Evaluation of Forklift Operators' Risk of Musculoskeletal Disorders at Two Manufacturing Plants

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Contents

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from a fiberglass insulation manufacturer and a clothes dryer manufacturer. The employers of both companies were concerned about musculoskeletal injuries to employees who frequently operate forklifts in reverse.

What We Did

- We visited the facilities in June and August 2012.
- We measured the seated postures of forklift operators during forklift operation.
- We measured the whole body vibration exposure of forklift operators during forklift operation.
- We surveyed the musculoskeletal health and work conditions of forklift operators and office workers who were not involved in forklift operations.
- We compared neck and back pain cases between forklift operators and office workers.

What We Found

- Forklift operators sometimes rotated their neck to extreme positions when driving in reverse.
- Forklift operators may be at risk of developing neck pain.
- Forklift operators' daily exposure to whole body vibration was sometimes above exposure limits.
- Forty-five percent of forklift operators reported non-accident related neck pain in the previous year, but only 7% of office workers reported non-accident related neck pain.
- Sixty-two percent of forklift operators reported non-accident related back pain in the previous year, but none of the office workers reported any non-accident related back pain.
- Forklift operators and office workers did not have significant differences in psychosocial stress and manual work (sit time, manual pushing/pulling/lifting).

We evaluated forklift operators' risk for neck and back pain from poor body postures and whole body vibration when operating a forklift. Driving a forklift in reverse increased the risk of neck problems because of excessive neck rotation and extreme positions. We recommended minimizing forklift operations that require driving in reverse, pilot testing swivel seat designs that may reduce extreme head and torso rotation, and using job rotation to reduce the time forklift operators spend in extreme head and torso postures.

What the Employer Can Do

- Use tugger train systems instead of forklifts to eliminate driving in reverse.
- Pilot test forklifts with models that have swivel seats or install swivel seats on current forklifts. Evaluate forklift operators' comfort level for using the swivel seats and their ability to accomplish their job tasks.
- Rotate forklift operators between standard seat forklifts and swivel seat forklifts if the availability of swivel seat forklifts is limited.
- Reduce total time that forklift operators use standard seat forklifts by rotating them to jobs that do not require extreme head and torso postures.
- Train employees on how to properly adjust the seats of swivel seat forklifts.
- Monitor the body posture of forklift operators using redesigned or new forklifts.

What Employees Can Do

- Minimize driving forklifts in reverse.
- When adjustable seats are available, learn about their features and adjust the seat to reduce extreme head and torso postures.
- Report health concerns, injuries, and unsafe working conditions to your supervisor
- Tell your doctor about your work activities and any neck or back problems you believe are work related.

Abbreviations

ISO	International Organization for Standardization
MSD	Musculoskeletal disorder
m/s/s	Meters per second per second
NIOSH	National Institute for Occupational Safety and Health
RMS	Root-mean-squared

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Introduction

The Health Hazard Evaluation Program received a request from the employers of two manufacturing companies to evaluate potential ergonomic issues and musculoskeletal symptoms among forklift operators, particularly when driving forklifts in reverse. Company A manufactured fiberglass insulation for residential and industrial applications. Approximately 500 employees worked at company A. Several employees operated forklifts during each of the three work shifts. Company B manufactured residential clothes dryers with approximately 4,000 employees working in three shifts. An estimated 50–100 employees operated forklifts at company B in each of the three work shifts. Forklifts were used to transport parts and products to employee workstations or warehousing areas. In both companies, the forklift operators often drove loaded forklifts in reverse to avoid part/product damage.

Objectives

The objectives of these evaluations were to (1) evaluate forklift operators' risk of musculoskeletal disorders (MSDs) (specifically, neck and back pain) due to head and torso rotation when operating forklifts, (2) assess forklift operators' exposures to whole body vibration, and (3) assess forklift operators' MSD risk factors through a musculoskeletal health, work practices, and psychosocial factors survey.

Methods

Overview of the Evaluation

For these evaluations, we identified an exposure group and a comparison group not working with forklifts. Eligibility criteria for inclusion into the exposure group were: (1) having been employed at least 12 months in the current position and (2) having driven a forklift every day for at least 2 hours. Participants in the comparison group were (1) office workers in the same organizations, (2) employed at least 12 months in the current office position, and (3) not exposed to any significant work-related risk factor for MSDs (e.g., no significant manual lifting, pushing, pulling, and lifting), as determined by a review of work tasks by National Institute for Occupational Safety and Health (NIOSH) ergonomists.

After giving written informed consent, we instructed the participants in both groups to visit our data collection station at the work site to fill out a standardized, self-reported questionnaire for assessing workplace factors and musculoskeletal health. After completing the survey, all participants in the exposure group were asked to wear the body posture measurement system and participate in the whole body vibration analysis during their routine work activities. We also instructed these participants to check in at the data collection station every 30–60 minutes, as availability permitted, to assure that proper equipment set-up was maintained and to calibrate the body posture equipment. The NIOSH Institutional Review Board reviewed and approved the protocol and procedures for this evaluation.

Body Posture Measurements

We used the Measurand Incorporated ShapeTape™ measuring system to monitor head and torso orientation on employees in the exposure group during forklift operations. The system consisted of a data recorder and a flexible tape with fiber optic sensors capable of making six-degree-of-freedom measurements. Data were recorded at a 97 Hertz sampling rate (i.e., 97 samples per second) in one to five (median = 3) collection periods (mean ± standard deviation = 32 ± 9.7 minutes) on each forklift operator in the exposure group. The ShapeTape was looped down from the forklift operators' hard hat, attached to the chest, and then looped down to the waist in an "S" configuration. The portion attached to the top of the helmet was configured for measuring head orientation, while the portion attached to the chest area was configured for measuring torso orientation. The data recorder for the ShapeTape system was securely attached to the belt worn by the forklift operator. Data collection started with the forklift operator sitting and facing forward with both hands on the steering wheel. A typical set-up of the posture measuring system is shown in Figure 1.

Figure 1. A typical set-up of the body posture measuring system. Photo by NIOSH.

We observed drift in the head and torso orientation measurement data during data collection as evidenced by the central tendency of the time series data to consistently deviate in the same direction from the baseline of 0 degrees (corresponding to the starting neutral orientation of the head and torso). This most likely occurred because of an increase in the sensors' temperatures with progression of data collection. We corrected this drift in the raw time series data using a linear regression technique before performing further calculations [Harley et al. 2012]. After the correction, the data were processed to determine percentile of head and torso rotation in degrees in relation to the waist. The time spent in different ranges of rotation or posture zones was also calculated. Generally, the percentage time spent in each posture zone (extreme left, moderate left, neutral, moderate right and extreme right) suggests different risk levels. The posture zones and their risk levels of MSDs were defined as follows [Ariens et al. 2001]:

Extreme left: Extreme rotation angle to the left beyond 45° (high risk)
Moderate left: Rotation angle to the left between 15° and 45° (moderate risk)
Neutral: Rotation angle between 15° to the left and 15° to the right (safe level)
Moderate right: Rotation angle to the right between 15° and 45° (moderate risk)
Extreme right: Extreme rotation angle to the right beyond 45° (high risk)

Whole Body Vibration Measurements

We measured the vibration motions on the exposure group participants during forklift operations using a NexGen Vibration Analysis ToolSet (VATS™) with a series 2 accelerometer that detects acceleration in three directions. The accelerometer was embedded in a rubber seat pad that was placed on the forklift seat and oriented as specified by International Organization for Standardization (ISO) 2631-1 [ISO 1997]. ISO 2631-1 is an accepted standard for measuring, analyzing, and reporting results for whole body vibration of a seated operator in a vehicle cab. We measured whole body vibration across all frequencies from 0.1–400 Hertz. The sampling rate was 1,000 Hertz. The positive z-axis was the vertical upward direction perpendicular to the seating surface, and the positive x-axis was the forward direction from the forklift operator. The system was equipped with a data logger mounted to the side of the operator's seat. We ran the cables from the accelerometer to the underside and back of the seat so the measurement device was not intrusive to the forklift operator. Because of the limitations of the measuring systems for posture and whole body vibration, we did not synchronize the two systems automatically. To maximize the synchronization of the two data collection systems, we started the two systems manually at the same time.

Musculoskeletal Health and Workplace Factor Survey

All participants were asked to complete a survey on health and workplace factors. A copy of the survey is in Appendix A.

Musculoskeletal Health

The survey asked about pain symptoms in the neck and back regions that had occurred in the previous year. We defined back or neck pain as aches, pains, or discomfort in the back or neck regions that persisted every day for a week or more. If the answer was "Yes" to this question, the participant was prompted to answer additional questions on whether the pain had resulted in workers' compensation claims and missing days from work and whether the pain was brought on by repeated activities/single accident or injury/constant loading activities at work. The pain cases caused by accidents (slips, falls, car accidents, or forklift accidents) were excluded from further statistical analysis, because these were not related to routine forklift operations.

Work Practices and Psychosocial Factors

Work practices, job satisfaction, and work-related psychosocial factors (i.e., relationship with supervisor and coworkers) were evaluated because these variables have been shown to be associated with the development of MSDs [Bigos et al. 1986; da Costa and Vieira 2010; Kerr et al. 2001; Marras et al. 1995; Norman et al. 1998]. Sitting time, manual pushing or pulling, manual lifting of 25 pounds or more, and manual lifting of 50 pounds or more were evaluated. The sitting time was quantified on a scale from (1) less than 2 hours, (2) about half day, and (3) most of the day. Three types of manual work (pushing/pulling, lifting 25 pounds, and lifting 50 pounds) were each assessed on a scale from (1) never, (2) less than 10 times, or (3) 10 or more times on an average day. A single question about job satisfaction was measured on a scale from (1) not at all satisfied, (2) not too satisfied, (3) somewhat satisfied, to (4) very satisfied. Relationship with supervisor and coworkers were each assessed on a scale from (1) very much, (2) somewhat, (3) a little, to (4) not at all. For each type of relationship, the responses to the following four questions were averaged for each respondent: (1) does the supervisor/coworker make work life easier, (2) is it easy to talk to supervisor/coworker, (3) do you rely on the supervisor/coworkers when the job is tough, (4) the supervisor/coworkers listen to your personal problems. These categorical variables were analyzed using the Chi-Square test with a p value of 0.05 for detecting a significantly statistical difference between groups.

Results and Discussion

Body Posture Measurements

We measured postures on 8 forklift operators at company A and 12 forklift operators at company B. Measurements from two forklift operators at company B were not used because of a technical problem that prevented some of the data recorder files from being read. Table 1 shows the percentage of time the employees at company A and company B spent at different ranges of neck and torso rotation.

Table 1. Mean (standard deviation) percent time (minutes) spent in different ranges of neck and torso rotation during forklift operation

	Number of operators	Extreme left	Moderate left	Neutral	Moderate right	Extreme right
Company A neck rotation	8	11.1 (8.5)	14.6 (3.7)	46.8 (17.2)	21.1 (3.4)	6.4 (8.5)
Company B neck rotation	10	15.6 (5.5)	15.7 (5.0)	31.9 (9.7)	27.0 (5.0)	9.7 (4.0)
Company A torso rotation	8	0.5 (1.3)	4.7 (3.5)	91.7 (6.1)	3.1 (3.7)	0 (0)
Company B torso rotation	10	0.4 (1.1)	9.0 (3.0)	85.3 (6.1)	5.1 (4.3)	0.1 (0.3)

Company A forklift operators' neck rotations stayed in the neutral zone (±15° from the neutral position of 0°) 47% of the time, followed by in the moderate risk zone (±15°–45°) 36% of the time, and in the high risk zone 17% of the time. High risk neck rotation occurs when rotation is greater than 45° [Ariens et al. 2001].

Company B forklift operators' neck rotation was in the neutral zone for 32% of the time, in the moderate risk zone for 43% of the time, and in the high risk zone for 25% of the time. Both company A and company B forklift operators had a slightly greater percent time rotated moderately right compared to the percent time rotated moderately left. In contrast, the percent time in extreme neck rotation was slightly greater for left rotation versus right rotation.

Company A forklift operators' torso rotations stayed in the neutral zone for most of the time (about 92%). Similarly, company B forklift operators' torso rotation was in the neutral zone for about 85% of the time. Company B forklift operators' torso rotation was in the moderate zone for about 14% of the time.

The body posture data of participating forklift operators at companies A and B showing the 50th and 95th percentiles of the net neck rotation in relation to the torso and the 50th and 95th percentiles of net torso rotation in relation to the waist are presented in Table 2. Because the posture rotation data were not evenly distributed across all posture rotation angles, we present the median (50th percentile) and the "near" maximal (95th percentile) risk exposure levels.

Table 2. Mean (standard deviation) 50th and 95th percentile neck and torso rotation of forklift operators

	Number of operators	Total sample time (minutes)	Neck 50th percentile (degrees)	Neck 95th percentile (degrees)	Torso 50th percentile (degrees)	Torso 95th percentile (degrees)
Company A	8	116.2 (43.2)	16.7 (10.9)	58.9 (16.0)	4.7 (1.7)	17.5 (6.6)
Company B	10	76.5 (17.7)	23.2 (6.7)	68.9 (14.4)	5.9 (1.4)	21.5 (5.3)

The mean 50th percentile neck rotation for the forklift operators at company A was about 17° and was about 23° for the forklift operators at company B. Previous research suggests that the risk of neck problems increases when neck rotation exceeds ±15° from the absolute neutral position [NIOSH 1997; Ohlsson et al. 1995]. Company A forklift operators had a mean 95th percentile neck rotation of nearly 60°, but had neck rotation greater than 60° for 5% of the time. The mean 95th percentile neck rotation for company B forklift operators was nearly 70°. Although the percent time that forklift operators were exposed to extreme neck rotation was relatively low (5%), this exposure may play an important role in contributing to development of neck problems.

The maximum range of motion for the neck varies from 60°–90° [Swartz et al. 2005]. Neck rotation within this range are exposed to a near maximum risk level for potential neck problems. The 95th percentile for forklift operators' neck rotation at both companies showed a high risk for neck problems. In combination with the risk information based on the percent time (17% for company A and 25% for company B) spent in high risk neck rotation greater than 45°, we consider forklift operators at company A to have a moderate likelihood and forklift operators at company B to have a moderate to high likelihood risk of developing neck disorders due to their postural risk factors.

We found that company A forklift operators' torso rotation ranged from a mean 50th percentile of 4.7° to a mean 95th percentile of 17.5°. These results indicate that their torso rotation was mostly maintained within the neutral rotation range (±15° torso rotation). Company B forklift operators' torso rotation was slightly greater and ranged from a mean 50th percentile of 5.9° to a mean 95th percentile of 21.5°, which exceeded neutral rotation by about 7°. In terms of percent time spent in torso rotation risk zones, the forklift operators in both companies spent nearly 90% of their time in a neutral torso posture (±15° torso rotation). Torso rotation greater than 45% occurred only occasionally (~1%). The torso rotation levels of the forklift operators at both companies showed a low risk level for back disorders on the basis of the magnitudes and time spent on non-neutral posture zones.

Our data suggest that driving a forklift in reverse requires extreme neck rotation, near the end of the range of motion. Although we do not have direct evidence to show the magnitudes of pelvis rotation, the small magnitudes of the recorded torso rotation were most likely caused by the rotation of the pelvis. Because of the anatomical constraints of the spine for rotating the thoracic and pelvis regions, the forklift operators rotated their necks more than their torso to obtain the visual clearance for driving in reverse. Therefore, forklift operators who drive the forklift in reverse may have a greater risk of developing neck problems than developing back problems.

Whole Body Vibration Measurement

In the United States, an estimated 7 million employees are exposed to whole body vibration at work [Wasserman et al. 1974]. Exposure can lead to chronic health effects [Cohen et al. 1977; Wasserman and Badger 1973]. Most of the known chronic effects of whole body vibration are concerned with changes in the spine and back. Strong evidence of an association between whole body vibration and low back disorder was found in 15 of 19 studies that NIOSH reviewed. Whole body vibration may act in combination with other work factors, such as prolonged sitting, lifting, and awkward positions, to cause increased risk of back disorders [NIOSH 1997].

A summary of our whole body vibration measurements on 8 forklift operators at company A and 10 forklift operators at company B is provided in Table 3. Measurements from two forklift operators at company B were not used because of a technical problem that prevented some of the data recorder files from being read. We compared our results to the weighted root-mean-squared (RMS) acceleration exposure limits recommended in ISO standard 2631-1 [ISO 1997].

Table 3. Mean (standard deviation) whole body vibration (weighted RMS acceleration around the z-axis) during forklift operation

	Number of operators	Total sample time (minutes)	Weighted RMS acceleration (m/s/s)
Company A	8	143.97 (21.7)	0.63 (0.27)
Company B	10	92.58 (17.66)	0.72 (0.14)

m/s/s = meters per second per second

The mean of the weighted RMS acceleration values for the 8 forklift operators at company A was 0.63 meters per second per second (m/s/s) and ranged 0.42–1.27 m/s/s over an average 144-minute sampling period. On the basis of their self-reported operation time, ranging 8.5–10 hours per day, and the mean RMS acceleration values of 0.63 m/s/s, company A forklift operators' whole body vibration exposures were within the ISO health guidance caution zone limits of 0.45–0.75 m/s/s for an exposure duration of 10 hours per day. Exposures greater than the upper limit of the health guidance caution zone may cause adverse health effects [ISO 1997]. We found that the weighted RMS acceleration value (1.27 m/s/s) for one of the forklift operators at company A was nearly twice the level of the next highest RMS value. It is unclear why this forklift operators' exposure was substantially greater than the others, but could be a result of an atypical event during the measurement period. Additional measurements may be needed. A weighted RMS acceleration value of 1.27 m/s/s presents a risk of adverse health effects.

The mean of the weighted RMS acceleration values of the 10 forklift operators at company B was 0.72 m/s/s and ranged from 0.56–0.92 m/s/s over an average 93-minute sampling period. On the basis of the forklift operators' reported operation time, ranging from 7.5 to 8 hours per day, and the mean RMS acceleration values we measured, the mean whole body vibration exposures were within the ISO health guidance caution zone limits of 0.5–0.8 m/s/s for an exposure duration of 8 hours per day [ISO 1997]. However, three of the forklift operators had RMS acceleration values that exceeded the upper limit of the ISO health guidance caution zone for an 8-hour exposure period. This indicates that forklift operators are sometimes exposed to whole body vibration at levels that could put them at an increased risk of health effects.

Musculoskeletal Health and Workplace Factor Survey

Thirteen employees from company A and 44 employees from company B participated in the survey. Personal and job characteristics of the survey participants are shown in Table 4.

Table 4. Personal and job characteristics (mean ± standard deviation) of the survey participants in the exposure group (forklift operators) and comparison group (office workers)

	Company A		Company B	
	Forklift (n = 8)	Comparison (n = 5)	Forklift (n = 34)	Comparison (n = 10)
Age (years)	54.3 ± 4.4	45.4 ± 11.4	45.3 ± 10.7	43.2 ± 11.9
Height (inches)	71.8 ± 1.8	70.0 ± 1.9	69.5 ± 4.2	68.0 ± 5.1
Weight (pounds)	234.4 ± 34.7	200.5 ± 28.9	208.6 ± 53.7	180.2 ± 32.2
Male	100%	40%	82%	60%
Employment at this company (years)	31.8 ± 8.2	12.0 ± 13.0	11.9 ± 7.1	18.1 ± 10.1
Time in current job (years)	18.4 ± 15.2	3.9 ± 4.7	4.7 ± 4.8	7.6 ± 6.2

As seen in Table 4, on average, the participants in the exposure group were heavier, slightly taller, and older than the comparison group for both companies. All the forklift operators in the exposure group of company A and 82% of the forklift operators of company B were male. The comparison groups had much lower percentage of male participants (40% at company A, 60% at company B). The average duration of employment for the exposure group at company A was about 20 years longer than the comparison group. In company B the average duration of employment for the comparison group was about 6 years longer than the exposure group. The average time working in the current job for the exposure group of company A was about 14 years longer than that for the comparison group. In contrast, the average time working in the current job for the exposure group of company B was about 3 years shorter than that for the comparison group.

The main pain variable (pain in last 12 months) used in this evaluation was defined as, "During the previous 12 months, have you had pain which lasted every day for a week or more?" We used the same pain definition for neck pain and for back pain. We asked additional neck and back health-related questions to exclude pain cases that were not related to current work. The results of the pain survey for the neck are presented in Table 5 and results of the pain survey for the back are presented in Table 6.

During the previous 12 months, approximately 38% (3 out of 8) of the forklift operators at company A and 36% (12 out of 33; 1 missing data point) at company B reported neck pain which lasted every day for a week or more. None of the participants in the control group at company A reported any neck pain, and only one participant (10%) in the control group at company B reported neck pain in the previous year. For company A, 3 out of 8 (38%) forklift operators reported non-accident-related neck pain in the previous 12 months that lasted every day for a week or more. None of the office workers in the control group reported any neck pain. For company B, 7 out of 34 (21%) forklift operators reported non-accident-related neck pain in the previous 12 months that lasted every day for a week. Only one office worker (10%) in the control group reported neck pain.

Table 5. Neck pain survey results*

	Company A		Company B	
	Forklift (n = 8)	Comparison (n = 5)	Forklift (n = 34)	Comparison (n = 10)
Did you ever have pain?	38%	0%	47%	10%
Pain in the past 12 months?	38%	0%	36%†	10%
Non-accident-related pain?‡	38%	0%	21%	10%

*Two variables (“missed work due to pain” and “pain resulting in workers’ compensation”) are not presented due to a large percentage (> 75%) of missing data.

†One missing data point

‡Derived statistics from the variable “accident on the current job”

During the previous year, 38% (3 out of 8) of the forklift operators at company A and 36% (12 out of 33; one missing data point) at company B reported back pain which lasted every day for a week or more. None of the participants in the control groups at these two companies reported back pain in the previous year. For company A, 2 out of 8 (25%) forklift operators reported non-accident-related back pain in the previous 12 months that lasted every day for a week or more compared with one of the office workers in the comparison group. For company B, 6 out of 31 (19%; 3 missing data) forklift operators reported non-accident-related back pain in the previous 12 months that lasted every day for a week or more compared with none of the office workers in the comparison group.

Table 6. Back pain survey results*

	Company A		Company B	
	Forklift (n = 8)	Comparison (n = 5)	Forklift (n = 34)	Comparison (n = 10)
Did you ever have pain?	75%	40%	59%	50%
Pain in the past 12 months?	38%	0%	36%†	0%
Non-accident-related pain?‡	25%*	0%	19%*	0%

*Two variables “missed work due to pain” and “pain resulting in workers’ compensation” are not presented due to a large percentage (> 75%) of missing data.

†One missing data point

‡Derived statistics from the variable “accident on the current job”

Analysis of the combined data from both companies showed that 19 out of 42 (45%) forklift operators, but only 1 out of 15 (7%) office workers reported ever having neck pain that lasted for a week or more. Regarding history of back pain, 26 of 42 (62%) of the forklift operators and 7 out of 15 (47%) of the office workers reported having back pain lasting for a week or more. Previous research has shown that a history of musculoskeletal pain is highly associated with recurrent pain at work [Ferguson et al. 2005].

Excluding pain cases resulting from accidents (slips, falls, car accidents, or forklift accidents), the percentage of forklift operators across both companies reporting non-accident-related neck pain was 24% (10 out of 42), while the percentage in the office workers was 7% (1 out of 15). Twenty percent (8 out of 42) of the forklift operators across both companies reported non-accident-related back pain, while none of the office workers reported any non-accident back pain.

The higher rates of non-accident-related pain in the forklift operators suggest that forklift operators are at increased risk of developing pain in the neck and back regions. Results of health assessments for neck and back are somewhat difficult to interpret because of the lack of generally accepted objective diagnostic criteria and the episodic nature of these disorders. For example, only a small percentage of back pain cases have a clinically identified cause, and in the majority of cases the cause is probably muscle strain and cannot be determined objectively [Riihimaki 1999]. Most cases of back disorders are classified as idiopathic or nonspecific back pain [NIOSH 1997; Riihimaki 1999]. However, it is standard practice to use a standardized symptom survey to identify cases of back pain. Compared to other definitions of back pain lasting for one day, we opted to use the stricter definition of back pain lasting one week or more to increase the specificity of our diagnostic criterion. NIOSH has used this pain definition in previous studies related to MSDs [Dickinson et al. 1992; Guo et al. 1995; Kuorinka et al. 1987; Lu et al. 2014; Waters et al. 2011].

Our analysis of the combined data for both plants showed that 32% of the forklift operators and 40% of the office workers reported doing some pushing or pulling work. Seven percent of the forklift operators, and none of the office workers, reported doing pushing or pulling work more than 10 times a day. Most of the forklift operators (86%) and office workers (73%) reported spending most of the day sitting, while only 12% of the forklift operators and 27% of the office workers reported spending about half of the day sitting. Previous research has shown prolonged sitting to be associated with neck and back pain [Ariens et al. 2001; Inoue et al. 2015]. Although the forklift operators and office workers spent a similar amount of time sitting, we found that a greater percentage of forklift operators reported non-accident-related back pain and neck pain. We did not measure neck rotation in the office workers; however, our observations of their work activities suggested that it occurred much less frequently than in the forklift operators. This suggests that additional risk factors, such as neck rotation, could be leading to increased neck or back pain in forklift operators.

Studies have shown that psychosocial factors may be associated with MSDs in the workplace [Lu et al. 2014; National Research Council 2001; Waters et al. 2011]. Among the psychosocial factors, job satisfaction, supervisory support, and coworker support appear to be particularly relevant to the development of work-related MSDs [Lu et al. 2014; National Research Council 2001; Waters et al. 2011]. In this evaluation, we asked about these psychosocial factors to determine if they contributed to the reporting of neck and back pain. On the basis of the combined data from both companies, results of the survey show no meaningful difference in the psychosocial factors between forklift operators and office workers, except for supervisory support. Most forklift operators (88%) and office workers (93%) were “somewhat” to “very much” satisfied with their current job. Forklift operators reported an average score of 1.5 for the supervisory support variable and 1.8 for the coworker support variable, while office workers reported 2.1 for the supervisory support variable and 2.2 for the coworker support variable. Although there was a statistically significant difference ($P < 0.05$) in the psychosocial score for supervisory support between the forklift operators and office workers, both scores fell into the same effect category between “very much” and “somewhat” satisfied.

Overall Musculoskeletal Disorder Risk Evaluation

The differences in the pain prevalence between the forklift operators and the office worker comparison group indicates that job-related factors may be leading to increased pain. The posture risk data suggest that neck pain may be associated with neck posture for forklift operations. The whole body vibration exposures of some forklift operators may be contributing to the increased reporting of back pain among forklift operators. Back pain might also be attributed to other unmeasured posture risk factors such as torso flexion and dynamics of the torso movements, both of which have been shown to be associated with the development of back pain [Kerr et al. 2001; Marras et al. 1995]. Psychosocial factors may also be playing a role. Reported levels of supervisory support, which has been linked to increased reporting of neck and back problems, was lower in forklift operators than the comparison group of office workers [National Research Council 2001; NIOSH 1997].

Limitations

We found that the rates of lifetime history of neck and back pain among the forklift operators were high. Because of this finding and the cross-sectional design of our evaluation, we are unable to determine whether the self-reported pain cases were new cases attributed to forklift operations or recurring problems exacerbated by forklift operations. Moreover, we observed differences in some personal factors and job characteristics between the exposure and comparison groups. Because of the relatively small number of participants, we are unable to determine the extent to which these differences contributed to the differences in pain rates.

Although some of our exposure measurement methods had limitations, we believe these did not significantly affect our findings as explained below. The direct reading measurements used in this evaluation for quantifying head and torso postures are considered more reliable and accurate than the observational methods (checklists or estimated posture by human eye from video recording) used in previous studies [Lowe 2004].

- The measurement system did not allow for full-shift sampling and the length of sampling periods for recording neck rotation varied. However, because of the repetitive characteristics of forklift operations, we believe the measurement results were representative and could be used for evaluating the operators’ total exposure risk.

- We observed that posture data collected with the ShapeTape system drifted around the baseline because of thermal effects as the sampling time increased. However, we used a regression analysis technique to adjust for the shifted baseline data [Harley et al. 2012]. To minimize the thermal effects, we collected multiple trials on each forklift operator.

Conclusions

Driving a forklift in reverse may lead to an increased risk of neck problems, primarily because of excessive neck rotation to extreme positions. In addition, forklift operators' exposures to whole body vibration exposures sometimes exceeded recommended limits, which could lead to increased risk of health effects.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage both companies use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations.

Our recommendations are based on an approach known as the hierarchy of controls. This approach groups actions by their likely effectiveness in reducing or removing ergonomic hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed. The recommendations below may be applied to both companies.

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Pilot test commercially available swivel seat forklifts that allow the operator to adjust the seat to avoid extreme head or torso rotation while driving in reverse. Evaluate forklift operators' comfort level for using the swivel seats and their ability to accomplish their job tasks.
2. Evaluate whether tugger train systems could be used in place of forklifts for material delivery. Tugger train systems eliminate driving in reverse and therefore the need for turning the head and torso to look over the shoulder.

Administrative Controls

The term administrative controls refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Reduce the total exposure duration of forklift operations by assigning operators for part of their work shift to different jobs that do not require extreme head and torso postures if swivel seat forklifts are not feasible.
2. Rotate forklift operators between using the current-design forklifts and swivel seat forklifts to reduce the total risk exposure time if the recommended redesigned forklifts with swivel seats are not feasible for all forklift operations.
3. Train employees on the use of the swivel seat adjustment to ensure the proper use of the new equipment to reduce excessive head and torso rotation. Conduct a postural risk assessment for the musculoskeletal health of forklift operators who use swivel seat forklifts to assure that the forklifts are effective in reducing the risk of MSDs.
4. Advise employees to report neck, back, or other health problems from their work to their healthcare provider and to the company.
5. Encourage employees to report any unsafe working conditions to their supervisor.

Appendix A: Musculoskeletal Health and Workplace Factor Survey

National Institute for Occupational Safety and Health
United States Department of Health and Human Services
Forklift Operator Study Survey

1. What is your name?
   Last Name ____________________ First Name______________________

2. What is your employee ID # (either clock # or social security number)
   ____

3. What is your home address? (Optional)
   ____
   Street Address
   _____________________________   ____________________
   City   State
   ____
   Zip Code

4. What is your home telephone number?
   _____ ____ ____ ____ ____ ____- _____ _____ _____ _____
   Area Code   Telephone number

5. What is your gender? (please circle)   Male   Female

6. What is your date of birth? ________ _________ _______
   Month   Day   Year

7. When did you begin working at this company? ________ _______.
   Month   Year

8. What is the name of the job you are working on today?
   ____

9. What work shift are you working on today?   _______________

10. How long have you worked at the job you are working on today?
    Years _____   Months ______

BACK PAIN

11. Have you **ever** had **back pain** which lasted everyday for a week or more?

____ ____
Yes No

If YES to #11:
a. In what year did you first experience this back pain? Year_______
b. Was this pain severe enough to interfere with your normal work or home activities?
______ ______
Yes No

12. During the **previous 12 months**, have you had **back pain** which lasted everyday for a week or more? _____ ______
Yes No

If Yes to #12: (circle Y for yes and N for no)		Yes	No
a.	Was any of this pain brought on by repeated activities such as lifting, pushing or bending?	Y	N
b.	Do you do these repeated activities at work?	Y	N
c.	Did any of this back pain result from a single accident or injury, such as slipping, falling, or a car or forklift accident? **If Yes, when did it occur** year ______	Y	N
d.	Were you at work when this accident occurred?	Y	N
e.	Were you working on the job you are doing today when this injury occurred? **If No, what job were you doing** _________________________________	Y	N
f.	Did this back pain result in a workers compensation claim?	Y	N
g.	Did you miss any work due to this back pain? **If Yes, how many days did you miss?** _______ days	Y	N

NECK PAIN

13. Have you **ever** had **neck pain**, which lasted everyday for a week or more? ____ _____
Yes No

If YES to #13**:**

a. In what year did you first experience this neck pain? **year**_______

b. Was this pain severe enough to interfere with your normal work or home activities?

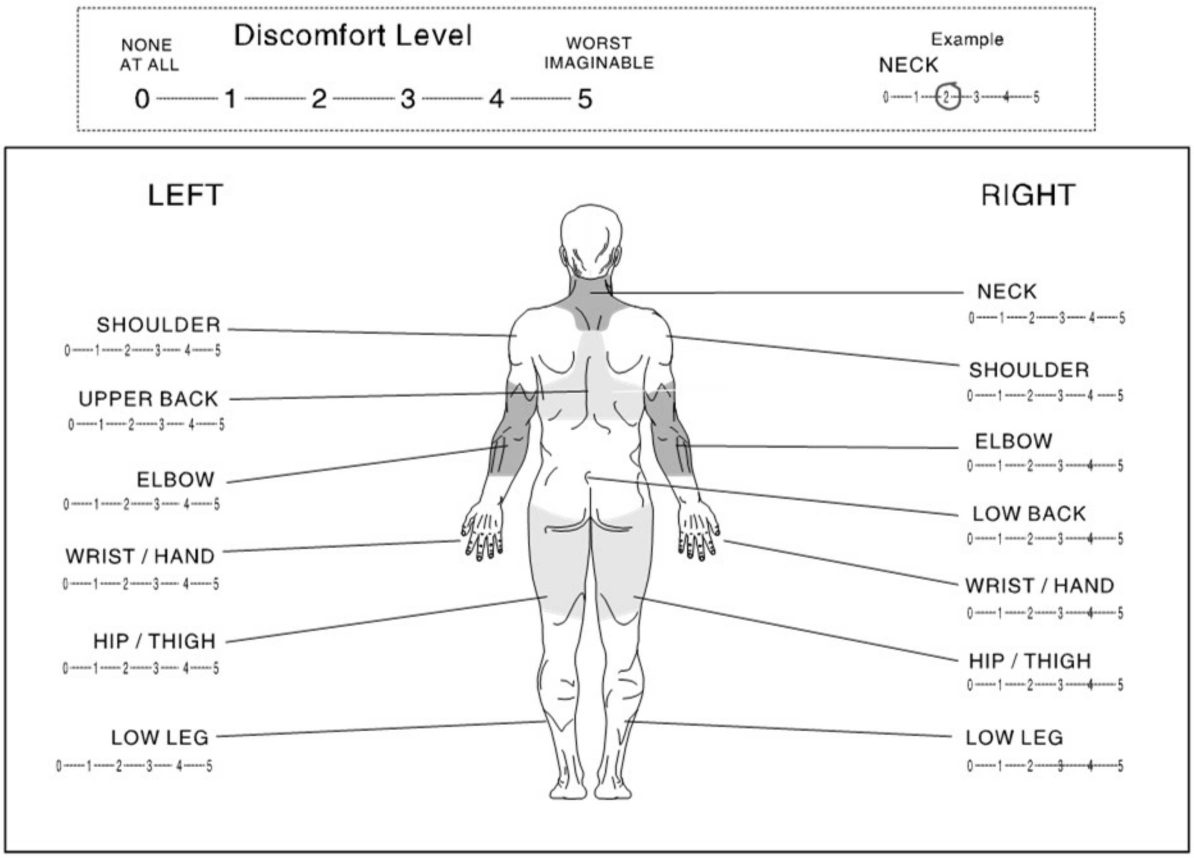
______ ______
Yes No

14. During the **previous 12 months** have you had **neck pain** which lasted everyday for a week or more? _____ ______
Yes No

If Yes to # 14: (circle Y for yes and N for no)	**Yes**	**No**
a. Was any of this pain brought on by repeated activities such as twisting of the head or neck?	Y	N
b. Do you do these repeated activities at work?	Y	N
c. Did any of this neck pain result from a single accident or injury, such as slipping, falling, or a car or forklift accident? **If Yes, when did it occur** Year ______	Y	N
d. Were you at work when this accident occurred?	Y	N
e. Were you working on the job you are doing today when this injury occurred? **If No, what job were you doing** ____	Y	N
f. Did this neck pain result in a workers compensation claim?	Y	N
g. Did you miss any work due to this neck pain? **If Yes, how many days did you miss?** _______ days	Y	N

15. During the previous 12 months, have you had pain or discomfort that lasted at least a week in any of the areas shown in this picture?_____ yes _____ no

If **YES**, circle the intensity of pain for ALL areas where you have had discomfort.



16. Please rate the OVERALL **<u>physical effort</u>** level demanded by your job today. In other words, how hard is your work? (Please circle the number)

10 Maximum
9
8
7 Very Heavy
6
5 Heavy
4
3 Moderate
2
1 Very Light
0 Nothing at all

17. What is your: Height: ____ ______ Weight: ______
Ft Inches Pounds

18. On average, how long do you spend as the driver or passenger of a vehicle on your way to work each day (one way time)? ________Minutes

19. Do you smoke cigarettes? Yes _____ No _____

The following questions are designed to give us information about your work with forklift vehicles. If you **do not** regularly drive a forklift vehicle as part of your job, skip to Question 27.

20. How many hours per day do you operate a forklift vehicle?
______ Enter estimated number of hours per day spent operating a forklift?

21. How many hours per day do you operate the vehicle driving backward?
______ Enter estimated number of hours operating a forklift backward?

22. Do you wear a seat belt while operating the forklift vehicle?
_______ Yes ______ No

23. Do you believe that the seat belt makes you twist your head and back more when driving the vehicle backward than when you don't wear a seat belt?
_______ Yes ______ No ______ Don't Know

24. Do you feel like the forklift causes a lot of vibration when you drive it?
When carrying a full load? _______ Yes ______ No
When not carrying a load? _______ Yes ______ No

25. Are the operating controls (pedals, levers, switches, etc.) easy to reach and use?
_______ Yes ______ No

26. How much force is required to operate the controls on the forklift vehicle?
Foot Pedals ____ High Force ____ Medium Force ____ Low Force
Hand Levers ____ High Force ____ Medium Force ____ Low Force
Steering Wheel ____ High Force ____ Medium Force ____ Low Force

27. Do you also do a lot of lifting, pushing, pulling, or carrying of objects on your job?
_______ Yes ______ No

The following questions are designed to give us information on how you feel about your job and your health. Please circle the number of the appropriate response.

28. All in all, how satisfied would you say you are with your job?

Not at all Satisfied	Not Too Satisfied	Somewhat Satisfied	Very Satisfied
1	2	3	4

29. Generally, how difficult is it for you to meet the production requirements or standards on your job?

Not at all Difficult	A Little Difficult	Somewhat Difficult	Very Difficult
1	2	3	4

30. How often are you **physically** exhausted after work?

Never	Seldom	Often	Always
1	2	3	4

31. How often are you **mentally** exhausted after work?

Never	Seldom	Often	Always
1	2	3	4

32. How often do the following occur on your job?

	Rarely	Occasionally	Sometimes	Fairly Often	Very Often
a. How often does your job require you to work very fast?	1	2	3	4	5
b. How often does your job require you to work very hard?	1	2	3	4	5
c. How often does your job leave you with little time to get things done?	1	2	3	4	5
d. How often is there a great deal to be done?	1	2	3	4	5

33. How much influence do you have over the following:

	Very Little	Little	Moderate	Much	Very Much
a. The variety of tasks you perform?	1	2	3	4	5
b. The amount of work you do?	1	2	3	4	5
c. The order in which you perform tasks at work?	1	2	3	4	5
d. The pace of your work, that is how fast or slow you do your work?	1	2	3	4	5
e. The quality of the work that you do?	1	2	3	4	5

34. To what extent do the following apply in your job?

	Very Little	Little	Moderate	Much	Very Much
a. To what extent can you work ahead & take a short rest break during work hours?	1	2	3	4	5
b. In general, how much influence do you have over your work?	1	2	3	4	5

35. How much do each of these people go out of their way to do things to **make your work life easier** for you?

	Very Much	Somewhat	A Little	Not at All	Don't Have Any Such Person
a. Your immediate supervisor (boss)	1	2	3	4	5
b. Other people at work	1	2	3	4	5
c. Your spouse, friends and relatives	1	2	3	4	5

36. How easy is it to talk with each of the following people?

	Very Much	Somewhat	A Little	Not at All	Don't Have Any Such Person
a. Your immediate supervisor (boss)	1	2	3	4	5
b. Other people at work	1	2	3	4	5
c. Your spouse, friends and relatives	1	2	3	4	5

37. How much can each of these people be **relied** on when things get tough at work?

	Very Much	Somewhat	A Little	Not at All	Don't Have Any Such Person
a. Your immediate supervisor (boss)	1	2	3	4	5
b. Other people at work	1	2	3	4	5
c. Your spouse, friends and relatives	1	2	3	4	5

38. How much is each of the following willing to listen to your personal problems?

	Very Much	Somewhat	A Little	Not at All	Don't Have Any Such Person
a. Your immediate supervisor (boss)	1	2	3	4	5
b. Other people at work	1	2	3	4	5
c. Your spouse, friends and relatives	1	2	3	4	5

39. How much time during an average work day do you spend sitting down?
(Include time spent operating or sitting in the forklift truck)
___ Less than 2 hours
___ About half the day
___ Most of the day

40. How often during a typical work day does your job involve heavy pushing or pulling?
(Similar to pushing or pulling a couch across a room)
___ Never
___ Less than 10 times
___ 10 or more times

41. How often during an average day of work do you lift 25 pounds or more?
(25 pounds is the same as about 4 gallons of milk)
___ Never
___ Less than 10 times
___ 10 or more times

42. During an average day of work do you ever lift 50 pounds or more?
___ Never
___ Less than 10 times
___ 10 or more times

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