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Case Report

Job Hazard Analyses for Musculoskeletal Disorder Risk Factors in Pressing Operations of Dry-cleaning Establishments

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ABSTRACT

Job hazard analyses were conducted to assess exposure to musculoskeletal disorder (MSD) risk factors in seven workers of three dry-cleaning establishments. In accordance with the Washington State Ergonomics Rule, the analyses were performed in two separate steps: (1) observation and checklist approaches were made to identify a "caution zone job" in the seven workers' pressing operations across the three shops; and (2) detailed posture and motion analyses were undertaken to determine a "MSD hazard" in one worker's operation using a video technique. One "caution zone job" was identified and it was the pressing operation job in which five physical risk factors were found in the pressing operations. The detailed analyses confirmed that one "MSD hazard", i.e., awkward posture in shoulders, was prevalent in the pressing operations of the three dry-cleaning facilities. It would be desirable to reduce MSD risk factors including awkward shoulder posture in the dry-cleaning industry.

1. Introduction

Dry cleaning is predominantly a small business industry that consists of approximately 36,000 shops in the US [1]. Most of these shops employ one to four workers who are exposed to a variety of risk factors [2,3].

Exposure to awkward postures and repetitive motions for prolonged periods can lead to a variety of potentially disabling injuries and disorders of musculoskeletal tissues and/or peripheral nerves [4]. Ergonomic stressors in the dry-cleaning industry are visible among workers performing pressing operations, which are dynamic and repetitive tasks requiring reaching, precision gripping, maintenance of awkward postures, and long standing [5–8].

Musculoskeletal disorder (MSD) incidence rate was 80.5 cases per 10,000 full-time workers (FTW) for laundry and dry-cleaning workers in the US in 2011, which was quite higher than that (38.5 cases per 10,000 FTW) for all occupations [9]. In 2014, compared with the incidence rates of carpal tunnel syndrome (0.7 cases per 10,000 FTW) and tendonitis (0.2 cases per 10,000 FTW) for all occupations in the country, those rates for laundry and dry-cleaning workers were 5.7 and 7 times higher, respectively [10], indicating that MSDs of pressing operation workers have drawn attention to the dry-cleaning industry.

There was an effort to characterize exposure to MSD risk factors in the pressing operations of several dry-cleaning shops in the early of 2000s [6]. The effort was made because, despite high incidence rates of MSDs for the laundry and dry-cleaning workers, there was, even today, little scientific documentation of ergonomic hazard analyses in the dry-cleaning sector. In fact, the incidence rate of injuries and illnesses was also higher in the laundry, cleaning, and garment services sector than that in private industry of the US in 2000 [11]. In this regard, it is likely desirable to document and inform the effort work performed in the dry-cleaning shops.

This study aimed to document job hazard analyses which were conducted to identify physical risk factors for MSDs in the pressing operations of three dry-cleaning establishments and suggest recommendations for reducing the risk factors identified.

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2. Methods

2.1. Study and participants

This study was part of a capstone project for a master program at the University of Massachusetts Lowell [6]. Ergonomic job hazard analyses were undertaken by assessing exposure to MSD risk factors at three dry-cleaning establishments in Massachusetts, USA. The three shops were randomly selected through telephone contacts and seven workers voluntarily participated in the study. The seven individuals, two or three workers from each facility, were those working in pressing operations and had experiences in pressing for 2 years or more.

2.2. Methods

2.2.1. General

A variety of information, including the participants' anthropometry and workstation dimension data, was gathered through walkthroughs and interviews during the capstone project. Job hazard analyses were performed in accordance with part of Washington Administrative Codes (WACs) under the Washington State Ergonomics Rule (WA Rule; WAC 296-62-051) [12]. For the analyses, three WACs were employed: WAC 296-62-05105 (CZ Checklist: What is a "caution zone job"?); WAC 296-62-05130 (What options do employers have for analyzing and reducing work-related MSD hazards?); and WAC 296-62-05174 (HZ Checklist; Appendix B: Criteria for analyzing and reducing work-related MSD hazards for employers who choose the Specific Performance Approach). The WA Checklists were selected in that they were simply enabled for use in ergonomic hazard analyses [6,13]. Validity and repeatability of the Checklists, along with utility aspects, were addressed elsewhere [14–17].

In this study, a "caution zone job" was defined as a job where the workers' typical work activities included any physical risk factors as specified in the CZ Checklist (Table 1). A "MSD hazard" was defined as a hazard, based on the HZ Checklist where a criterion is stated for each of 21 physical risk factors, in that all of the conditions relating to a physical risk factor were present in the caution zone job identified. A MSD hazard was excluded in cases where it was present in less than three workers' operations.

2.2.2. Job hazard analysis

The job hazard analyses were conducted in two steps. Step 1 included assessing exposure to MSD risk factors using observation and checklist approaches at the workplaces. The seven participants' work activities were directly observed to seek the physical risk factors for MSDs during a typical production shift at the three dry-cleaning shops. As any physical risk factors of a caution zone job were found using the CZ Checklist and, according to the Specific Performance Approach of the WAC 296-62-01530, the criterion of a MSD hazard was examined using the HZ Checklist accordingly. Once a MSD hazard was visually identified, it was regarded as a MSD hazard candidate for future analyses.

Step 2 was only for the MSD risk factors of both the caution zone job and MSD hazard candidates which were identified in Step 1. The workers' activities were videotaped using a video technique for detailed analyses at a personal computer (PC). At least five work cycles were videotaped at each worker's own workstation across the seven participants' pressing operations. A work cycle was defined as the time interval to complete a pressing operation for a garment. The videotaping data were intended for work sampling as

Table 1
Physical risk factors characterized for use in this study

Physical risk factor	
Description	Criterion*
Awkward posture in head or shoulder (posture: shoulder raising)	Working with the hand(s) above the head or the elbow(s) above the shoulder more than 2 hours total per day
Awkward posture in neck or back (posture: back 30°)	Working with the neck or back bent more than 30°(without support or the ability to vary posture) more than 2 hours total per day
Awkward posture in squatting (posture: squatting)	Squatting more than 2 hours total per day
Awkward posture in kneeling (posture: kneeling)	Kneeling more than 2 hours total per day
Heavy, frequent, or awkward lifting (force: heavy lifting)	Lifting objects weighing more than 34 kg once per day or more than 25 kg more than 10 times per day
Heavy, frequent, or awkward lifting (force: frequent lifting)	Lifting objects weighting more than 4.5 kg if done more than twice per minute more than 2 hours total per day
Heavy, frequent or awkward lifting (force: awkward lifting)	Lifting objects weighting more than 11 kg above the shoulders, below the knees, or at arm length more than 25 times per day
High hand force in pinching (force: pinching)	Pinching an unsupported object weighing 1 kg or more per hand, or pinching with a force of 2 kg or more per hand, more than 2 hours total per day (comparable to pinching half a ream of paper)
High hand force gripping (force: gripping)	Gripping an unsupported object weighing 4.5 kg or more per hand, or gripping with a force of 4.5 kg or more per hand more than 2 hours total per day (comparable to clamping light duty automotive jumper cables onto a battery)
Highly repetitive motion in upper extremities (repetition: repeating)	Repeating the same motion with the neck, shoulders, elbows, wrists, or hands (excluding keying activities) with little or no variation every few seconds more than 2 hours total per day
Highly repetitive motion in keying (repetition: keying)	Performing intensive keying more than 2 hours total per day
Repeated impact (impact)	Using the hand (heel/base of palm) or knee as a hammer more than 10 times per hour more than 2 hours total per day
Moderate to high hand-arm vibration (vibration: high)	Using impact wrenches, carpet strippers, chain saws, percussive tools (jack hammer, scalers, riveting, or chipping hammers) or other hand tools that typically have high vibration levels more than 30 minutes total per day
Moderate to high hand-arm vibration (vibration: moderate)	Using grinders, sanders, jig saws, or other hand tools that typically have moderate vibration levels more than 2 hours total per day

* Specified in Washington Administrative Code 296-62-05105.

well. Videotaping and motion analysis were made according to both National Institute for Occupational Safety and Health and Occupational Safety and Health Administration guidelines [18,19]. A video camera (DCR-TRV230, Sony, Japan) was used for videotaping and a MGI Video Wave (Version 4.0, MGI Software Corp., Canada) was installed on the PC for motion analyses.

For work analyses at the PC, 35 work cycles (five work cycles × seven workers) were looked at and fundamental cycles were characterized in each work cycle. A work cycle largely consisted of four fundamental work cycles: (1) picking a garment from a rack (picking); (2) pad-covering, ironing, or steaming the garment (pressing); (3) inspecting and making up (inspecting); and (4) returning the garment to rack (back to rack). The pressing fundamental cycle included initial pad-covering, ironing, or steaming motions. The inspecting cycle included rework such as finish pad-covering, ironing, or steaming motions. The length of each fundamental cycle was defined as the time elapsed from initialing that activity until the beginning of the next fundamental cycle [20].

For MSD hazard candidates visually identified in Step 1, detailed posture and repetitive motion analyses were undertaken for one female worker's pressing operation in order to determine whether the caution zone job met the criterion of the identified MSD hazard candidate as specified in the HZ Checklist. Video images were manually stopped when necessary to observe specific actions more closely. The worker's pressing operation was assumed as a typical operation in the dry-cleaning industry.

2.3. Data management and analysis

Study data were managed and analyzed at a biomechanical laboratory. The frequency of awkward posture was calculated and compared with the designated criterion. For analyses of repetitive motion of body parts, each of the 20 fundamental work cycles (five work cycles × four fundamental cycles) was analyzed separately by counting the repetition number of the identified motion pattern (e.g., one back-and-forth motion of the iron). All data collected were analyzed using Microsoft Excel (Microsoft Corp., Redmond, WA, USA).

3. Results

3.1. Participants

Five female and two male workers were observed for this study and their anthropometric data are shown in Table 2. The participants were all right-handed. The average age was 40 (19–53) years and work experience in pressing ranged from 2.3 years to 35 years.

3.2. Work analyses

Workstation dimensions and work conditions varied across the seven workers' pressing operations (Table 3). The pressing operations were performed normally for more than 7 hours in total during the workday. About 12 minutes (742 seconds) of work time was observed per worker (median). The median duration of five work cycles per worker ranged from 101 seconds to 195 seconds. The length of a work cycle depended on the type of garment handled, and these were highly variable. Within each work cycle, the sequence of fundamental cycles and work method were judged to be similar among all seven workers.

Table 2
Anthropometry of the subjects by sex

Description	Mean and standard deviation (cm)					
	Female ($n=5$)		Male ($n=2$)		All ($N=7$)	
Height	167.2	6.8	176.4	5.2	169.8	7.5
Forearm length	24.7	0.7	25.7	0.8	25.0	0.9
Shoulder height	136.7	5.6	144.3	4.2	138.9	6.1
Elbow height	105.3	4.3	111.1	3.3	107.0	4.7
Arm length	73.6	3.0	77.6	2.3	74.7	3.3
Vertical reach	210.3	8.6	221.8	6.5	213.6	9.4
Horizontal reach	73.6	3.0	77.6	2.3	74.7	3.3

Table 3
Workstation dimensions and work conditions of seven participants

Description	Mean and SD	
Workstation dimension		
Press table height (cm)	77.6	1.7
Press table length (cm)	144.4	5.7
Press table width (cm)	70.9	5.0
Press pad height (cm)	104.3	1.2
Iron stand (cm)	105.6	6.9
Conveyor height (cm)	183.0	5.0
Work area (m^2/worker)	1.9	0.4
Work condition		
Mean working time/d (h)	7.6	0.6
Mean work cycle time/garment (s)	148.5	35.5
Mean rest time/d (min)	5.7	9.8
Mean lunch time (min)	8.6	14.6
Mean iron weight (kg)	1.0	0.2

SD, standard deviation.

3.3. Job hazard analyses

3.3.1. Step 1

One caution zone job was identified—the pressing operation job—where five physical risk factors were present across the seven workers' pressing operations in the three dry-cleaning shops. With regard to the caution zone job, the five physical risk factors are shown in Fig. 1.

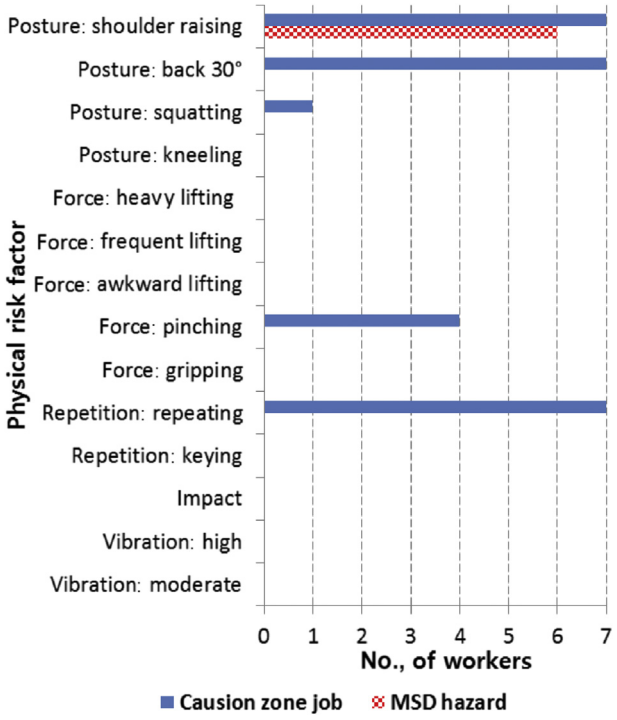

Fig. 1. Physical risk factors identified with respect to both one caution zone job in seven workers' pressing operations and one musculoskeletal disorder (MSD) hazard in six workers' pressing operations of three dry-cleaning shops.

In addition, two MSD hazard candidates were sought using the HZ Checklist in the six out of seven workers' pressing operations. The two candidates were associated with two physical risk factors, respectively, of the identified caution zone job as shown in Table 1 and Fig. 1: (1) posture: shoulder raising; and (2) repetition: repeating.

3.3.2. Step 2

For the one participant's pressing operation, detailed data of work analysis were obtained and those of posture and repetitive motion analysis were produced as well. The duration of five work cycles was 659 seconds in total. In these work cycles five garments were handled, i.e., ivory long dress for 208 seconds, black shirt A for 33 seconds, brown jacket for 247 seconds, purple long dress for 115 seconds, and black shirt B for 56 seconds, respectively. A total of 20 fundamental cycles were analyzed across five work cycles of the worker's operation. The median duration for each fundamental cycle was 4 seconds for picking, 99 seconds for pressing, 9 seconds for inspecting, and 3 seconds for back to rack. Pressing accounted for the largest portion of time in every work cycle.

For one MSD hazard candidate found in Step 1, the detailed analysis data varied across both work cycles and fundamental cycles in the worker's pressing operation. The median frequency of awkward shoulder postures was 5.2 times/min across the work cycles while it was 7.0 times/min across the fundamental cycles (Table 4). The awkward shoulder postures were associated with motions, e.g., reaching to the conveyor or rack and holding a garment over the head for inspection, and those postures were taken by the worker for more than 4 hours in total per day in the operation. Therefore, the hazard candidate was finally determined as a MSD hazard because its criterion, "repetitively raising the hands above the head or the elbow above the shoulders more than once per minute more than 4 hours in total per day," was exceeded by both the physical risk factor and work condition across work cycles and fundamental cycles in the worker's pressing operation (Fig. 1, Table 4).

For the other MSD hazard candidate, the detailed data also varied in the worker's pressing operation. There were three different types of repetitive motion such as pad-covering, ironing, and steaming in the pressing operation. The three repetitive motions accounted for 83% of the entire duration (659 seconds) which consisted of 23% for pad-covering, 51% for ironing, and 9% for steaming.

The median frequency of repetitive motions was 7.3 times/min for ironing, 0.7 times/min for pad-covering, and 0 times/min for steaming, respectively, across the work cycles (Table 5). The median frequency of repetitive ironing motions was 7.3 times/min across the work cycles while it was 2.9 times/min across the fundamental cycles (Table 6). No repetitive motions were found in the picking and back to rack activities. The estimated duration of ironing motions was 245 minutes on the basis of 8 hours in total per workday.

Table 5
Frequency of repetitive motions by motion type and work cycle in the one worker's pressing operation

Motion type	Total	Work cycle (no. of motions/min)*				
		1	2	3	4	5
Pad-covering	9.1	3.2	0	0.7	5.2	0
Ironing	37.8	13.3	0	17.2	7.3	0
Steaming	6.8	0	3.6	0	0	3.2

* Garments for each work cycle: 1 = ivory long dress; 2 = black shirt A; 3 = brown jacket; 4 = purple long dress; and 5 = black shirt B.

Any of those different motions was not performed "every few seconds" by the worker during the pressing operation. In this regard, the other candidate was not determined as a MSD hazard since its criterion, "using the same motion with little or no variation every few seconds with wrists bent in flexion 30° or more, or in extension 45° or more, or in variation every few seconds with wrists bent in flexion 30° or more, or in extension 45° or more, or in ulnar deviation 30° or more and high, forceful exertions with the hands more than 2 hours total per day," was not exceeded by both the physical risk factor and work condition.

4. Discussion

A range of job hazard analyses were conducted to assess exposure to MSD risk factors in seven workers of the three dry-cleaning shops. Among the items of workstation dimension and work condition, work area, rest time, and lunch time were not likely appropriate. One "caution zone job", in accordance with the WA Rule, was the pressing operation job in which five physical risk factors were identified as specified in the CZ Checklist.

One MSD hazard was finally determined in the caution zone job where the MSD hazard criterion was exceeded by the job as specified in the HZ Checklist. The "MSD hazard" was the awkward shoulder posture which was prevalent over the three facilities. Reaching above shoulder level and highly repetitive arm motions frequently occurred in the observed dry-cleaning shops during the hanging and pressing of garments. In detailed analysis for awkward postures of the shoulders, each of two median frequencies exceeded its criterion in the HZ Checklist while the duration of exposure to awkward shoulder postures was more than 4 hours in total per workday. Frequent or sustained awkward shoulder postures, combined with iron weight, can pose a risk of biomechanical stress to the joints of the upper extremities and surrounding soft tissues [4,7,19]. It is necessary to control the identified MSD hazard below the criterion, through ergonomic interventions such as employee training, improvement of workstation design, and work condition, at their own shops [7,12,21].

In the detailed analysis for repetitive ironing motions, each of the median frequencies did not exceed its criterion whereas the

Table 4
Frequency of awkward shoulder postures by fundamental cycle and work cycle in one worker's pressing operation

Fundamental work cycle	Total	Work cycle (no. of awkward shoulder postures /min)*				
		1	2	3	4	5
Total	32.9	5	9	4.1	5.2	9.6
Picking	7.1	0.6	3.6	0.2	1.6	1.1
Pressing	6.9	0.9	0	0.7	2.1	3.2
Inspecting	12.7	3.2	3.6	1.7	1.0	3.2
Back to rack	6.2	0.3	1.8	1.5	0.5	2.1

* Garments for each work cycle: 1 = ivory long dress; 2 = black shirt A; 3 = brown jacket; 4 = purple long dress; and 5 = black shirt B.

Table 6
Frequency of repetitive ironing motions by fundamental cycle and work cycle in the one worker's pressing operation

Fundamental work cycle	Total	Work cycle (no. of ironing motions/min)*				
		1	2	3	4	5
Total	37.8	13.3	0	17.2	7.3	0
Picking	–	–	–	–	–	–
Pressing	32.0	8.7	0	16	7.3	0
Inspecting	5.8	4.6	0	1.2	0	0
Back to rack	–	–	–	–	–	–

* Garments for each work cycle: 1 = ivory long dress; 2 = black shirt A; 3 = brown jacket; 4 = purple long dress; and 5 = black shirt B.

total duration of ironing motions (245 minutes) exceeded the criterion, implying that, under the WA Rule, the job might not be hazardous in terms of ironing motion activities. However, repetitiveness has been defined in various ways. For example, "high repetitive jobs" were defined as those with a work cycle time of less than 30 seconds, or more than 50% of the cycle time involved performing the same kind of fundamental cycles [22]. Criteria for "high repetitive" of more than 10 movements/min for the upper arm/elbow and forearm/wrist body regions, and more than 2.5 movements/min for the shoulders, have been recommended by Kilbom [23]. The repetitive ironing motion of the worker's pressing operation was "highly repetitive" for the shoulders because the ironing motion accounted for over 50% of the total cycle time, and also its median frequency of the ironing motions exceeded 2.5 movements/min. No work exceeded the recommended guideline for upper arm/elbow and forearm/wrist body regions. In this regard, it is recognized that the MSD hazard candidate of repetitive motions would have been underestimated by the HZ Checklist, which supports Eppes's finding that the hazard zone criteria reflect a low sensitivity and a low specificity [16].

MSDs of the upper extremities are a major cause of lost work in many hand-intensive industries. Although the dry-cleaning shops in this study were not necessarily representative of the industry nationwide, numerous MSD risk factors including awkward shoulder posture are common throughout small businesses like dry-cleaning shops [5–8]. Further research is needed to evaluate and control exposure to such MSD risk factors in the dry-cleaning industry.

In conclusion, it is notable that a MSD hazard, awkward shoulder posture, was determined in six of seven workers performing pressing operations. The detailed analyses confirmed the checklist determination that the shoulders were exposed to excessive awkward posture across the three dry-cleaning shops. It may be difficult to design a feasible way to reduce MSD risk factors in small and economically marginal workplaces such as dry-cleaning establishments. However, feasible controls may include measures such as lowering the height of conveyor/rack, use of lighter iron, appropriate work/rest ratio, and employee training. With such measures, it would be desirable to reduce MSD risk factors such as awkward posture of shoulders in the dry-cleaning industry.

Conflicts of interest

The author has nothing to disclose.

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