Journal of Ergonomics

Alabdulwahab et al., J Ergonomics 2016, 6:5
DOI: 10.4172/2165-7556.1000178

Research Article | Open Access

Physical Risk Factors Associated with Upper Extremity Musculoskeletal Disorders among Aluminum Manufacturing Workers

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Abstract

This study defines prevalence of upper musculoskeletal disorders (UMSDs) and identifies physical risk factors associated with upper extremity disorders among aluminum factory workers in Saudi Arabia, during the spring of 2015. We administered a survey to 115 production line workers in an aluminum factory. Surveys addressed demographics, work history, job performance, pain and medical history. Three occupational health experts evaluated risk of UMSDs in each department and created an expert scale indicating UMSDs risk. Overall 45.2% of the workers reported at least one type of pain; joint pain was the most common. 39% of non-Saudi reported pain compared to 18% of Saudi. Muscle pain was associated ($p \le 0.001$) with repetitive movement (RR=5.8), lifting (RR=5.75), pushing and pulling (RR=5.17), awkward movement (RR=3.81). Joint pain was associated ($p \le 0.001$) with repetitive motion (RR=7.12), lifting (RR=3.28), pushing and pulling (RR=3.28) and awkward movement (RR=2.64). A logistic regression model including nationality (OR=3.229, CI=1.052, 9.9) (p=0.041), and department indicates that only anodizing (OR=5.286; CI=1.28, 21.77) (p=0.021), was related to muscle pain when using painting unit as a reference.

Keywords: Risk factors; Upper extremity; Musculoskeletal disorders; Aluminum; Workers

Introduction

Work-related musculoskeletal disorders have become a major problem in modern society and an important cause of morbidity and disability during the past few decades [1-3]. They are one of the leading workplace injuries in US industry and make up over half of injuries sustained [4]. Internationally, research points to cumulative trauma disorders as being the most common form of work-related ill health, severely affecting millions of employees, organizations and society at a physical, psychological and financial level [5-8].

Cumulative trauma disorders (CTDs) comprise musculoskeletal disorders affecting muscles, tendons, nerves and blood vessels or other soft tissues and joints [9]. They are also called repetitive strain injury, regional musculoskeletal disorders, repetitive motion disorders, overuse syndromes, or repetitive motion injuries [9]. Common symptoms include a burning sensation, muscle weakness, pain, paresthesia (tingling), hot or cold sensations, swelling, stiffness or cramps, loss of normal sensations, or grip strength and fatigability [6]. Work-related musculoskeletal disorders affecting the neck, shoulder, arm, wrist and/or hand are called upper extremity musculoskeletal disorders (UMSDs), which will be discussed in this study [2,10].

Presently, musculoskeletal disorders are one of the most important problems ergonomists encounter in the workplace around the world. In Australia, from a total of 12 million Australians who worked during the 12 month period prior to October 2009, 5.3% (640,700) experienced at least one work-related injury or illness. It has been reported also in an Australian study that 356,500 men and 284,300 women experienced a work-related injury in 2009-10 [11-13]. CTDs account for over half of all occupational-related illnesses and diseases in the United States and New Zealand. In the United Kingdom, an estimated 538,000 people who worked in 2008/2009 believed that they were suffering from CTDs that were caused or aggravated by their current or past work. As a result, 7.3 million workdays were lost [5-8]. Estimated costs associated with compensation claims include $215 billion in the US in 1995, $26 billion in Canada in 1998, and $350 million in New Zealand annually [14]. Algadir and Anwer [15] found that the prevalence of musculoskeletal pain among construction workers in Saudi Arabia to be high, (48.5%). The responding workers reported pain in the neck, shoulders, hand, knee or ankle; the most prevalent type of pain was a dull ache followed by cramping. Risk factors associated with pain included years of work, duration of breaks during work, and use of protective equipment [15]. In the United Kingdom, the prevalence of UMSDs in 2014-15 was 233,000 (case rate of 730 per 100,000 people employed) [16].

The objectives of this study are to determine the prevalence of upper musculoskeletal disorders and identify physical risk factors associated with upper extremity disorders in aluminum factory workers in Saudi Arabia.

Subjects and Methods

During the spring of 2015, we evaluated UMSDs through a cross-sectional survey of aluminum factory workers using validated questionnaires laid out by Keyserling et al. [17,18] and a concise index for the assessment of exposure to repetitive movements of the upper limbs (OCRA index) [18]. The questionnaire had five sections addressing demographic data, job performance and work, pain and medical history. The factory population (n=300) consisted of workers on the production line (n=250) and office workers (n=50). However, office workers were not included in the study. We invited a convenience sample of 125 male production line workers to participate, out of which,

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Received September 17, 2016; **Accepted** September 25, 2016; **Published** September 30, 2016

Citation: Alabdulwahab Z, Al-Otaibi ST, Abugad HA, Harber P (2016) Physical Risk Factors Associated with Upper Extremity Musculoskeletal Disorders among Aluminum Manufacturing Workers. J Ergonomics 6: 178. doi: 10.4178/2165-7556.1000178

ten refused to participate. The response rate was 92%. We administered the questionnaires in the factory clinic through personally interviewing the workers in English and Arabic language. We included male workers who were 18 years of age or older and who had at least one year of work in production. At this factory, there were no women working on the production line. Office workers and those with a fracture or operation on the upper extremities were excluded.

The factory produced molded aluminum products; there were nine major departments in the facility: Department-Task Description

- Cast aluminum-Heating raw aluminum to high temperature
- Press aluminum-Pressing aluminum into shapes
- Wood-Making aluminum that looks like wood
- Dye shop-Dying aluminum in different colors
- Paint-line-Painting aluminium products
- Packing/Shipping- Packing aluminum products
- Stores-Storage of aluminum products
- Maintenance-Equipment maintenance
- Anodizing Cleaning aluminum by chemical application

The assessed risk factors included demographic factors and physical actions (task repetition, lifting, pushing and pulling, pinching, gripping, awkward postures, contact stress and vibration).

We examined the work tasks of each department and combined those performing similar activities. The molten line group comprised employees who cast aluminum and then pressed it into molds. Other processes are undertaken and then the aluminum is made so that it looks like wood. Next, we merged the dye shop and paint-line workers into a single group. Common movements were made by workers of the supply department and those of packing/shipping, stores and maintenance. Anodizing was not combined with any other department.

Expert scale of UMSDs

In addition to relying upon each worker's self-report of his ergonomic risks, two additional methods of characterizing the ergonomic hazard level of each department were utilized. First, we used an "expert rating" method, whereby three occupational physicians visited the facility and scored each of the departments in terms of risk of developing UMSDs on a scale of 1 to 5 (5=Greatest risk). Each performed the rating independently and they were blinded from each other. Each of the evaluator's scored risk factors included repetition, lifting, pushing, pull motions, and awkward postures. The scores for each factor or an average among the physicians for each department were used in subsequent t-test analyses that compared the average expected closure values among those with any type of pain.

Work factor exposure index

The Work Factor Exposure index was developed to quantitatively estimate the frequency of the four ergonomic risk factors according to department. The index was calculated separately for each of the four exposure factors (e.g., repetition) by determining what percentage of all respondents within the department reported on the questionnaire that they had excessive repetitive motion. For example, in the Supply department, 18 subjects said they had repetitive motion and 14 said they did not. Therefore, the Work Exposure index for Repetition=18/(18+14) or 56%. Once this was calculated for each of the four ergonomic factors for each department, the Work Exposure Index of the factor was assigned to each worker in the department for the subsequent analysis linking health outcomes with exposures. This approach is preferable to the alternative in which the associations between health effect and repetition are measured based upon each individual's statement about excessive repetition. The latter approach is potentially biased since workers with muscle pain may be more likely to claim that the job had excessive repetition.

An additional measure, the Total Exposure Work Factor, was calculated for each department by adding together the Work Factor Exposure index for repetition, lift, push/pull, and awkward posture in the department.

Data Analysis

The data were entered using SPSS version 16.1. Data were evaluated using frequencies and univariate descriptive statistics (frequency and percentages). Bivariate analysis (Chi-squared tests) were undertaken to examine the relationships between muscle pain and joint pain for independent variables (demographic, departments and physical risk factors including repetitive, lifting, awkward posture, push and pulling). To assess the impact of individual personal or work exposure factors, relative risks were calculated. For the multivariable analyses, odds ratios were utilized in a logistic regression model. Point estimates and 95% confidence of goals are included where appropriate. A P value <0.05 was considered significant.

Results

The study population characteristics are reported in Table 1. Of the 115 participants, 24% were Saudi and 76 % were non Saudi. The entire population was male and mean age was 37 years (standard deviation [SD]: 11.40 years); 25% were smokers. Fifty-seven percent of the workers had been on the job for more than three years. Thirty-three percent of the employees worked regular shifts; 67% of the workers worked irregular shifts. There were two categories of job title, supervisory/technician and laborer. On the production line, there were nine departments, and as described in the methods section, some were combined, resulting in four risk-related groups including molten-line (29%), painting (32%), supply (28%) and anodizing (11%).

Overall, 45% of the participants reported at least one type of pain. Among those reporting pain, joint pain was more common, being reported by 44% of all participants; 34% reported muscle pain. Nearly all subjects with muscle pain also reported joint pain (38/39), whereas many (13/51) with joint pain did not have muscle pain.

Table 2 showed that muscle pain was significantly associated with repetitive motions and resulted in a 5.8-fold increase in the risk of muscle pain (95% CI=(3.05, 10.99)). Lifting was associated with a similar response (RR=5.75; 95% CI=(3.68, 8.97)). Pushing and pulling (RR=5.17; 95% CI=(3.34, 8.02)), and awkward movement (RR=3.81; 95% CI=(2.75, 5.27)), were also found to be significant risk factors for muscle pain. All muscle pain risk factors are significant at $p<0.001$.

Joint pain was significantly associated with the same risk factors at $p<0.001$. Repetitive motion had a RR=7.12 (95% CI=(3.99, 12.69)), lifting had a RR=3.28 (95% CI=(2.41, 4.47)), pushing and pulling had a RR=3.28 (95% CI=(2.41, 4.47)), and awkward motion had a RR=2.64 (95% CI=(2.06, 3.38)). Both muscle and joint pain were not significantly associated with demographic variables, including age, marital status, smoking, educational level, job title, job duties, work duration, shift work or previous job. Moreover, there was no significant association

Characteristics		N	Percentage
Age	<28	36	31%
	28-35	26	23%
	36-45	26	23%
	>45	27	23%
Nationality	Saudi	28	24%
	Non-Saudi	87	76%
Marital status	Single or widowed	25	22%
	Married	90	78%
Smoking status	Never	86	75%
	Previous or current	29	25%
Educational level	Intermediate or below	62	54%
	Secondary or above	53	46%
Job title	Supervisor, technician or writer	59	51%
	Laborer	56	49%
Work duration	Through 3 years	49	43%
	>3 years	66	57%
Work shifts*	Regular	38	33%
	Irregular	77	67%
Departments	Molten line	33	29%
	Painting	37	32%
	Supply work	32	28%
	Anodizing	13	11%

*Work shifts are schedule in which groups of workers rotate through set of periods where group of workers' time from 6 AM to 6 PM and another group of workers time from 6 PM to 6 AM throughout the day

Table 1: Demographic characteristics (N=115).

					Muscles pain						Joint pain	
Independent variables	**Yes**	**%**	**No**	**%**	**p value**	**RR**	**Yes**	**%**	**No**	**%**	**p value**	**RR**
Nationality					0.042	2.18					0.1	
Saudi	5	18	23	82.1			9	32.1	19	67.9		
Non-Saudi	34	39	53	60.9			42	48.3	45	51.7		
Departments					0.021						0.044	
Painting	11	30	26	70.3		Reference	12	32.4	25	67.6		Reference
Molten line	12	36	21	63.6		1.22	12	36.4	21	63.6		1.12
Supply work	7	22	25	78.1		0.73	18	56.2	14	43.8		1.5
Anodizing	9	69	4	30.8		2.32	9	69.2	4	30.8		2.13
Repetition					<0.001	5.8					<0.001	7.12
Yes	30	71	12	28.6			41	97.6	1	2.4		
No	9	12	64	87.7			10	13.7	63	86.3		
Lifting					<0.001	5.75					<0.001	3.28
Yes	23	100	0	0			23	100	0	0		
No	16	17	76	82.6			28	30.4	64	69.6		
Pushing/pulling					<0.001	5.17					<0.001	3.28
Yes	22	96	1	4.3			23	100	0	0		
No	17	19	75	81.5			28	30.4	64	69.6		
Awkward posture					<0.001	3.81					<0.001	2.64
Yes	12	100	0	0			12	100	0	0		
No	27	26	76	73.8			39	37.9	64	62.1		
Sick leave					<0.001	3.74					<0.001	2.93
Yes	16	89	2	11.1			18	100	0	0		
No	23	24	74	76.3			33	34	64	66		
Taking therapy					<0.001						<0.001	
Yes	39	75	13	25			51	98.1	1	1.9		
No	0	0	63	100			0	0	63	100		

Table 2: Demographic and self-reported work factors associated with reported pain.

with self-reported work factors, including pinching, gripping, contact stress and vibration with muscle and joint pain. Nationality (comparing non-Saudi to Saudi) was associated with a 2.18% increase in risk of muscle pain (p value=0.042). Both lost work time and the need for treatment were more frequently found in workers who reported joint and/or muscle pain (p<0.001).

We examined the relationship between departments, nationality and muscle pain using logistic regression. The model indicated that nationality (OR=3.229, CI=(1.052, 9.9) (p=0.041)), and employment in the anodizing department were related to the presence of muscle pain (anodizing OR=5.286; CI=(1.28, 21.77), p=0.021) when using the painting department as a reference (Table 3).

We used the expert scale defined in the methods to evaluate UMSD risks associated with production line departments. Results are presented in Table 4. The department with the greatest risk was the supply department (68.75% employees at risk), painting (67.5%) had the next highest level of expected risk; anodizing (66.25%), and molten (60%) had the lowest level of expected risk.

Repetitive motion was common in the supply department (56.2%), but only half as common in anodizing (30.8%), molten (30.2%) and painting departments (27%) (Table 5). This exposure was found to be significantly different when a chi-squared test was performed (p<0.05). Lifting of items was greatest in the anodizing department (53.3%), whereas lifting in the molten (18.2%), painting (16.5%) and supply (12.5%) departments were less frequent. This exposure difference was also found to be statistically significant by a chi-squared test (p<0.01). Activities using pushing and pulling motions were most common in the anodizing department (61.5%) followed by supply (18.8%), painting (13.5%), and molten (12.1%) departments. The chi-squared test for this exposure difference had a p-value of <0.001. Awkward motion was borderline significantly associated with all departments (p=0.07). Anodizing had the highest risk (30.8%), supply was next (9.4%), then molten (9.1%) and finally painting (5.4%). A comprehensive evaluation by department for all risk factors indicated that anodizing was the department with the highest total risk (44.2%) followed by supply (24.2%), molten (17.4%) and painting (15.5%); a Chi-squared test of the association of total risk and department resulted in a p-value of <0.0001.

Using the expert exposure values, we found that there was no significant difference in the amount of exposure to the various risk factors for those with and without muscle or joint pain. The expert exposure was very different from the exposure reported by workers for each risk factor within the departments. Using the reported work factor exposure, it was found that exposure to several of the risk factors varied significantly for those with and without muscle or joint pain (Tables 6 and 7). The lifting, pushing and pulling, awkward and total exposure work factors were significantly higher (p<0.05) for those with muscle pain compared to those without muscle pain. The pushing and pulling, awkward and total exposure work factors were significantly higher (p<0.05) for those with joint pain compared to those without joint pain. These results indicate that the amount of exposure to various risk factors in each department was related to the amount of pain experienced within the departments. The overall exposure, taking everyone in the department into account, was significantly associated with both types of pain for many of the risk factors.

Variable	OR	95% CI		p value
		Lower	Upper	
Painting		Reference		0.037
Supply work	0.585	0.191	1.795	0.349
molten line	1.178	0.422	3.288	0.755
Anodizing	5.286	1.283	21.777	0.021
Nationality (Non-Saudi)	3.229	1.052	9.911	0.041

Table 3: Logistic regression model results logistic regression analysis of muscle pain in department and nationality.

Discussion

This study describes important risks associated with the prevalence of upper musculoskeletal disorders and identifies physical factors of these disorders in in aluminum factory workers in Saudi Arabia. Overall 45.2% of the workers reported at least one type of pain, but joint pain was the most common. The subjects could effectively differentiate between joint pain and muscle pain. Furthermore, joint pain appears to be a more specific condition than muscle pain since 13 out of the 51 of the workers with joint pain did not have muscle discomfort. It was reported that workers in general are more oriented about joint pain than muscular pain and indeed they can express this type of pain more easily than muscular pain [19-21].

Overall, these results suggest that use of a musculoskeletal symptom discomfort questionnaire is useful for plant floor ergonomic surveys. The results of this study show that departments with higher pain prevalence can be identified and that workers can meaningfully differentiate among types of discomfort.

The one-year prevalence of any UMSD complaints in our population totaled 45.2% in an all-male work force. A study of aluminum workers from Norway indicated total body musculoskeletal disorders prevalence of 93.0% among male and female workers [22]. Prevalence of neck (17%) and shoulder symptoms (22%) were reported in males. UMSD symptoms were reported by participants for elbows and hands at 7-10%, respectively [22]. When combined, these upper extremity symptoms comprise 56% although many of these workers may have symptoms in multiple UMSD locations. Hughes et al. conducted a study in workers of an aluminum smelter and found UMSDs of 0.8% for neck, 14.9% for shoulder, 11.6% for elbow/forearm and 14.9% for the hand/wrist. The combined UMSD prevalence was 42.2% in an aluminum smelting facility [23]. These results are virtually the same as for our study (45.2%) in an aluminum molding facility. Aghilinejad et al. investigated UMSDs in an all-male working population of aluminum industries in Iran and found a prevalence of 41.09% for shoulder injuries and 36.64% for neck related injuries [24]. Construction workers in Saudi Arabia report a 48% prevalence of UMSDs [15].

There are several ways to assess the prevalence of UMSDs among workers. Medical examination and self-reports by a questionnaire are the two primary approaches although they yield different and incomparable results. Our study employed administered-questionnaires. Overall, studies reported the most frequent musculoskeletal disorders complaints occur in the upper exremities [22,24]. Our findings are similar to those of other studies in the developing world (Iran and Saudi Arabia). More importantly, they are similar to countries in the developed world (US and Norway) where workplace standards exist and are enforced. Clearly the industry, as a whole, would benefit from implementation of a UMSD prevention program.

We used three measurements of exposure-health outcome. First workers reported muscle or joint pain and any exposure to four physical risk factors: Repetitive motion, lifting, pushing/pulling and awkward motions. All were highly significantly related to both types of pain. Self-reported pain and exposure are likely biased since individuals that have

Expert Score										
Department	**Repetition ESR**	**%**	**Lift ESL**	**%**	**Push/pull ESP/ESP**	**%**	**Awkward ESA**	**%**	**Total EST**	**Percentage %**
Supply	3.5	70	4.25	85	4	80	2	40	15.75	78.75
Paint	4.25	85	3.75	75	2.75	55	2.75	55	13.5	67.5
Molten line	3.25	65	3.25	65	2.75	55	2.75	55	12	60
Anodizing	4.5	90	3.75	75	2.75	55	2.25	45	13.25	66.25

ESR: Expert score repetition; **ESL**: Expert score lift; **ESP**: Expert score push and pull
ESA: Expert score awkward; **EST:** Expert score total; **% means:** Take averages of three occupational experts then divided on 5 then multiply 100 for percentage

Table 4: Expert score rating by department.

Department	**Repetition**			**Lift**			**Push/pull**			**Awkward**			**Total**		
	Yes	No	% Yes	Yes	No	% Yes	Yes	No	% Yes	Yes	No	% Yes	Yes	No	% Yes
Supply	18	14	56.2	4	28	12.5	6	26	18.8	3	29	9.4	31	97	24.2%
Paint	10	27	27	6	31	16.5	5	32	13.5	2	35	5.4	23	125	15.5%
Molten line	10	23	30.3	6	27	18.2	4	29	12.1	3	30	9.1	23	109	17.4%
Anodizing	4	9	30.8	7	6	53.3	8	5	61.5	4	9	30.8	23	29	44.2%
p value	-	-	0.05	-	-	0.01	-	-	0.001	-	-	0.07	-	-	0.0001

Table 5: Work factor reports by department.

Expert Ratings Exposure									
	Muscle pain					**Joint pain**			
Risk factors	**Yes**	**No**	**T-Stat**	**p value (2-tailed)**	**Risk factors**	**Yes**	**No**	**T-Stat**	**p value (2-tailed)**
ESR	3.86	3.74	1.31	0.2	ESR	3.79	3.77	0.227	0.821
ESL	3.68	3.77	-1.21	0.2	ESL	3.8	3.69	1.613	0.11
ESP	2.97	3.16	-1.7	0.1	ESP	3.19	3.02	1.59	0.113
ESA	2.61	2.5	1.7	0.1	ESA	2.48	2.59	-1.59	0.113
EST	13.38	13.8	-1.52	0.1	EST	13.89	13.48	1.54	0.125

Table 6: Expert ratings exposure and work factor reported exposure.

Work Factor Reported Exposure									
	Muscle pain				**Joint pain**				
Risk factors	**Yes**	**No**	**T-Stat**	**p value (2-tailed)**	**Risk factors**	**Yes**	**No**	**T-Stat**	**p value (2-tailed)**
WRR%	34.13	37.7	-1.47	0.1	WRR%	38.75	34.7	1.75	0.08
WRL%	24.79	17.6	3.13	0	WRL%	21.98	18.48	1.54	0.125
WRP%	25.09	17.4	2.65	0	WRP%	23.51	17.2	2.26	0.025
WRA%	13.11	9.07	2.81	0	WRA%	12.16	9.07	2.23	0.028
WRT%	24.26	20.4	2.27	0	WRT%	24.08	19.82	2.65	0.009

WRR%: Work report repatative; **WRL%:** Work report lift; **WRP%:** Work report push and pull; **WRA%:** Work report awkward; **WRT%:** Work report awkward
ESR: Expert score repetition; **ESL**: Expert score lift; **ESP**: Expert score push and pull; **ESA:** Expert score awkward; **EST:** Expert score total

Table 7: Expert ratings exposure and work factor reported exposure.

pain are more likely to recall an exposure.

Secondly, expert ratings were assigned to each department for each risk factor. Here, no significant differences were found, which is consistent with a previous study [25], most probably due to the discrepancies between expert exposure and observed exposure. Additionally, since the experts had not visited the factory frequently, their understanding of the requirements and demands of each department may not have been complete. Thirdly, work factor reported exposure, which was derived from the proportion of individuals exposed to each factor within each department, had significant differences in exposure between pain and no pain for lifting, awkward posture, and pushing/pulling. The measurements of exposure-health outcome reduce the individual recall bias issue of the self-reported measurement.

Contrary to other studies that found a relationship between duration of employment and UMSDs, our study found no relationship with duration of employment [22,26,27]. The lack of a relationship may be associated with inexperience and reduced knowledge of the operation. Another risk factor associated with UMSDs was nationality. Saudi Arabia hires many international workers who commonly perform manual labor. As a result, we found an increase in UMSDs among the non-Saudi workers. UMSDs are significantly associated with repetitive motion tasks [28-33]. We found that tasks associated with awkward posture lead to complaints of UMSDs, as found in other studies [24,30-32,34]. Lifting, pushing and pulling of heavy loads are associated with UMSDs pain; this finding is consistent with previous studies [24,32,34-36]. The anodizing department of our study is significantly associated with reports of upper UMSDs pain and elevated physical risk factors.

When the workers experienced UMSDs, it was found that joint pain and muscle pain reports are significantly associated with sick leave (muscle RR=3.74, joint RR=2.93). Other studies [15,34,37,38] report similar findings, where these results indicated that it was associated with the health effects rather than simply representing minor discomfort. Our study found a significant relationship between treatment, such as hot and cold treatment, and the use of medication such as analgesics, which is similar to the findings of previous studies [15,37].

Pathophysiologic mechanisms that may involve these physical risk factors and lead to pain in upper extremities could include application of frequent force to soft tissue such as tendons, muscles, or nerves over a prolonged period. This kind of trauma causes micro-tears to the tendon, leading to inflammation and consequently to the disorder. Furthermore, reduced blood supply to the muscle and tendon caused by tension, the inflammatory effects from the breakdown of synovial fluid and endoneural edema, along with increased intrafascicular pressure and the displacement of myelin in a dose response manner can cause the USMD pain [9,39-42].

Simple survey instruments, such as the one used in this study, can be extremely useful in selecting the highest priority for preventive interventions. Our study showed that each of the four work factors studied was significantly assessed by the work factor method. Therefore, each of the four factors should be addressed in prevention. Our study also showed that risks were considerably greater in one department (anodizing). This strongly suggests the need to focus job worksite redesign in this particular area. This method of simple workplace surveys can be easily performed in many work places on a cost-efficient basis.

It is likely that preventive intervention can be implemented to reduce the risk of injuries among workers in this study (Preventive intervention include e.g., job modification, screening of workers and health promotion).

The limitations of this study include single gender evaluation as only men worked in this factory, differences in languages spoken by the workforce (compensated for by administering the questionnaire), lack of clinical evaluation of UMSDs and potential recall bias by the workers when completing the questionnaire. The study relies upon the self-reports by the workers without objective evaluation of their clinical state. In addition, we utilized the workers' own descriptions of physical demands without making quantitative ergonomic worksite measurements. As a cross-sectional study, workers who left the job because of severe pain would not have been included. In the future, a longitudinal study would be helpful to assess causal relationships more directly.

Conclusion

UMSDs are common, affecting 45% of workers in this study. These disorders have a significant impact on work (e.g. 88% missed work due to muscle pain and all missed work due to joint pain). All four risk factors (lifting, pushing/pulling, awkward motion, repetition) were found to be significantly related to both types of pain when looking at individual level exposure. When considering the expert exposure values assigned for each risk factor to each department, none of the risk factors were significantly related to either type of pain. This is likely due to the discrepancy between the assumed exposure and the observed exposure in the data. Finally, when using the work factor reported exposure values, each individual within a department was assigned the same exposure value for a particular risk factor. This uniform assignment was designed to reduce potential individual-level recall bias. Pushing/pulling and awkward motions were found to be significantly associated with both types of pain when using these exposure values. Additionally, lifting was significantly associated with muscle pain. When looking at individual or group values, it is clear that the risk factors are highly prevalent in this population and that they are strongly related to UMSDs.

Acknowledgement

The authors would like to thank Mary Kay O'Rourke, Ph.D from Community, Environment, and Policy, the University of Arizona, Tucson, Arizona, USA and Mr. Nathan Grunow from Biostatistics and Epidemiology, the University of Arizona, Tucson, Arizona, USA for their help in reviewing the manuscript.

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