Ergonomics of Household Appliance Assembly

Cheryl Fairfield Estill[1] and Leslie A. MacDonald[2]

National Institute for Occupational Safety and Health, [1]4676 Columbia Parkway C-24, Cincinnati, Ohio 45226, CEstill@cdc.gov, (513) 533-8404, fax (513) 533-8596; [2]4676 Columbia Parkway R-15, Cincinnati, Ohio 45226, LMacDonald@cdc.gov, (513) 841-4529, fax (513) 841-4486

Abstract

The household appliance industry is listed by the Bureau of Labor Statistics as the industry group with the 15th highest rate of illness cases for disorders associated with repeated trauma with 213 cases per 10,000 workers. To investigate physical job stressors within this industry and to identify and develop ergonomic solutions to reduce these stressors, NIOSH investigators conducted walk-through surveys at 12 household appliance manufacturing plants. A more detailed investigation of workplace stressors and musculoskeletal disorders was also performed at a single appliance facility, involving blue- and white-collar workers. Participants completed a detailed questionnaire concerning demographics, work history, leisure activities, musculoskeletal symptoms and exposure to physical and psychosocial job stressors. Physical job stressors were also evaluated using observation-based checklists. Using criteria from OSHA's draft 1995 Ergonomic Protection Standard, most blue-collar workers (75%) were found to exceed the proposed threshold for exposure to physical upper extremity stressors. Engineers can aid in the reduction of physical job demands within the appliance industry by implementing ergonomic improvements. Four areas are highlighted in this article that engineers can work on to reduce the physical risk factors present in appliance production jobs: short work cycles, forceful and repetitive pinch grips, working with hands over shoulder height, and manual handling of heavy parts. Additionally some fundamental engineering changes that should be implemented at all appliance facilities are listed.

Introduction

The Ergonomic Program Standard of the Occupational Safety and Health Administration (OSHA) was passed in November 2000, but rescinded by congress in March 2001. While there is no regulatory mandate at the national level, voluntary guidelines on workplace ergonomics have recently been issued by the ACGIH (American Conference of Governmental Industrial Hygienists)[1] and the National Safety Council.[2] Additionally, two states (California and Washington) have adopted standards regarding workplace ergonomics. In addition to the development of voluntary guidelines and state-based regulatory initiatives, workplace ergonomics is increasingly a topic being addressed in collective bargaining, keeping the issue of ergonomics on the front burner.

The Household Appliance Industry has long been among the industries with the highest rate of costly worker illness cases classified as Disorders Associated with Repeated Trauma. For 1999, the latest data available from the Bureau of Labor Statistics, the Household Appliance Industry was ranked 15th among those industries with the highest rates of repeated trauma, with 213 cases per 10,000 workers.[3] When compared to all industry sectors, the manufacture of Household Refrigerators and Freezers was ranked 4th and Household Laundry Equipment was ranked 8th, having 344 and 324 cases of repeated trauma per 10,000 workers, respectively.

There is evidence that work-related musculoskeletal disorders (MSDs) result from repetitive or sustained microtrauma that interferes with the functioning of specific tissues (or structures) of the musculoskeletal system over time. Physical job stressors associated with MSDs include repetitive motion, awkward postures, forceful or static (sustained) exertions, contact stress and vibration. These job stressors comprise the external demands of work that produce internal tissue loads. A review of the scientific evidence showed that there is strong evidence of an association between MSDs and certain physical job stressors when exposures are intense, prolonged, and particularly when there is exposure to more than one job stressor simultaneously.[4]

Research also shows that psychosocial job stressors are associated with MSDs, although the findings to date are not consistent.[4] These job stressors include factors such as psychological job demands, job control (decision latitude, task control), job strain (the ratio of psychological demands and decision latitude), supervisor support and job insecurity, among others. Psychosocial job stressors are hypothesized to be indirectly associated with MSDs through a relationship with physical stressors or through associated co-morbidities (e.g., fatigue,

depression, anxiety) that, in turn, are directly and indirectly (via related consequences such as tonic activation or behavioral response) associated with the development of MSDs.[5]

First Steps

Many appliance plants have already accomplished these first steps in their ergonomic programs. If your facility has never had an ergonomic program, start by providing these fundamental engineering changes that can reduce workers risk of musculoskeletal disorders. Provide anti-fatigue mats to all employees who stand continuously.

- Provide suspension for powered hand tools which are commonly used. The height should be lower than the shoulder (avg 52" women, 56" men), the tension should be properly adjusted, and the tool should be located directly above the point of activation.
- Provide proper tooling as needed. For example, provide rubber mallets so that workers do not use their hand as a hammer.
- Provide manual and power hand tools with handle sizes ranging from 1-3/8" to 2-1/8" in diameter. This handle diameter range will provide workers with maximum grip strength capability.
- Eliminate all lifting from the floor by putting parts on tables or pallet jacks.
- Eliminate all overhead work by placing workers on platforms or by lowering the work.

Ergonomics is an engineering disciple concerned with the fit between job requirements and the capabilities of workers. Companies in many industries have found that proactive workplace ergonomic programs are effective in reducing musculoskeletal injuries, as well as associated direct and indirect costs (indirect costs include lost productivity, training of replacement workers, increased administrative costs). Within two years of establishing an ergonomics program, which provided the impetus for the replacement of manual wiring with pneumatic tool-assisted wiring, one appliance company showed a reduction in medical cost claims of $45,000 per year for carpal tunnel syndrome. In addition to the injury reduction and associated cost savings, this ergonomic solution provided the added benefit of a reduction in the service call rate (rate of inoperable appliances returned) by almost one-quarter.[6]

Ergonomic programs do not have to be expensive to be effective. One company reported that 67% of their ergonomic changes cost $500 or less.[7] At another

appliance company, justification for the cost of engineering changes to reduce the physical job stressors in a manual bellows insertion task did not meet plant-specific limits for economic payback until projected cost savings from injury prevention were added. It was later learned that production volume increases experienced at this plant could not have been achieved without considerable added labor cost had the ergonomic improvement not been implemented, thus increasing the benefits realized from this ergonomic improvement.[8]

Methods

To investigate the type and prevalence of physical job stressors within the appliance industry, and to identify and develop ergonomic solutions to reduce these stressors, NIOSH investigators conducted walk-through surveys at 12 household appliance manufacturing plants. In addition to walk-through surveys, a detailed investigation of job stressors and MSD prevalence was performed at a single large manufacturing facility where household laundry equipment was produced.[9] Four hundred and ten blue- and white-collar employees participated in the study (84% participation). Participants completed a detailed questionnaire concerning demographics, work history, leisure activities, musculoskeletal symptoms and exposure to physical and psychosocial job stressors (e.g., job strain, job control). A composite physical job stressor score was computed by weighting individual physical stressors by intensity and duration criteria as specified by OSHA's 1995 draft ergonomic protection standard;[10] score values greater than five defined high exposure to physical job stressors.

Physical Job Stressors and Workplace Improvements

Physical job stressors identified were short fixed-pace work cycles, forceful and repetitive pinch grips, working with hands over shoulder height, and manual handling of heavy items. Engineers can aid in the reduction of physical risk factors within the appliance industry by implementing ergonomic improvements.

Short fixed-paced work cycles are prevalent in the appliance industry. Many employees work on assembly lines which move at fixed rates. Sub-assembly

operations are often also tied to the same assembly rate. Typical cycle time on the assembly lines allotted workers approximately 30 seconds per appliance to perform their assembly tasks. The stereotypic movements, postures, and exertions throughout the work day result in repeated or sustained activation of task-specific muscle groups and related tissues and structures within the musculoskeletal system. Even under ideal circumstances where part tolerances accommodate the ease of assembly, recovery time between work cycles may be too short to prevent residual strain and localized fatigue. Short cycle work can be improved by expanding job content, as in the assembly of a whole unit rather than a small part. Expanding job content would permit workers to perform a wider variety of tasks allowing different muscle groups to alternate between recovery and activation.

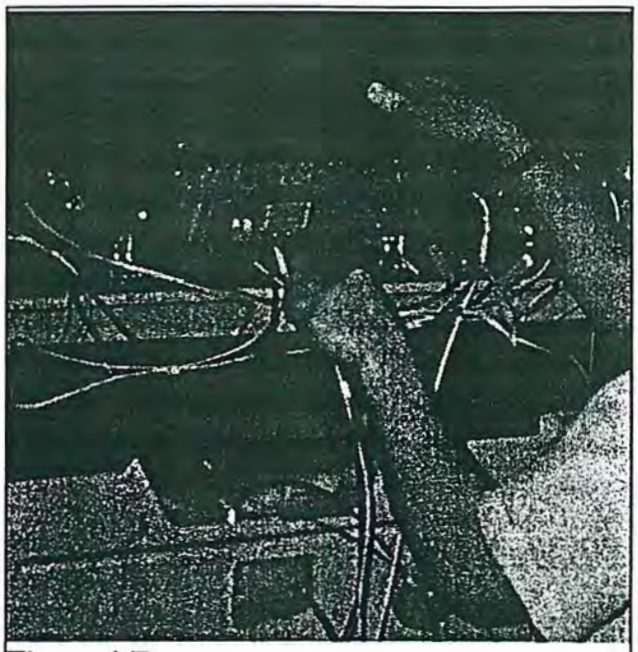

Figure 1 Tape is worn on thumbs to protect the high forces of connecting wire terminals.

Use of the thumb and opposing finger is called a pinch grip. Pinch grips were found to be common among assembly and subassembly operations. When pinch grips are performed repeatedly and in combination with high force, workers are at increased risk of hand or wrist disorders. Electrical wiring was a common work activity in the appliance industry that involved extensive use of the pinch grip. Wiring tasks require both high repetition (about 15 per minute) and high force (about 12 to 32 lb).[11] Many workers wrap tape on their fingers to protect against contact stress (Figure 1). Forceful pinch grips used for wiring jobs can be reduced or avoided as follows:

1. low-insertion force terminals can be used to reduce the amount of force required; these have the added advantage of improving quality because the worker can feel that the terminal is properly seated;

2. pneumatic hand tools can be purchased to connect terminals; these move the force from the worker's fingers to the tool and these are especially good for large sized terminals that can be connected at a stationary work table;
3. manual hand tools such as pliers or specially designed tools can be used to effectively move the high forces from the workers finger tips to the whole hand; and
4. wiring blocks (e.g., the brand, Molex) can be used to reduce the total number of connections required during assembly, thus reducing the frequency of forceful pinch postures.

Press operators often work with their hands over shoulder height. Average shoulder height for men and women is 56.2 and 51.6 inches, respectively. At one facility, the average height of the activation buttons on press machines was 70.3 inches, resulting in workers spending an average of 28 percent of their time with their hands above shoulder height.[12] Packaging also typically requires overhead work both for retrieving empty boxes from overhead stacks and for tossing boxes over appliances (Figure 2). Both tasks can be changed to reduce the amount of overhead work required. A different activation method can be used for the press operations. Heat sensing buttons placed at waist height (Figure 3) can be as effective at operating the press and avoiding safety hazards but without the postural loading that increases the risk of shoulder disorders. Self-leveling pallets can be used for

Figure 2 Lifting box overhead to package appliance.

stacking empty appliance boxes. The pallet can be adjusted so that the empty box to be removed is always between waist and chest height of the worker thus avoiding stooping postures and reaching over head. Workers can also stand on platforms so that the top of the appliance is at a waist height, allowing the worker to use the force of gravity to lower the empty box over the appliance rather than raising the large empty box overhead (Figure 4).

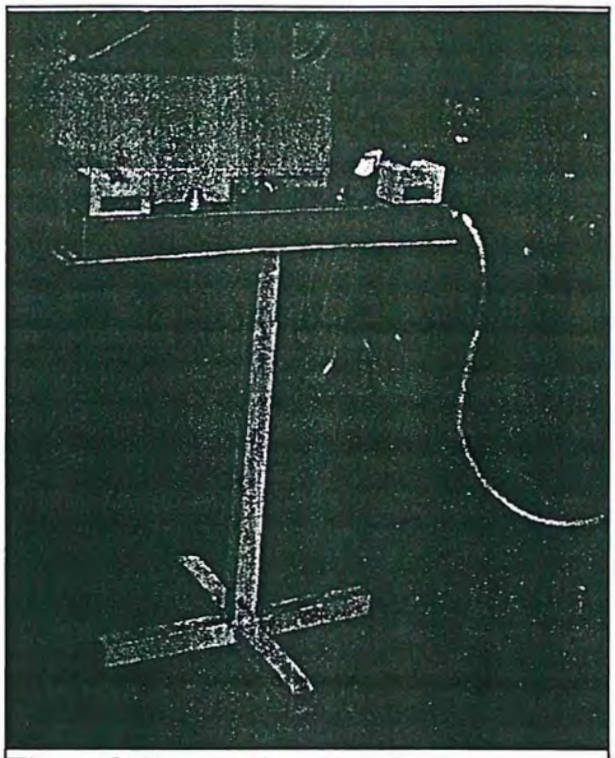

Figure 3 Heat-sensing controls to activate presses.

While lifting of objects weighing more than 10 pounds was not a common exposure condition in appliance assembly operations, some assembly jobs were found to require frequent heavy lifting. On one assembly line,[12] a worker manually lifted and rotated by 180° a 36 pound appliance during each 30 second cycle. Such frequent heavy lifting can pose a risk of back injury to workers. The risk of injury inherent in lifting tasks can be objectively evaluated using the NIOSH lifting equation, where a Lifting Index (LI) is computed from several dimensional parameters of the lifting condition (e.g., location of the object from the floor) and the weight of the object. If the LI has a value of one or less, the job does not pose a hazard to most workers. For LI above one, risk for lifting-related low back pain is increased for some fraction of the workforce.[13] Workers performing lifting tasks above two are 2-1/2 times more likely to report low back pain than workers who do not lift.[14] For the case of the 36 pound appliance, the LI was 1.9. This lift could be avoided using a mechanical assist device. A less expensive alternative is to provided a slanted table adjacent to the assembly line with a slick surface. The worker could push the appliance onto the slanted table

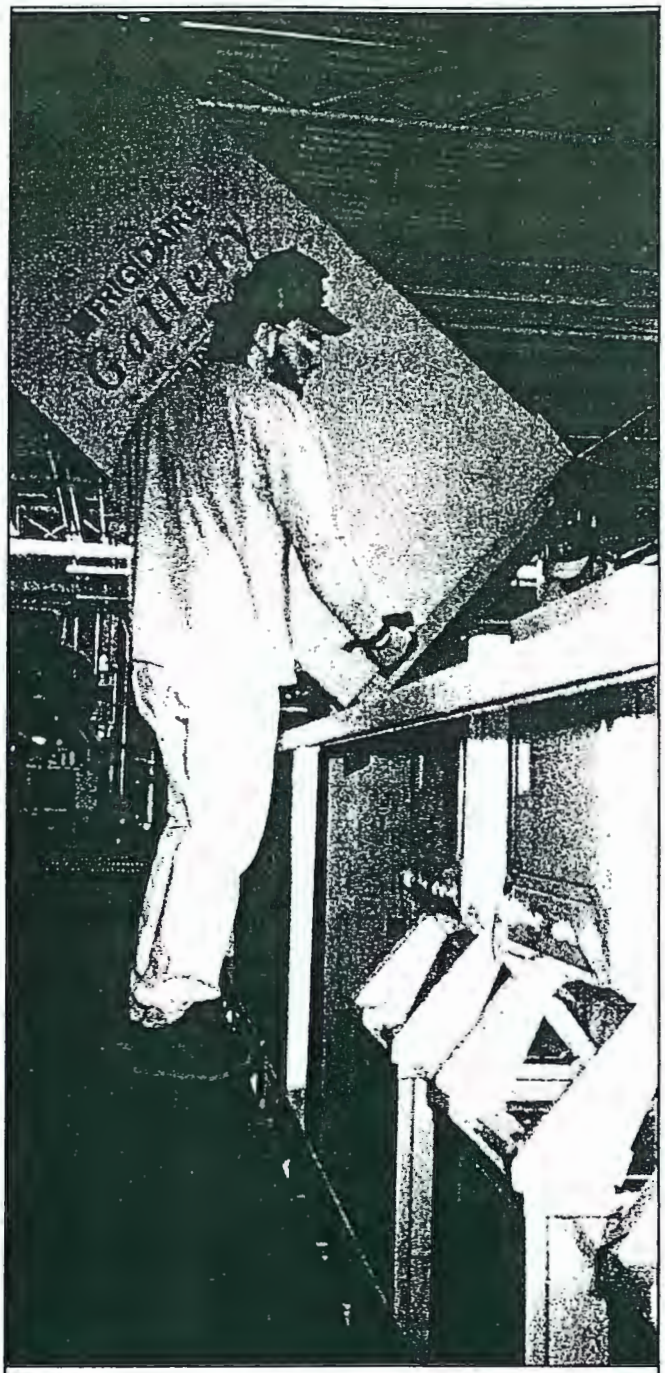

Figure 4 Worker stands on a platform to avoid lifting the bulky boxes overhead.

and then slide it onto its side (repeat to turn upside down).

Single Site Study Findings

In the detailed research study, physical job stressor scores showed that most blue-collar workers (75%) exceeded the proposed threshold (a value of five) for physical loading of the upper extremities, while loading of the back and lower extremities (LEs) was exceeded less often (32%). The thresholds were exceeded less often among the white-collar workers: 16% for upper extremity and 1% for back or LEs. For the lower extremities, it was found that workers who stood more than 4 hours per day were five times more likely to have significant foot or ankle pain even after adjustment for factors such as body mass index.

Physical job stressors were found to be highly correlated with psychosocial job stressors (high job strain and low job control). Occupational groups were plotted by their group median values for decision latitude (or job control) and the physical job stressor score for the upper extremities, showing a steep inverse relationship (Figure 5). The relative exposure level for

each occupation on these two job stressor dimensions is consistent with observations of working conditions at the appliance plant. A very strong negative correlation was found between these two job stressors using the group aggregate measures (r= -0.91, p=0.001), indicating that workers exposed to high levels of physical job demands had low job control and high job strain (ratio of psychological job demands and job control).

Workers with both high physical loads and high job strain were found to have higher levels of anxiety and fatigue, less job satisfaction, felt less job security, had less schedule control, experienced less co-worker support and more group pressure, and had higher mental demands. After adjustment for factors such as employment at a second job, job seniority and blunt trauma, blue-collar workers with exposure to high physical demands had more than a two-fold increased risk of upper extremity MSDs; risk was further increased by about 50% among those exposed to both high physical demands and high job strain.

Conclusion

Workers' in the Household Appliance Industry experience a high incidence of repeated trauma disorders, which can lead to disability among the afflicted and can be disruptive to production and costly to the employer. NIOSH investigations found that a high proportion of workers employed in production areas of the appliance industry are exposed to high levels of physical stressors, such as highly repetitive motion patterns, forceful pinch grips, stressful working postures and, occasionally, repeated heavy lifting. Jobs with high exposure to physical stressors were also found to have unfavorable exposure to psychosocial stressors such as low job control (e.g., fixed pacing demands) and high mental or psychological job demands (e.g., sustained vigilance); this combined exposure situation appears to increase risk for MSDs above the levels found for high exposure to physical stressors alone.

Engineering improvements based upon ergonomic design guidelines can effectively reduce these job stressors. Practical ergonomic job assessment methods are available for evaluating jobs for risk to the upper limbs (ACGIH[1]) and back (NIOSH Lifting Equation[13]). Ergonomic solutions range from part modification or substitution (e.g., low insertion force terminals or Molex wiring block connectors) to providing tools (e.g. with proper grip diameters) that fit workers better to rearranging the design of the workstation. Additionally, these solutions are often inexpensive, expenditures can often be recouped with reductions in the indirect and direct costs of MSDs and sometimes have the added benefit of improving quality.

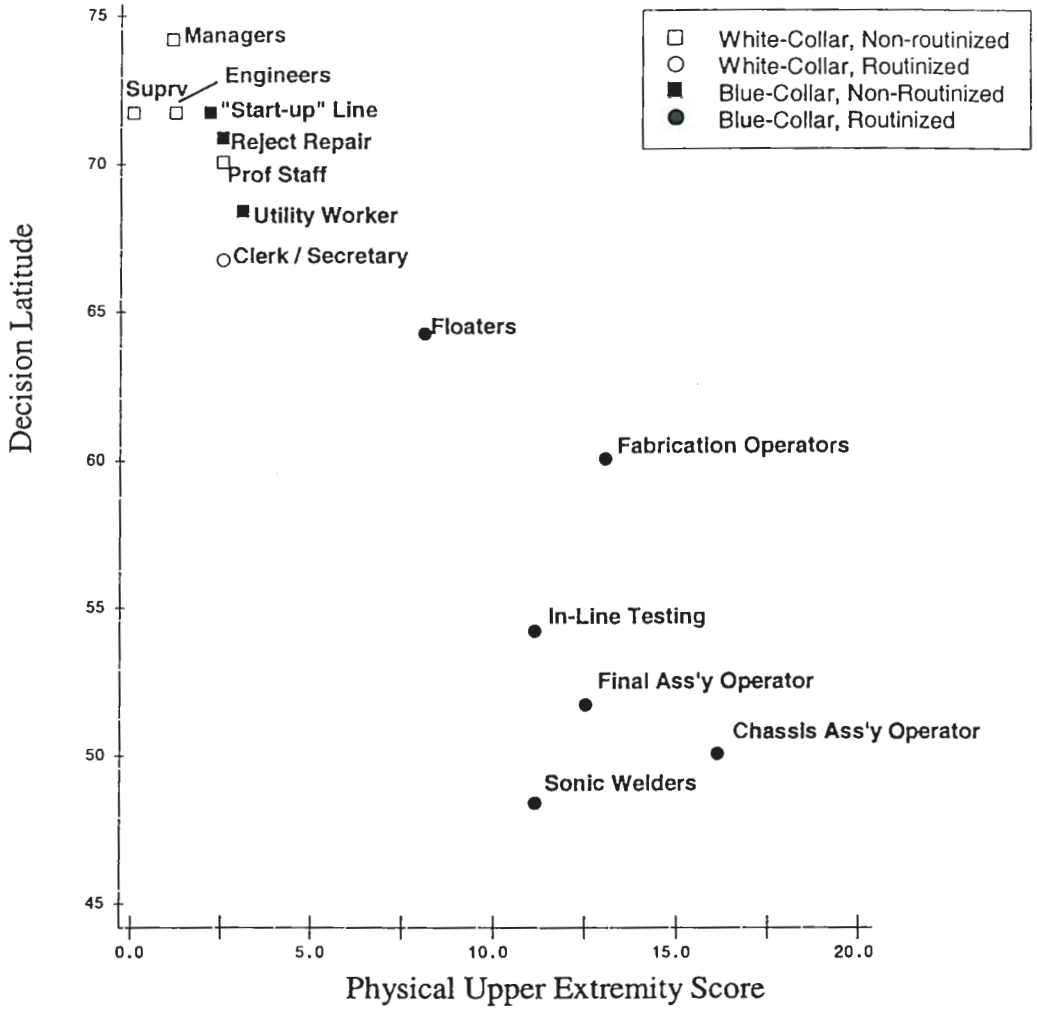

Figure 5. Distribution of occupations, r=-0.91 (p=0.001)

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Cheryl Fairfield Estill, Industrial Engineer
Leslie A. MacDonald

Robert A. Taft Laboratories
National Institute for Occupational Safety and Health
4676 Columbia Parkway C-24
Cincinnati OH 45226

Phone: 513-533-8404
Fax: 513-533-8596
Cestill@cdc.gov
LmacDonald@cdc.gov

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