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Case Studies

Ergonomic Assessment of Trimming Jobs at a Shoe Manufacturing Plant

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Reported by Nancy Clark Burton, Leslie MacDonald, and Cheryl Fairfield Estill

Background

The National Institute for Occupational Safety and Health (NIOSH) received a request from employees at a shoe manufacturing facility in West Virginia concerning exposure to ergonomic risk factors, including repetitive motion, and reports that employees in the trimming department were experiencing wrist, back, and shoulder pain. This plant produces men's welt (sewn) and cement (glued) shoes.

Work-related musculoskeletal disorders (WRMDs) have been found in previous studies to occur in workers whose jobs require repetitive movements, forceful exertions, and awkward body postures. WRMDs can affect the tendons, tendon sheaths, muscles, and nerves. Studies have shown that WRMDs can be precipitated or aggravated by activities that require repeated or stereotyped movements, forceful exertions, awkward postures, or exposure to hand/arm vibration.[1–3] Men's footwear, except athletic (SIC 3143) is listed among the Bureau of Labor Statistics "industries with the highest nonfatal illness rates of disorders associated with repeated trauma, private industry, 1995."[4] The 1995 incidence rate was 267.8 per 10,000 full-time workers.[4]

Process Description

The shoe production industry is a very specialized industry which uses precise equipment for dedicated operations, and handwork remains a quality trademark. This investigation centered around the trimming department. At the time of the site visit, this department employed 67 individuals on the first and second shifts. These employees work in accordance with a piece rate pay system. In the trimming department for welt shoes, lasts (shoe forms) are removed and heels are attached by nailing. The heel area of the shoe is then trimmed and scoured. The next operation is edge trimming, where shape is given to the sole edge and where the edges are slicked. Dye and ink are applied to sole edges using hand brushes. The sole edges are burnished (shined) using wax and mechanical brushes. Shoe bottoms are cleaned or sanded. Some shoe bottoms are stained and then bottom finished. Cement construction shoes have lasts pulled, heels nailed, and bottoms brushed in this department.

Methods

Questionnaires were administered to all trimming department employees who were present during the site visit. The questionnaire solicited information on personal demographics; length of employment; and self-reported exposure and task characteristics, including lifting, bending, pushing, estimates of force used to perform the job, and hand tool use. The questionnaire also asked workers to report injuries at work and any musculoskeletal discomfort that occurred in the past year on a four-point scale (0 = no discomfort, 3 = extremely uncomfortable).

All jobs in the trimming department were videotaped. Forty-eight workers were videotaped performing their usual assigned job for at least three work cycles. Nonneutral, upper extremity (UE) postural categories were defined according to the work of Armstrong *et al.*,[5] and nonneutral back postures were defined according to the work of Keyserling *et al.*[6] Hand postures are classified as open, closed, lateral pinch, or finger press grip. Wrist postures and postural (angular) ranges are characterized in terms of flexion (>30 degrees), extension (>45 degrees), ulnar deviation (angle not specified), and radial deviation (angle not specified). Ulnar deviation is defined as bending the wrist toward the little finger; radial deviation is bending the wrist toward the thumb; extension is bending the wrist up and back; and flexion is bending the wrist down toward the palm. Forearm postures are identified as pronation (palm down) or supination (palm up). Shoulder postures and postural (angular) ranges are classified as elevation (angle not specified), extension (behind midline of torso), flexion (>45 degrees), abduction (>45 degrees), or adduction (angle not specified). Neck flexion (>20 degrees) is also identified where present. Trunk postures and postural (angular) ranges are characterized as lateral bending (>20 degrees), mild flexion (20 to 44 degrees), severe flexion (>45 degrees), and twisting (>20 degrees).

Results

Demographics

Sixty-five individuals completed the questionnaire. Two employees were absent from the facility during the site visit due to long-term disability. Forty-nine (75%) of the employees were male and 14 (22%) were female. Two individuals (3%) did not answer the gender question. The average ages for male and female workers were 34.5 years (range: 17 to 64 years) and 33.4 years (range: 18 to 57 years), respectively. The average anthropometry (size) for the male employees was 5 ft 9 inches (range: 5 ft 1 inch to 6 ft 4 inches) and 183 lbs. For female employees, the average anthropometry was 5 ft 4 inches (range: 5 ft 1 inch to 5 ft 9 inches) and 152 lbs. Average employment was 9.7 years (range: 1 month to 26 years) for males and 9.5 years (range: <1 month to 27 years) for females. The employees worked 40 hours each week, with the exception of a utility worker and a supervisor, who averaged 44 hours per week. One individual reported working 1 year at another shoe manufacturing facility prior to employment at this facility. Due to job rotations, 22 of the employees could work at different workstations each day.

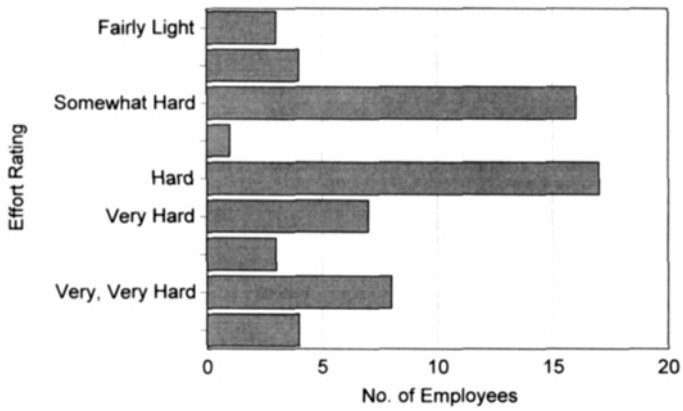

FIGURE 1. Physical effort to perform job.

Workers' Self-Reported Exposure and Task Characteristics

Forty respondents (62%) classified the physical effort necessary to perform their job as hard; very hard; or very, very hard (see Figure 1). Fifty-five employees (85%) reported some body discomfort in any location for the year prior to the site visit (not necessarily work related). Sixteen individuals (25%) reported being very or extremely uncomfortable in the neck and left shoulder, 11 (17%) in the neck and right shoulder, 26 (40%) in the left hand and arm, 21 (32%) in the right hand and arm, 18 (28%) in the left leg and foot, 12 (18%) in the right leg and foot, and 21 (32%) in the back. Combining the reports for discomfort of the UE (neck, shoulder, hand, and arm), 53 (82%) reported some body discomfort for the year prior to the site visit (not necessarily work related).

Injury symptom data were evaluated from the questionnaires. Thirty-three questionnaire respondents (51%) reported that some type of injury had occurred at the workplace within the year prior to the survey. The injuries reported by the employees by location are shown in Table 1. (Some individuals reported more than one injury.) The fingers and thumb were the body parts most frequently injured.

Fifty-nine employees (91%) reported using a pinch grip to perform their job tasks. Forty-nine (83%) reported using a pinch grip on a relatively constant basis (67 to 100% of the time); five workers (8%) used a pinch grip on a frequent basis (34 to 66% of the time); and two individuals (3%) reported using a pinch grip on an occasional basis (1 to 33% of the time). Figure 2 shows the reported effort exerted when using a pinch grip. Thirty-one employees (53%) reported using at least a hard pinch grip.

Table 2 shows the amount of time employees reported that they spend sitting, standing, walking, bending, reaching overhead, using their arms repetitively, or using repetitive leg and/or foot movements. The majority of respondents did not answer every question. Thirty-nine individuals (60%) reported that they are never seated while working, 45 (69%) reported standing frequently or constantly, 34 (52%) reported walking frequently or constantly, 45 (69%) reported bending at the waist frequently or constantly, 40 (62%) reported reaching overhead at least occasionally, 55 (85%) reported constantly moving their arms in a repetitive manner, and 32 (49%) reported moving their legs and/or feet in a repetitive way at least occasionally.

Sixty-two respondents (95%) indicated that they do some form of lifting while performing their job activities. One individual answered "no" to the lifting question and two did not answer the question. Workers were asked to classify the types of lift used as floor to knuckle

TABLE 1. Work-Related Injuries Reported on Questionnaire (for Prior Year)

Body Part	Type of Injury and Number of Reports
Head	Smash (1)
Neck	Strain (1)
Back	Ruptured disc (1), strain (1), sprain (1)
Shoulder	Pain (1), pinched nerve (1)
Side	Strained muscles (1)
Fingers/thumb	Scrape (3), cut (5), muscle cramps (1), hairline fractures (1), puncture (2), burn (1)
Hand	Cut (2), pain (2)
Wrist	Pain (3), carpal tunnel syndrome (2), sprain (1)
Elbow	Tendinitis (1), tennis elbow (1)
Arm	Cut (2), pain (1)
Eyes	Foreign object (1)

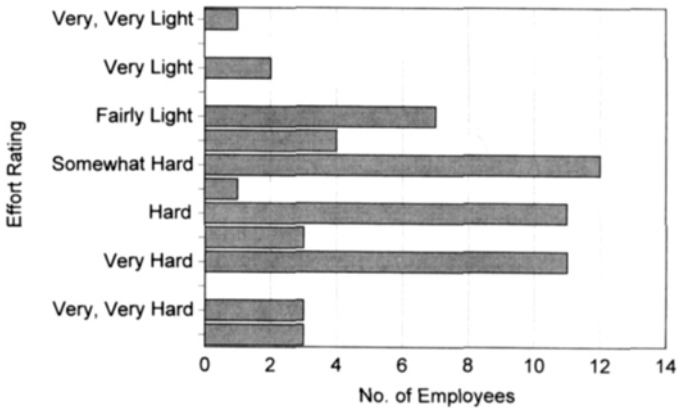

FIGURE 2. Effort when using pinch grip.

(natural), floor to knuckle (bent leg), knee to knuckle, knuckle to shoulder, and shoulder to overhead. Table 3 shows the number of employees who reportedly do each type of lift and how often they do such a task. The employees estimated that the weights reportedly lifted varied greatly within and between job categories. The reported or estimated weights ranged from 0.25 to 40 lbs, depending on job activities.

The employees use a variety of hand tools while performing their job tasks. Based on workers' self-reports on usage, the tools used are as follows: scissors (47), pencil/pen (26), ink brush (9), knife (8), hammer (7), screwdriver (5), wrench (5), wax bar (5), pliers (4), punch (3), rag (3), sharpener (2), staple puller (2), caster (1), heel remover (1), and lace cutter (1).

Videotape Analysis

Of the 48 jobs analyzed, 41 (85%) have a work cycle time of less than 30 seconds. Nine (19%) of the jobs involve use of a foot pedal to activate machinery. Of the jobs requiring the use of a foot pedal, all are performed in a standing position.

Nonneutral postures of the trunk (or torso) were found in 43 (90%) of the jobs, and 14 (29%) involved static loading of the trunk muscles (i.e., the postures were sustained for at least two sequential work elements). Of the four trunk postures coded, lateral bending or bending to the side was the most prevalent exposure condition for the trunk (65%), followed by moderate forward flexion (48%) and trunk twisting (23%). No severe forward flexion of the trunk was observed. Static postural conditions of the trunk were observed to occur most often within the moderate forward flexion classification (19%). Forward neck flexion was found to occur in 41 (85%) of the jobs analyzed, and 35 (73%) involved static loading of the muscles to maintain this posture.

Nonneutral postures of the shoulder were found in almost all (98%) of the jobs. Of the five postures coded, abduction (92%) and flexion (90%) were the most prevalent exposure conditions for the shoulders. Shoulder elevation was found in 44 percent of the jobs, extension in 35 percent, and adduction in 25 percent. Static exertions to maintain nonneutral shoulder postures were observed in the majority of the jobs (81%). Static exertions were especially involved to maintain shoulder abduction (63%) and flexion (27%). Nonneutral postures of the forearm were found in all 48 of the jobs analyzed. Of the two nonneutral forearm postures coded, pronation (palm facing downward) was the most prevalent exposure condition for the forearm (94%), but supination of the forearm was also extensively used (83%). For most jobs (67%), both forearms were pronated at least once in the work cycle. Less than half (42%) of the jobs involved the supination of both forearms.

Nonneutral postures of the wrist were found in the majority (94%) of the jobs analyzed. Of the four wrist postures coded, ulnar deviation was the most prevalent exposure condition for the wrist (81%), followed closely by wrist extension (67%). Wrist flexion was observed to occur in 15 (31%) of the jobs, and radial deviation was observed in six jobs (13%). Static exertions to maintain nonneutral wrist postures were not uncommon, especially with extension and ulnar deviation.

Three types of hand grips (open pinch, closed pinch, and lateral pinch) and conditions of finger pressing were coded. All jobs required the use of a pinch grip.

TABLE 2. Amount of Employee Reported Time Spent in Position or Performing Repetitive Motions (Number of Respondents = 65)

Frequency of Activity	Sitting	Standing	Walking	Bending at Waist	Reaching Overhead	Repetitive Arm Movement	Repetitive Leg/Foot Movement
Never	39	7	6	1	25	2	33
Occasional (1–33%)	3	4	17	11	21	2	8
Frequent (34–66%)	0	2	18	14	5	3	4
Constant (67–100%)	9	43	16	31	7	55	11

Respondents did not answer every question.

TABLE 3. Type of Lift (Number of Respondents = 65)

Frequency of Type of Lift	Floor to Knuckle (Natural)	Floor to Knuckle (Bent)	Knee to Knuckle	Knuckle to Shoulder	Shoulder to Overhead
Occasional (1–33%)	18	14	9	7	9
Frequent (34–66%)	3	0	4	7	4
Constant (67–100%)	4	1	18	38	4

Open pinch grips were used in the majority of jobs (98%), and this grip was static or sustained over multiple work elements in all but two instances. Closed pinch grips were observed to occur in 16 jobs (33%), and the lateral pinch was observed in 11 jobs (23%). The fingers were used for pressing in 11 jobs (23%).

Discussion and Conclusions

This investigation documents that the majority of the jobs evaluated in the trimming department expose workers to multiple ergonomic risk factors, which have been found in previous studies to increase risk of developing WRMDs. Forty questionnaire respondents (62%) classified the physical effort necessary to perform their job as hard to very, very hard. Fifty-five (85%) reported some body discomfort (not necessarily work related) for the year prior to the site visit (82% UE and 52% back). Almost all of the 48 production jobs analyzed had risk factors for WRMDs, including short work cycle times (85% were less than 30 seconds), piece work rates, and nonneutral postures of the trunk (43 to 90%), shoulder (47 to 98%), and wrist (45 to 94%). All of the jobs required pinch grips to perform their job tasks. To address some of the exposure issues, the company has instituted ergonomic changes such as job rotation; process changes, including an automatic last puller; medical management programs; and a voluntary exercise program. Ergonomic risk factors continue to exist, particularly for the UE; therefore, additional prevention efforts are required to reduce worker exposure.

Recommendations

The equipment found in this facility was highly specialized. Engineering solutions were available for reducing some, but not all exposure conditions. The following recommendations were made to reduce workplace stressors at this facility.

- Air-powered shears could be utilized to avoid contact stresses on the forefinger and thumb from the use of scissors, which most employees used.
- Adjustable-height swivel chairs with low back (lumbar) cushioning are recommended for seated operations to improve postural conditions for the worker. Height adjustment allows workers of different anthropometry to modify the vertical positioning of the body to obtain the best manual and visual orientation to the work task. A swivel seat pan was identified as an important design feature because of the frequent twisting of the back identified among seated workers who turn to the side to grasp and release shoes from racks located on both sides of their chairs. Lumbar support is necessary in seated operations to maintain spinal lordosis (the natural curvature of the spine in the lower back); otherwise, there is elevated compression on the spinal discs.
- Sit–stand stools or lean bars are recommended for job tasks requiring prolonged standing to reduce venous insufficiency and whole-body fatigue. Equipment that is activated by a foot control is generally used for stationary work, which would permit use of a sit–stand stool or lean bar without interfering with whole-body motion patterns. The optimal work position for use of a foot pedal is a 115- to 120-degree angle between the foot and lower leg, which is why a seated or semiseated position is generally recommended for continuous use of a foot pedal. When the ankle joint is less than 105 degrees, the muscles and tendons in the lower leg can be strained, causing the muscles to work less efficiently.
- Antifatigue mats or shoe cushioning could be used for standing jobs to aid in reducing generalized fatigue.
- Task lighting for visually demanding jobs such as grinding and edge trimming could help reduce neck flexion and possible eye strain.
- Arm and elbow support could be used to reduce postural loading on the shoulders, such as exists in the edge trimming job, where there is prolonged shoulder abduction and flexion.
- Due to the highly specialized nature of the work at this facility, it was recommended that employee suggestions be actively solicited and considered with respect to equipment and other job changes that may aid in reducing exposure to ergonomic stressors.

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