner	35 (14.2)		42 (15.4)		
Other	12 (4.9)		14 (5.2)		
Farming is primary occupation	177 (72.2)		193 (71.8)		0.90
Age first worked on a farm		15.8 (9.4)		18.2 (11.7)	0.01
Previous musculoskeletal diagnoses					
Back	88 (36.2)		99 (52.9)		0.07
Neck	49 (20.1)		54 (20.3)		0.92
Shoulder	70 (29.0)		82 (30.9)		0.64
Elbow	36 (14.9)		36 (14.1)		0.80
Wrist/hand	57 (24.1)		77 (29.3)		0.19
Autoimmune disease	10 (4.2)		18 (7.0)		0.18
Employed in labor-intensive second job	45 (18.3)		41 (15.1)		0.33

pain, the mean (SD) number of days for which the pain affected participants' ability to work during the previous 2 weeks was 3.5 (5.1) for low back pain, 3.1 (3.5) for neck/shoulder pain, and 2.6 (4.8) for elbow/wrist/hand pain. No statistically significant differences were observed between groups A and B in the prevalence of musculoskeletal pain in any body region, in the ratings of pain severity, or in the number of days pain affected the ability to work during the previous 2 weeks (Table V).

Average Hours Per Week Engaged in Agricultural Activities

Group B was enrolled 6 months after group A. Consequently, the 3-month period for which participants reported average hours per week engaged in agricultural activities also differed between groups A and B by 6 months. Regardless, few statistically significant differences in the self-reported average hours per week engaged in agricultural

activities were observed between groups A and B (Fig. 1). Group B participants reported substantially greater average hours per week of field work with a self-powered vehicle compared to group A participants (16.4 hr vs. 6.4 hr; $P < 0.01$). Compared to group B participants, group A participants also reported statistically significantly greater average hours per week of feeding animals (6.1 hr vs. 3.1 hr; $P < 0.01$) and of paperwork or other farm-related business duties (4.8 hr vs. 2.9 hr, $P < 0.01$).

Associations With Musculoskeletal Pain Low back pain

Statistically significant unadjusted associations were observed between low back pain and body mass index (odds ratio [OR] = 1.04, $P = 0.05$), reporting a previous back-related musculoskeletal diagnosis (OR = 5.98, $P < 0.01$), reporting an autoimmune condition (OR = 2.19, $P = 0.04$), job strain ratio (OR = 0.57, $P < 0.01$), and negative

TABLE II. Farm Operation Location and Characteristics, by Enrollment Group

	Group A (N = 246)		Group B (N = 272)		P-value
	N (%)	Missing (N)	N (%)	Missing (N)	
State of farm operation					<0.01
Iowa	63 (25.6)		32 (11.8)		
Illinois	29 (11.8)		116 (42.7)		
Kansas	24 (9.8)		23 (8.4)		
Minnesota	35 (14.2)		17 (6.2)		
Missouri	26 (10.6)		24 (8.8)		
Nebraska	18 (7.3)		10 (3.7)		
North Dakota	8 (3.2)		4 (1.5)		
South Dakota	9 (3.7)		14 (5.1)		
Wisconsin	34 (13.8)		32 (11.8)		
Gross agricultural sales during previous year ^a		11		19	0.37
<\$10,000	30 (12.8)		41 (16.2)		
\$10,000–\$49,999	36 (15.3)		48 (19.0)		
\$50,000–\$99,999	36 (15.3)		39 (15.4)		
≥\$100,000	133 (56.6)		125 (49.4)		
Primary source of agricultural sales					0.49
Grain only	82 (33.3)		105 (38.6)		
Beef cattle only	7 (2.9)		12 (4.4)		
Hogs only	0		0		
Dairy only	8 (3.2)		4 (1.5)		
Specialty commodities	9 (3.7)		8 (2.9)		
Two commodities	100 (40.7)		96 (35.3)		
Three or more commodities	21 (8.5)		21 (7.7)		
Other	19 (7.7)		26 (9.6)		

^aFor all participants, the previous year was 2011.

affectivity (OR = 2.16, $P < 0.01$). The protective direction of the observed unadjusted association between low back pain and job strain ratio indicates that participants reporting greater levels of decision latitude relative to psychological job demands were less likely to report symptoms in comparison to participants reporting lesser levels of decision latitude relative to psychological job demands.

Statistically significant unadjusted associations were observed between low back pain and the average hours per week engaged in equipment repair and maintenance (OR = 1.03, $P = 0.02$) and feeding animals (OR = 1.02, $P = 0.04$). A statistically significant adjusted association was observed between low back pain and the average hours per week engaged in equipment repair or maintenance (OR = 1.02, 95% confidence interval [CI] = 1.00–1.05; Table VI).

Neck/shoulder pain

A statistically significant unadjusted association was observed between neck/shoulder pain and education level. Specifically, participants with a university degree were more

likely to report neck/shoulder pain compared to those with up to, and including, a high school diploma (OR = 1.69, $P = 0.02$). Statistically significant unadjusted associations were also observed between neck/shoulder pain and reporting a previous neck or shoulder-related musculoskeletal diagnosis (OR = 5.46, $P < 0.01$), reporting an autoimmune condition (OR = 3.88, $P < 0.01$), job strain ratio (OR = 0.47, $P < 0.01$), and negative affectivity (OR = 1.83, $P < 0.01$).

Statistically significant unadjusted associations were observed between neck/shoulder pain and the average hours per week engaged in equipment repair and maintenance (OR = 1.02, $P = 0.05$), manual material handling (OR = 1.06, $P = 0.05$), and milking animals (OR = 1.04, $P = 0.03$). The unadjusted association between neck/shoulder pain and the average hours per week engaged in paperwork or other farm-related business duties was also elevated (OR = 1.03, $P = 0.06$). Statistically significant adjusted associations were observed between neck/shoulder pain and the average hours per week engaged in moving/loading/sorting animals (OR = 1.14, CI = 1.00–1.30), milking animals (OR = 1.05, CI = 1.00–1.09), and paperwork or

TABLE III. Commodities Produced and Associated Acreage in Production or Number of animals (n = 518)

Commodity	N (%)	Acres (median, IQR)	Number of Animals (median, IQR)
Grain (e.g., corn, soybeans, or wheat)			
Yes	351 (67.8)	370 (150–840)	
No	126 (24.3)		
Mismatch ^a	41 (7.9)	6.3 (0–155)	
Field crops (e.g., hay)			
Yes	127 (24.5)	50 (25–125)	
No	294 (56.8)		
Mismatch	97 (18.7)	35 (10–80)	
Beef cattle			
Yes	133 (25.7)		60 (25–110)
No	320 (61.8)		
Mismatch	62 (12.5)		0 (0–5)
Dairy cattle			
Yes	28 (5.4)		100 (50–175)
No	473 (91.3)		
Mismatch	17 (3.3)		0 (0–0)
Hogs			
Yes	19 (3.7)		250 (25–3,600)
No	486 (93.8)		
Mismatch	13 (2.5)		0 (0–2)
Specialty animals (e.g., chickens or horses)			
Yes	14 (2.7)		66 (20–350)
No	476 (91.8)		
Mismatch	29 (5.5)		5 (2–20)
Specialty items (e.g., fruits or vegetables)			
Yes	16 (3.1)	15 (1–50)	
No	489 (94.4)		
Mismatch	13 (2.5)	0 (0–0)	
Horticulture specialties (e.g., flowers or nursery)			
Yes	6 (1.2)	6 (1–14)	
No	504 (97.3)		
Mismatch	8 (1.5)	0 (0–0)	
Other livestock (e.g., goats or sheep)			
Yes	10 (1.9)		30 (25–35)
No	494 (95.4)		
Mismatch	14 (2.7)		4 (0–28)
Unspecified commodity			
Yes	1 (0.2)	40 (n/a)	50 (n/a)
No	458 (88.4)		
Mismatch	59 (11.4)	46 (0–240)	0 (0–0)

IQR, interquartile range.

^a“Mismatch” indicates participants who reported not producing the commodity but reported revenue associated with the commodity or, conversely, participants who reported producing the commodity but reported no revenue associated with the commodity.

TABLE IV. Descriptive Statistics of the Job Content Questionnaire Subscales and Negative Affectivity Portion of the Positive and Negative Affectivity Scale, by Enrollment Group

	Group A, mean (SD)	Group B, mean (SD)	P-value
Job Content Questionnaire			
Psychological job demands	24.1 (4.4)	23.2 (4.3)	0.05
Decision latitude	76.2 (8.5)	76.7 (8.5)	0.59
Strain ratio	3.3 (0.7)	3.4 (0.6)	0.05
Negative affectivity	17.8 (6.6)	16.8 (6.2)	0.07

other business duties (OR = 1.02, CI = 1.00–1.08). Regarding paperwork or other business duties, a stronger association was observed among group A participants (OR = 1.05; 95% CI = 1.01–1.09) than among group B participants (OR = 0.97; 95% CI = 0.90–1.04).

Elbow/wrist/hand pain

Statistically significant unadjusted associations were observed between elbow/wrist/hand pain and gender (OR = 2.44 for women, *P* = 0.02), reporting a previous elbow, wrist, or hand-related musculoskeletal diagnosis (OR = 7.94, *P* < 0.01), reporting an autoimmune condition (OR = 4.61, *P* < 0.01), and job strain ratio (OR = 0.56, *P* < 0.01).

Statistically significant unadjusted associations were observed between elbow/wrist/hand pain and the average hours per week engaged in manual material handling (OR = 1.10, *P* < 0.01), feeding animals (OR = 1.03, *P* < 0.01), moving/loading/sorting animals (OR = 1.07, *P* = 0.04), and milking animals (OR = 1.04, *P* = 0.04). Statistically significant adjusted associations were observed between elbow/wrist/hand pain and the average hours per week engaged in manual material handling (OR = 1.10, CI = 1.03–1.18) and milking animals (OR = 1.04, CI = 1.00–1.09).

DISCUSSION

Musculoskeletal Pain Prevalence

Musculoskeletal pain was reported frequently by study participants at baseline, with a 2-week low back pain prevalence of 33.2%, neck/shoulder pain prevalence of 30.8%, and elbow/wrist/hand pain prevalence of 21.6%. While estimates of musculoskeletal pain prevalence among agricultural workers vary considerably, our prevalence estimates and our observation that low back pain was more common than neck/shoulder pain and elbow/wrist/hand pain are both consistent with the results of several studies

TABLE V. Musculoskeletal Symptom, Symptom Severity and Days Affected by Symptoms, by Body Region and Enrollment Group (VAS, Visual Analog Scale)

	Group A (N = 246)	Group B (N = 272)	P-value
Low back pain			
Low back pain during past two weeks; N (%)	87 (35.3)	85 (31.2)	0.32
VAS score (among those w/pain); mean (sd)	4.7 (2.3)	4.9 (2.3)	0.71
Days affected (among those w/pain); mean (sd)	3.4 (4.9)	3.6 (5.3)	0.81
Neck/shoulder pain			
Neck/shoulder pain during past two weeks; N (%)	75 (30.5)	85 (31.2)	0.85
VAS score (among those w/pain); mean (sd)	4.8 (2.3)	4.3 (2.1)	0.22
Days affected (among those w/pain); mean (sd)	3.5 (2.3)	2.7 (4.2)	0.26
Elbow/wrist/hand pain			
Elbow/wrist/hand pain during past 2 weeks; N (%)	55 (22.3)	57 (21.0)	0.70
VAS score (among those w/pain); mean (sd)	3.9 (2.3)	4.2 (2.1)	0.42
Days affected (among those w/pain); mean (sd)	2.3 (4.5)	2.9 (5.1)	0.58

describing musculoskeletal symptoms among agricultural workers in the US and internationally, as reported in a recent review of the literature [Osborne et al., 2012].

Authors of previous studies of musculoskeletal pain among US agricultural workers have typically reported 12-month period prevalence estimates (rather than the 2-week period prevalence estimates reported in this study), limiting direct comparisons to our results. For example, 12-month prevalence estimates of low back pain include 31% among Iowa farmers [Park et al., 2001], 38% among Kansas farmers [Rosecrance et al., 2006], 29% among Colorado farmers

[Xiang et al., 1999], and 30% among US dairy parlor workers [Doughrath et al., 2014]. Similarly, Gomez et al. [2003] reported a 12-month prevalence of low back pain of 41% among 1,706 agricultural workers in New York State. Among those participants reporting low back pain during the 12-month period, just over one-third reported pain occurring during the previous week, resulting in a 7-day prevalence of 15%, a value of about half the 2-week low back pain prevalence observed in the current study. Although dairy was the most common primary farm commodity in Gomez et al. [2003] (in contrast to the current study, in which only 5.4% of participants produced dairy products), 7-day day neck/shoulder and hand/wrist prevalence estimates were also lower.

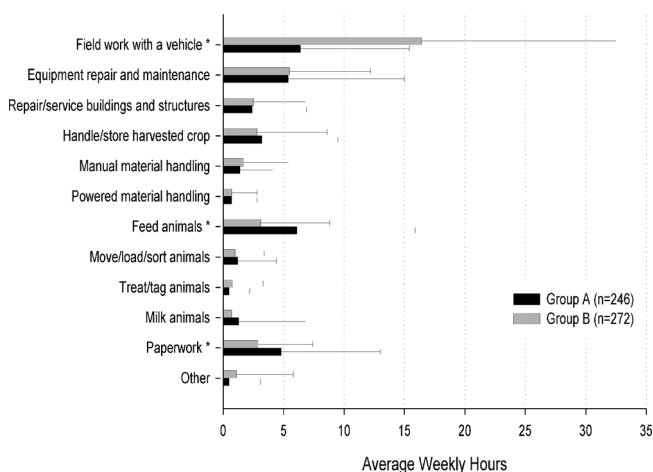


FIGURE 1. Self-reported average weekly hours engaged in agricultural activities during the 3 months prior to completion of baseline set of questionnaires, by enrollment group (*statistically significant difference between enrollment group distributions). Error bars represent standard deviations.

Staggered Enrollment Methods

Interpretation of the adjusted associations observed between the average hours per week engaged in common agricultural activities during the previous 3 months and musculoskeletal pain in the past 2 weeks is complicated by the staggered enrollment of the two study participant groups. Group A participants were enrolled in February 2012 and the 3-month recall period (from November 2011 through January 2012) encompassed a slower period for agricultural activities in the US Midwest. Group B participants were enrolled in August 2012 and the 3-month recall period (from May 2012 through July 2012) encompassed a busier period for agricultural activities in the US Midwest. Consequently, and not surprisingly, group A participants reported fewer average hours per week of field work with a vehicle and greater average hours per week engaged in feeding animals (vs. grazing for summer) and paperwork or other business

TABLE VI. Crude and Adjusted Associations Between the Average Weekly Hours Engaged in Agricultural Activities During the Previous 3 Months and Low Back, Neck/Shoulder, and Elbow/Wrist/Hand Pain During the Past 2 Weeks

	Low back ^a		Neck/shoulder ^b		Elbow/wrist/hand ^c	
	Unadjusted	Adjusted ^a	Unadjusted	Adjusted ^b	Unadjusted	Adjusted ^c
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Field work w/vehicle	1.01 (0.99–1.02)	1.00 (0.99–1.02)	1.00 (0.99–1.02)	1.01 (0.99–1.02)	1.01 (0.99–1.02)	1.01 (0.99–1.03)
Handling/storing crop	1.00 (0.98–1.04)	1.00 (0.96–1.03)	1.02 (0.99–1.05)	1.01 (0.98–1.05)	1.02 (0.98–1.05)	1.01 (0.97–1.04)
Equipment maint./repair	1.03 (1.00–1.05)	1.02 (1.00–1.05)	1.02 (1.00–1.04)	1.01 (0.99–1.04)	1.01 (0.99–1.04)	1.00 (0.97–1.03)
Building maint./repair	1.01 (0.97–1.06)	1.02 (0.97–1.06)	1.01 (0.96–1.05)	1.00 (0.95–1.05)	1.02 (0.97–1.06)	1.00 (0.94–1.06)
Manual handling	1.03 (0.97–1.09)	1.00 (0.94–1.06)	1.06 (1.00–1.12)	1.02 (0.96–1.08)	1.10 (1.04–1.17)	1.10 (1.03–1.18)
Powered handling	1.05 (0.97–1.15)	1.05 (0.95–1.15)	1.02 (0.93–1.11)	1.02 (0.93–1.12)	1.03 (0.94–1.13)	1.04 (0.93–1.16)
Feed animals	1.02 (1.00–1.04)	1.02 (0.99–1.04)	1.02 (0.99–1.04)	1.01 (0.98–1.03)	1.03 (1.01–1.06)	1.02 (0.99–1.05)
Treat/tag animals	1.03 (0.95–1.11)	0.98 (0.89–1.09)	0.96 (0.87–1.06)	0.96 (0.85–1.08)	1.05 (0.97–1.15)	1.01 (0.89–1.13)
Move/load/sort animals	1.04 (0.98–1.10)	1.02 (0.95–1.10)	0.99 (0.93–1.06)	1.14 (1.00–1.30)	1.07 (1.00–1.14)	1.05 (0.97–1.13)
Milk animals	1.01 (0.98–1.05)	1.02 (0.98–1.06)	1.04 (1.00–1.08)	1.05 (1.00–1.09)	1.04 (1.00–1.08)	1.04 (1.00–1.09)
Paperwork	1.01 (0.98–1.04)	0.99 (0.96–1.02)	1.03 (1.00–1.06)	1.02 (1.00–1.08)	1.01 (0.98–1.04)	1.00 (0.97–1.04)

Statistically significant adjusted associations are identified with bold typeface.

^aAssociations between low back pain and each activity adjusted for prior back-related musculoskeletal diagnosis and negative affectivity. Association between low back pain and equipment maintenance and repair also adjusted for alcohol use.

^bAssociations between neck/shoulder pain and each activity adjusted for prior neck- or shoulder-related musculoskeletal diagnosis and strain ratio. Association between neck/shoulder pain and moving/loading/sorting animals also adjusted for enrollment group status. Association between neck/shoulder pain and milking animals also adjusted for education level. Association between neck/shoulder pain and paperwork also adjusted for enrollment group status and education level.

^cAssociation between elbow/wrist/hand pain and each activity except manual material handling and moving/loading/sorting animals adjusted for prior elbow-, wrist-, or hand-related musculoskeletal diagnosis, gender, autoimmune condition, labor-intensive second job, and strain ratio. Association between elbow/wrist/hand pain and manual material handling and moving/loading/sorting animals adjusted for prior elbow-, wrist-, or hand-related musculoskeletal diagnosis, autoimmune condition, labor-intensive second job, and strain ratio.

duties in comparison to group B participants. A statistically significant interaction between group status and exposure was observed only for paperwork and other business duties. In the absence of significant interaction between exposure and group status, it is unlikely that the observed results were an artifact of the staggered enrollment procedure.

Exposure Estimation Strategies for Use in Agricultural Health Studies

Virtually, all previous studies have used self-report to ascertain exposure to risk factors for musculoskeletal health outcomes among agricultural workers. Among these studies, investigators have used two distinct strategies to capture exposure to such risk factors. The first strategy is to collect information about specific exertions, body positions, and other biomechanical hazards (e.g., work with arms over head, carrying heavy loads, and use of vibrating hand tools) in a way that is unrelated to specific agricultural tasks performed. For example, Xiao et al. [2013] categorized the average hours per week (over an entire farming career) that Latino farm workers reported engaging in activities such as stooping, kneeling or crawling, and walking while carrying loads

greater than 25 pounds. Stooping 30 hr or more per week was associated with hip pain among both men (OR = 2.49, CI = 1.03–5.99) and women (OR = 2.15, CI = 1.04–4.46). Among women, kneeling or crawling 25 hr or more per week was associated with back pain (OR = 2.96, CI = 1.27–6.93) and knee pain (OR = 3.02, CI = 1.07–8.50).

The second strategy is to ascertain duration of exposure to specific agricultural tasks, typically without information about specific biomechanical hazards. Using this strategy, participants may be asked to report experiences with specific agricultural activities, such as tractor use or milking. For example, Gomez et al. [2003] reported significant associations between tractor use during the previous year (dichotomized as ever/never) and low back pain (OR = 1.51, CI = 1.20–1.89), neck/shoulder pain (OR = 1.28, CI = 1.62), and hand/wrist pain (OR = 1.72, CI = 1.34–2.21). A few studies have used a combination of the two strategies [e.g., Shipp et al., 2007, 2009; Nonnenmann et al., 2008].

In the current study, we asked participants to report on the time spent engaged in specific agricultural tasks during the 3-month interval immediately prior to questionnaire completion (i.e., the second strategy). Using this approach, we observed several statistically significant adjusted associations between the average hours per week engaged in agricultural activities

and musculoskeletal pain. Our results are consistent with observations made among other agricultural populations. For example, the average hours per week milking animals was associated with both neck/shoulder pain and elbow/wrist/hand pain in our study sample, a result which is consistent with the observations of several studies among dairy farm workers in the US and elsewhere [Stål et al., 2000, 2003; Pinzke et al., 2001; Nonnenmann et al., 2008; Douphrate et al., 2012, 2014]. We also observed an association between the average hours per week performing equipment repair and maintenance and low back pain. Few studies have reported associations between equipment repair and maintenance and musculoskeletal pain in an agricultural setting, and none that we are aware of reported an association with low back pain. However, a high prevalence of low back pain has been observed among automobile mechanics [Torp et al., 1996], whose work may be similar to agricultural equipment repair and maintenance. Consistent with our results, Rosecrance et al. [2006] observed an elevated (but not statistically significant) adjusted association between the number of hours per year engaged in “machine repair” and shoulder pain (OR = 1.01, CI = 0.99–1.02). Similarly, we observed an elevated but not statistically significant association between the average hours per week performing equipment maintenance and repair and neck/shoulder pain (OR = 1.01, CI = 0.99–1.04).

The associations we observed between the average hours per week engaged in agricultural activities and musculoskeletal pain may provide useful information about agricultural activities for which interventions could be targeted. Ultimately, however, it is likely that both the identification of agricultural activities associated with musculoskeletal pain *and* the characterization of the fundamental biomechanics of those activities are needed to develop maximally effective intervention strategies. For each agricultural activity examined in this cross-sectional analysis, our prospective strategy will combine self-reported average hours per week captured at regular intervals with directly measured exposure information (muscle activity, posture, repetition, and vibration).

Occupational Psychosocial Stress and Negative Affectivity

We observed statistically significant unadjusted associations between job strain ratio and low back pain, neck/shoulder pain, and elbow/wrist/hand pain. Removal of the job strain ratio variable from the multivariable models resulted in a change in the estimate of association between exposure and outcome of >15%, therefore, job strain ratio was retained in *all* final multivariable models of association between agricultural activities and neck/shoulder pain and elbow/wrist/hand pain. For these two musculoskeletal outcomes, failure to control for job strain would have resulted in confounded estimates of association.

Occupational psychosocial stress, quantified with the JCQ, has been identified as an independent risk factor for musculoskeletal health outcomes among non-agricultural workers [Andersen et al., 2002; van den Heuvel et al., 2005; Smith et al., 2009; Gerr et al., 2014a]. While reporting of elevated levels of occupational psychosocial stress is well documented among agricultural workers [Fraser et al., 2005; Wallis and Dollard, 2008; Lunner Kolstrup et al., 2013], only a few studies of agricultural populations have explored relationships between these measures and musculoskeletal health outcomes (including traumatic injury). For example, based on qualitative analyses of focus group data, Kidd et al. [1996] suggested a relationship between stress, including mental demands, and farmers’ perceptions of injury risk. More recently, Trask et al. [2014] observed a statistically significant adjusted association between “self-rated work stress” and chronic back pain in a population-based study of 350 Canadian farmers. Holmberg et al. [2004] reported adjusted associations between low back pain and (i) greater JCQ psychological job demands and (ii) lesser JCQ decision latitude subscale scores. The direction of the unadjusted associations we observed between job strain ratio and musculoskeletal pain status was consistent with the results of Holmberg et al. [2004].

Similar to job strain ratio, we observed statistically significant unadjusted associations between negative affectivity and both, low/back pain, and neck/shoulder pain. Negative affectivity was also retained in *all* final multivariable models of association between agricultural activities and low back pain (because of its strength as a confounder). The affectivity instrument (PANAS) was selected because negative affectivity (a personality trait) may confound associations between the JCQ and reported musculoskeletal pain. Specifically, participants who characteristically experience greater generalized distress may respond with generalized negativity on both the JCQ and the musculoskeletal pain questionnaire. Previous epidemiological studies of musculoskeletal health outcomes among working people have used similar analyses to more completely control for confounding by negative affectivity [Andersen et al., 2002; Gerr et al., 2014b]. An interesting observation was that job strain ratio (but not negative affectivity) remained in the final multivariable models of association between agricultural activities and neck/shoulder pain and elbow/wrist/hand pain while, conversely, negative affectivity (but not job strain ratio) remained in the final multivariable models of association between agricultural activities and low back pain. Because of these complex patterns of confounding by both occupational psychosocial stressors and individual psychological characteristics, it is important that investigators capture and control for these variables in future studies examining associations between agricultural work and musculoskeletal health outcomes.

The multivariable modeling approach used in the current analyses was designed to control for potential confounding of

the associations between agricultural activities and musculoskeletal pain by job strain and negative affectivity but not to provide unbiased estimates of association between job strain and negative affectivity and musculoskeletal pain. We plan to more fully explore the associations between occupational psychosocial stressors and individual psychological characteristics and musculoskeletal pain among our cohort in future analyses.

Limitations of the Current Study

The results of this study must be interpreted in the context of several methodological limitations. Although we used well-established methods to encourage participation, including a monetary incentive to each participant upon completion of study questionnaires, a lottery prize, the scheduling of survey distribution during favorable periods of time, and reminders sent shortly after the initial mail-out [Pennings et al., 2002], the low response rate limits the extent to which the results may be generalized beyond the study sample.

Despite the low response rate, the distribution of commodity types among the study participants was similar to that of the general population of farm operations in the nine study states. For example, hog operations represent less than 3% of all farm operations in the nine study states [NASS, 2014]. About 4% of study participants reported producing hogs (in combination with at least one additional commodity), which is consistent with the US Census of Agriculture hog production data. Based on the similarities of the demographic and farm operation characteristics of the study sample in comparison to the general population of farm owner/operators and farm operations in the nine study states, we believe the FarmReach database provided a suitable frame from which to randomly sample and recruit participants. Although some differences between study participants and the general population of farm owner/operators in the nine study states were observed, most notably that study participants were somewhat older and proportionally more participants reported higher gross annual agricultural sales, we have no basis to conclude that the exposure-effect associations among participants differed meaningfully from non-participants.

Because prevalence data were collected, it is possible that those with the greatest adverse musculoskeletal health effects may have modified their agricultural activities prior to participating in the study. Such selective survival leads to an attenuation of observed associations, in comparison to the true adverse effect magnitude.

Both exposure and health outcome data were self-reported. Therefore, a reporting bias (i.e., an overestimation of exposure) may have occurred to a greater extent among those who experienced musculoskeletal pain in comparison to those who did not experience musculoskeletal pain. The magnitude of such overestimation is difficult to ascertain, but

when present, would lead to observed associations that are greater than the true associations.

Agricultural tasks selected for use in this study were adapted from the NIOSH National Occupational Research Agenda for Agriculture, Forestry and Fishing list of production agriculture activities [NORA AgFF Sector Council, 2008, pp. 76–77]. Our goal was to draw from a widely used source to best standardize the task variables and to accommodate the wide range of agricultural activities engaged in by the study sample. However, because agricultural task, rather than objectively measured physical exposure, was used as the exposure variable, each hour of task time may represent widely differing biomechanical load across and within participants. For example, the task “field work,” could include operating a self-propelled high clearance sprayer, an agricultural tractor, or a combine. For this reason, we anticipate considerable between-subject and within-subject variance of exposure estimation within each agricultural task (i.e., the tasks are heterogeneous). This artifactual inflation of variance will result in a decrease in the power to detect associations between exposure and outcome.

CONCLUSIONS

In this cross-sectional analysis of a large sample of US Midwest agricultural producers, associations were observed between several agricultural activities and musculoskeletal pain while controlling for important covariates including occupational psychosocial stressors and negative affectivity. After the initial data collection, we are continuing to follow this cohort for prospective assessment of musculoskeletal health status. In addition, in order to better characterize biomechanical exposures associated with agricultural tasks, we are also performing direct, on-farm, exposure assessment to minimize exposure estimation error. Ultimately, the results of these observational studies should be translated into interventions targeting agricultural activities associated with the highest exposure intensities and the greatest potential for harm.

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REFERENCES

- Andersen JH, Kaergaard A, Frost P, Thomsen JF, Bonde JP, Fallentin N, Borg V, Mikkelsen S. 2002. Physical, psychosocial, and individual risk factors for neck/shoulder pain with pressure tenderness in the muscles among workers performing monotonous, repetitive work. *Spine* 27:660–667.
- Douphrate DI, Fethke NB, Nonnenmann MW, Rosecrance JC, Reynolds SJ. 2012. Full shift arm inclinometry among dairy parlor workers: A feasibility study in a challenging work environment. *Appl Ergon* 43:604–613.
- Douphrate DI, Gimeno D, Nonnenmann MW, Hagevoort R, Rosas-Goulart C, Rosecrance JC. 2014. Prevalence of work-related musculoskeletal symptoms among US large-herd dairy parlor workers. *Am J Ind Med* 57:370–379.
- Fraser CE, Smith KB, Judd F, Humphreys JS, Fragar LJ, Henderson A. 2005. Farming and mental health problems and mental illness. *Int J Soc Psychiatry* 51:340–349.
- Gerr F, Fethke NB, Anton D, Merlino L, Rosecrance J, Marcus M, Jones MP. 2014a. A prospective study of musculoskeletal outcomes among manufacturing workers: II. Effects of psychosocial stress and work organization factors. *Hum Factors* 56:178–190.
- Gerr F, Fethke NB, Merlino L, Anton D, Rosecrance J, Jones MP, Marcus M, Meyers AR. 2014b. A prospective study of musculoskeletal outcomes among manufacturing workers: I. Effects of physical risk factors. *Hum Factors* 56:112–130.
- Gomez MI, Hwang S, Stark AD, May JJ, Hallman EM, Pantea CI. 2003. An analysis of self-reported joint pain among New York farmers. *J Agric Saf Health* 9:143–157.
- Holmberg S, Thelin A, Stiernström EL, Svärdsudd K. 2004. Psychosocial factors and low back pain, consultations, and sick leave among farmers and rural referents: A population-based study. *J Occup Environ Med* 46:993–998.
- Holmberg S, Thelin A, Stiernström EL, Svärdsudd K. 2005. Low back pain comorbidity among male farmers and rural referents: A population-based study. *Ann Agric Environ Med* 12:261–268.
- Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. 1998. The Job Content Questionnaire (JCQ): An instrument for internationally comparative assessment of psychosocial job characteristics. *J Occup Health Psychol* 3:332–335.
- Kidd P, Scharf T, Veazie M. 1996. Linking stress and injury in the farming environment: A secondary analysis of qualitative data. *Health Educ Q* 23:224–237.
- Kleinbaum DG, Kupper LL, Morgenstern H. 1982. *Epidemiologic Research: Principles and Quantitative Methods*. New York, NY: Von Nostrand Reinhold.
- Landsbergis PA, Schnall PL, Warren K, Pickering TG, Schwartz JE. 1994. Association between ambulatory blood pressure and alternative formulations of job strain. *Scand J Work Environ Health* 20:349–363.
- Leigh JP, Sheetz RM. 1989. Prevalence of back pain among fulltime United States workers. *Br J Ind Med* 46:651–657.
- Lunner Kolstrup C, Kallioniemi M, Lundqvist P, Kymäläinen HR, Stallones L, Brumby S. 2013. International perspectives on psychosocial working conditions, mental health, and stress of dairy farm operators. *J Agromed* 18:244–255.
- McDowell I. 2006. *Measuring Health*. Oxford, UK: Oxford University Press.
- Morse TF, Warren N, Dillon C, Diva U. 2007. A population based survey of ergonomic risk factors in Connecticut: Distribution by industry, occupation, and demographics. *Conn Med* 71:261–268.
- NASS. 2014. 2012 Census of Agriculture: United States Summary and State Data. Washington, DC: United States Department of Agriculture, National Agricultural Statistics Service.
- Nonnenmann MW, Anton D, Gerr F, Merlino L, Donham K. 2008. Musculoskeletal symptoms of the neck and upper extremities among Iowa dairy farmers. *Am J Ind Med* 51:443–451.
- NORA AgFF Sector Council. 2008. National Agriculture, Forestry, and Fishing Agenda. Washington, DC: National Institute for Occupational Safety and Health.
- Osborne A, Blake C, Fullen BM, Meredith D, Phelan J, McNamara J, Cunningham C. 2012. Prevalence of musculoskeletal disorders among farmers: A systematic review. *Am J Ind Med* 55:143–158.
- Park H, Sprince NL, Whitten PS, Burmeister LF, Zwerling C. 2001. Risk factors for back pain among male farmers: Analysis of Iowa Farm Family Health and Hazard Surveillance Study. *Am J Ind Med* 40:646–654.
- Pennings JME, Irwin SH, Good DL. 2002. Surveying farmers: A case study. *Appl Econ Perspect Pol* 24:277–299.
- Pinzke S, Stål M, Hansson G-Å. 2001. Physical workload on upper extremities in various operations during machine milking. *Ann Agric Environ Med* 8:63–70.
- Rosecrance J, Rodgers G, Merlino L. 2006. Low back pain and musculoskeletal symptoms among Kansas farmers. *Am J Ind Med* 49:547–556.
- Shipp EM, Cooper SP, del Junco DJ, Delclos GL, Burau KD, Tortolero SR. 2007. Severe back pain among farmworker high school students from Starr County, Texas: Baseline results. *Appl Epidemiol* 17:132–141.
- Shipp EM, Cooper SP, del Junco DJ, Delclos GL, Burau KD, Tortolero S, Whitworth RE. 2009. Chronic back pain and associated work and non-work variables among farmworkers from Starr County, Texas. *J Agromed* 14:22–32.
- Smith CK, Silverstein BA, Fan ZJ, Bao S, Johnson PW. 2009. Psychosocial factors and shoulder symptom development among workers. *Am J Ind Med* 52:57.
- Stål M, Hansson G-Å, Moritz U. 2000. Upper extremity muscular load during machine milking. *Int J Ind Ergon* 26:9–17.
- Stål M, Pinzke S, Hansson G-Å. 2003. The effect on workload by using a support arm in parlor milking. *Int J Ind Ergon* 32:121.
- Torp S, Riise T, Moen BE. 1996. Work-related musculoskeletal symptoms among car mechanics: A descriptive study. *Occup Med* 46:407–413.
- Trask C, Bath B, McCrosky J, Lawson J. 2014. A profile of farmers and other employed Canadians with chronic back pain: A population-based analysis of the 2009–2010 Canadian Community Health Surveys. *J Rural Health* 30:300–310.
- van den Heuvel SG, van der Beek AJ, Blatter BM, Hoogendoorn WE, Bongers PM. 2005. Psychosocial work characteristics in relation to neck and upper limb symptoms. *Pain* 114:47–53.
- Wallis A, Dollard MF. 2008. Local and global factors in work stress—The Australian dairy farming exemplar. *Scand J Work Environ Health* 34(6):66–74.
- Watson D, Clark LA, Tellegen A. 1988. Development and validation of brief measures of positive and negative affect: The PANAS scales. *J Pers Soc Psychol* 54:1063–1070.
- Xiang H, Stallones L, Keefe TJ. 1999. Back pain and agricultural work among farmers: An analysis of the Colorado Farm Family Health and Hazard Surveillance Survey. *Am J Ind Med* 35:310–316.
- Xiao H, McCurdy SA, Stoecklin-Marois MT, Li CS, Schenker MB. 2013. Agricultural work and chronic musculoskeletal pain among Latino farm workers: The MICASA study. *Am J Ind Med* 56:216–225.