CDC
Workplace Safety and Health

Ergonomic Evaluation of Surfacing and Finishing Tasks during Eyeglass Manufacturing – Minnesota

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Health Hazard Evaluation Report
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DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
NIOSH *National Institute for Occupational Safety and Health*

The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

Contents

Report

Appendix A

Appendix B

Acknowledgments

Abbreviations

HHE	Health hazard evaluation
MSD	Musculoskeletal disorder
NAICS	North American Industry Classification System
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
UE	Upper extremity
WMSD	Work-related musculoskeletal disorder

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at three eyeglass manufacturing facilities in Minnesota. Managers submitted the HHE request because of ergonomic concerns and musculoskeletal disorders of employees working in the surfacing and finishing departments.

What NIOSH Did

- We evaluated three facilities in November 2010.
- We watched employees doing routine job tasks and took video of these tasks. The video footage allows us to document employees' risk factors for work-related musculoskeletal disorders (WMSDs).
- We measured the heights of workstations and distances that employees reached to do a job task. These measurements determine the risk of injury.
- We talked with employees about their work and medical history.
- We reviewed occupational safety and health injury and illness logs. We also looked at employees' medical records.

What NIOSH Found

- Employees used awkward postures and repetitive motions in their jobs. These factors increased their risk for shoulder, arm, elbow, forearm, wrist, hand, and finger WMSDs.
- Employees were also at an increased risk for low back WMSDs. This risk was due to repeated bending and twisting.
- The most common WMSDs among finishing and surfacing employees were wrist, shoulder, hand, and back disorders.
- The rates of injuries and illnesses at this facility were higher than at most other eyeglass manufacturing facilities in the United States.

What Managers Can Do

- Design work areas to have a working height of 27–62 inches.
- Add tables that have adjustable heights so that employees can customize the height to their needs. Adjustable lifts with rotating platforms should also be added. Take part in safety and ergonomic committees.
- Rotate employees to different job tasks after every break. All employees should use the same rotation pattern.
- Educate employees on ergonomics and WMSDs. This will help them recognize and avoid risk factors that can lead to WMSDs.
- Encourage employees to report work-related musculoskeletal discomfort. These complaints should be logged to identify jobs that need to be modified.

What Employees Can Do

- Keep heavy loads close to your body when lifting and carrying.
- Learn about and use adjustability features of the workstations.
- Take part in safety and ergonomic committees.
- Report injuries and unsafe working conditions to your supervisor.
- Seek care from a healthcare provider if you are injured at work. The provider should be experienced in occupational health.

Summary

In June 2010, NIOSH received an HHE request from managers to evaluate potential ergonomic hazards and MSDs among employees at three eyeglass manufacturing facilities in Minnesota. The request concerned employees working in the surfacing and finishing departments.

We visited the three facilities on November 16–19, 2010. We observed work processes and practices and assessed workplace conditions. We videotaped surfacing and finishing tasks. We also measured workstation heights and reach distances. We talked with employees privately to discuss concerns about the workplace and their health. We also reviewed medical records related to MSDs.

Employees were exposed to a combination of risk factors for upper extremity WMSDs. Employees' job tasks often required repetitive motions such as twisting, reaching, wiping, and eyeglass assembly. Awkward postures such as extended reaches and reaches above the head were also risk factors. The overall rates of OSHA-reportable injuries and illnesses for all three facilities were higher than average for the eyeglass manufacturing industry. However, these rates declined in 2010.

We found that employees were exposed to a combination of risk factors for developing WMSDs, including awkward postures, forceful exertions, and repetitive motions. Of 60 interviewed employees, 45 reported having current or past MSD symptoms. Review of 19 employees' medical records found that most medically documented WMSDs involved the wrists, shoulders, hands, and back. Three employees had undergone surgery and three (one of whom had undergone surgery) were put on permanent work restrictions. Comparison of OSHA Form 300 Logs of Work-Related Injuries and Illnesses showed higher rates of injury and illness at this facility than at other eyeglass manufacturing facilities in the United States in 2007–2009, but by 2010, all but one facility's rates had declined to near the national industry average. On the basis of employee interviews and OSHA Logs, the most commonly reported MSDs were wrist, shoulder, hand, and back disorders.

We provided the facility with recommendations for reducing the risk of WMSDs. By designing work areas to have a working height of 27"–62" and rotating employees to different job tasks after every break, managers can reduce the risk of WMSDs. Training employees to recognize and avoid risk factors that can lead to musculoskeletal problems and encouraging employees to report work-related musculoskeletal discomfort can also reduce employees' risk of injury.

Keywords: NAICS 339115 (Ophthalmic Goods Manufacturing), ergonomics, WMSDs, finishing, surfacing, prescription lenses

Introduction

On June 1, 2010, NIOSH received an HHE request from managers to evaluate potential ergonomic hazards and MSDs among employees at three eyeglass manufacturing facilities in Minnesota. The request concerned employees working in the lens surfacing and finishing departments.

During November 16–19, 2010, we visited the three facilities. We held an opening meeting with managers and employee representatives. We observed work processes, practices, and workplace conditions. We took video of surfacing and finishing tasks and measured workstation design parameters. We also privately interviewed employees to discuss their health and workplace concerns and requested medical records related to WMSD symptoms possibly caused or aggravated by work tasks involving forceful exertions, awkward postures, and repetitive motions. On November 19, 2010, we held a closing meeting and provided preliminary recommendations to management and employee representatives. We sent a letter with our preliminary findings and recommendations on December 8, 2010.

Facility Descriptions

Facility 1 opened approximately 50 years ago and employed 250 at the time of our visit. Facility 2 opened around 1979 and also employed around 250. Facility 3 was acquired by the company in the late 1980s and employed 150. All facilities operated three shifts; however, different areas had different start times to allow for continuous workflow. Facility 1 had tried a 12-hour work shift for 3 years, but had stopped that program in May 2010 before our site visit.

Each facility had a health and safety committee that met once a month and discussed illnesses, injuries, and concerns. Employees were encouraged to use a safety suggestion form/box. Ergonomic concerns identified by each facility's health and safety committee during monthly departmental safety audits were provided to an ergonomics committee that also met every month. Ergonomics committee members received 1-day training, provided by the company's workers compensation insurance carrier, on the use of an ergonomics checklist. A safety incentive program, "Safety Star Certification," was in place to reinforce ideas and improve involvement.

The company contracted with an off-site occupational medicine clinic for managing work-related injuries and illnesses. If an injury or illness occurred, the employee reported it to his or her supervisor and the human resources department. If necessary, the employee was sent to the clinic for evaluation. Some employees were also evaluated by a company-contracted physical therapy group as needed. The supervisor

Figure 1. Machine used to attach blocks to lenses.

Figure 2. Rounds of tools used for fining and polishing.

and human resources staff evaluated the ill or injured employee's job for possible hazards. Temporary employees went through a different process and saw a different medical contractor. The company reported that they had several light-duty jobs and an aggressive return-to-work program. Facility 2 had a mandatory stretching program during work hours.

Surfacing Tasks

Taping

Employees placed each lens blank in a machine that put a tape/film on the lens to protect it from heat and damage.

Blocking

Employees positioned each lens into a blocking machine (Figure 1) that used a heated metal alloy to attach a block to the lens. The block held the lens in place during grinding, fining, and polishing.

Grinding

A generator ground optical curves into the back of each lens on the basis of the prescription.

Tool/Pad

After grinding, the lens was matched with the proper tool, on the basis of prescription, for fining and polishing (Figure 2).

Fining/Polishing

Some machines had a single-step process for polishing lenses. Others involved a two-step process, and pads on the tool were replaced between the steps. At each facility, employees loaded the lenses and tools into the polishing machines.

Deblock/Wash

A specially-designed deblocking cup (Figure 3) was used to remove the block from the lens. The tape was removed and the lens was inspected, washed, and dried before continuing to the finishing process.

Figure 3. Deblocking cup used to remove blocks from lenses.

Figure 4. Some of the tools used to insert lenses into frames.

Finishing Tasks

Tinting

The lenses could be tinted by placing them into tinting solution.

Verify/Lining/Chucking

For single vision lenses, a verifier machine was used and then chucks were attached before the lens was edged. For bifocal and progressive lenses, an instrument was used to properly line up the lens before placing chucks on them for edging. A chuck is a metal or plastic device that is placed on the lens to hold it during edging. Sometimes adding a chuck was fully automatic; however, employees also added the chuck manually.

Edging

Edging machines ground each lens to the proper shape for the frame and placed a bevel around the edge of the lens. The bevel removed the sharp edge from the lens and eased insertion into the frames.

Sanding

Metal or rimless frames required lenses with precise bevels; employees sanded these lenses by hand using a tabletop grinder.

Assembly

Employees inspected the lenses and used a lensometer to verify the correct prescription before inserting them into the frames using screwdrivers, pliers, and other tools (Figure 4).

Assessment

We observed surfacing and finishing tasks in the three facilities. We took digital videos to document the tasks and measured workstation heights. A full description of the ergonomic evaluation criteria we used to determine risk factors for WMSDs is provided in Appendix A.

We held confidential interviews with employees working in the finishing and surfacing departments of the three facilities. The interviews focused on medical and occupational histories. These included, but were not limited to, work type and duration, work-related injuries or illnesses, past or current health conditions, and possible workplace exposures. We also reviewed medical records of employees who had WMSD symptoms and OSHA Form 300 Logs of Work-Related Injuries and Illnesses for years 2007–2010.

Surfacing Tasks

Surfacing tasks described below were similar at each of the three facilities; the tools, storage, and machines at the facilities varied slightly. Table B1 (Appendix B) contains a list of ergonomic hazards in each surfacing area. These hazards are detailed in the following paragraphs.

Taping

We measured the location of the taping machine at facility 1. The table that held the taping machine was 35" high, and the location where lenses were loaded into the machine was 43" high. Tray dimensions were 10" wide, 8.5" long, and 3.25" deep; however, the tray did not have handles or handholds on the ends, which caused contact stress during lifting and carrying. During our observation, the incoming trays were stacked five high, and the outgoing trays were stacked eight high. These tray heights put reach measurements between 51¼"and 61". The taping machine was activated by a foot pedal. The employee who operated this machine was also responsible for retrieving used blocks, letting them soak to remove excess alloy, and using that alloy to refill the blocking machines. Facility 1 used a square tray to collect alloy, facility 2 used a teapot, and facility 3 used a handled pitcher. A handled pot or pitcher for pouring provides a power grip, which is preferred. Only the tables at facility 1 were adjustable to reduce the reach during metal pouring.

Blocking

Blocking employees received stacks of trays from the taping area; the height of the stacks varied. The employees used a video monitor to verify correct lens alignment. Blocking machines for facility 1 were on adjustable tables that could be set at 29"–36". Employees were seated for all machines at facility 1 but did not seem to have leg clearance under the table or proper workstation design because they were seated forward in the chair and did not use the backrest. Incoming trays were located to one side of the blocking machine and were stacked approximately 10 trays high, extending reaches above shoulder height for some of the employees (Figure 5). The chucks were in bins on the other side of the workstation. A scanner used by employees was located on the employees' left side, causing right-hand dominant employees to reach across their body to use it. A video display used for accuracy

Results (continued)

Figure 5. Stacks of trays causing reaches above shoulder height.

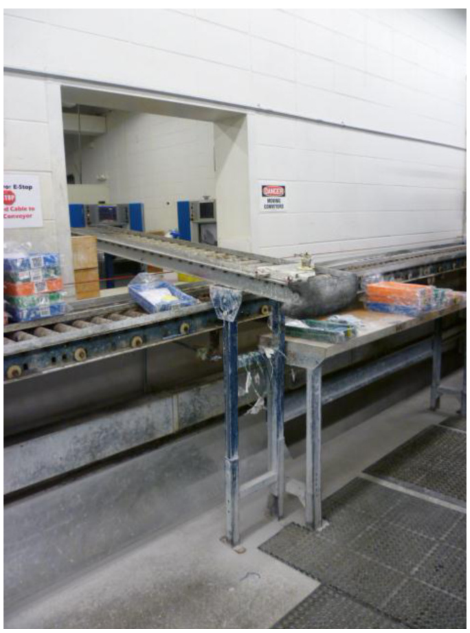

Figure 6. Conveyor between grinding and polishing.

of the block placement was shifted off to one side, causing neck twisting, but was at the employees' eye level. After the employee attached the block, he or she placed the tray on a tray takeaway to the grinding machine; the location of this takeaway caused extended reaches. When more trays were prepared than the grinding machine could accommodate, employees stacked the trays, which resulted in trays stacked above shoulder level.

Facility 2 had blocking machines for both traditional and digital surfacing, and employees did not rotate between the workstations. Traditional blocking workstations at facility 2 were all standing workstations. The workstation tables were not adjustable, and the fixed heights varied between machines, ranging from 35"–39.5". Employees were provided anti-fatigue mats; however, because of the location of the machine, incoming trays, and the outgoing tray conveyor, employees stepped off and on the mats while performing the job. The video display for the blocking machine was approximately at eye level for the employee observed. Because the scanner for this machine was on the employee's right side, reaching across the body as seen at facility 1 was not necessary. Digital blocking workstations at facility 2 were seated workstations; the tables were not adjustable. However, if the chair was properly adjusted it would probably result in reduced leg room as seen at facility 1. Incoming trays were located to one side of the machine and were stacked approximately eight trays high, placing the highest trays above shoulder height. The scanner was on the same side as the incoming trays, so reaching across the body was not necessary. The display for the machine was above eye level and resulted in neck extension while employees positioned the lenses in the blocking machine. The digital workstations had tray takeaways for the grinding machines; however, the location caused extended reaches. There was some contact stress on the employees' forearms from the placement of their arms while holding the lenses in the machine and the edge of the metal table.

Facility 3 had blocking machines for traditional surfacing; employees were specialists working towards technician status so they could rotate jobs. The heights of the workstation tables were not adjustable. The incoming trays were placed on the employee's left side, but the scanner was on the right of the blocking machine and caused the employee to reach across his or her body to use the scanner. Employees were observed tapping and pressing on lenses to release them, resulting in vibration and pinch forces.

Figure 7. Trays stacked on top of the machine, resulting in extended reaches.

Figure 8. Modified tool storage at facility 1.

Grinding

Facility 1 grinding generators were loaded automatically from the tray takeaway in the blocking department and, after grinding, the tray traveled automatically by conveyor to the fining/polishing area. Both facility 2 and facility 3 had grinding generators that had to be manually loaded and unloaded. At facility 2 the conveyor that employees placed trays on for transport to polishing was at or above shoulder level for some employees. The height of this conveyor was determined by the wall opening and the conveyor in the polishing area (Figure 6). There was no conveyor from one area to the other at facility 3; however, the carts had enough space to hold the multiple trays. Employees were stacking trays on top of the machines resulting in reaches of 50"–68" (Figure 7).

Tool/Pad

Each of the facilities had different tool storage methods. The tool rounds seen in Figure 3 were used at facilities 1 and 2. They required reaching overhead and bending at the back. Tool storage had been modified at facility 1 for more frequently used tools (Figure 8). Facility 1 had an employee dedicated to pulling tools and attaching polishing pads; this workstation also had a pad dispenser that separated the pad from the backing and reduced pinch forces. Facility 2 had pads on rolls at table height near the polishing machines. Facility 3 had pads on rolls above the machines, causing employees to reach overhead for the pads. Employees in this area restocked used tools that were received after polishing.

Fining/Polishing

Each of the facilities had different polishing and fining machines. An employee at facility 1 ran five combination polishing machines. The employee had a neutral wrist posture when loading and removing the tools, but had flexed and deviated wrist postures when loading and removing the lenses. The machines had a shelf in front to hold a tray; the employee placed trays for the next job on top of the machine. The employee used the 6 minutes between polishing jobs to soak the used tools to help with pad removal, removed the pads using a pinch grip, and threw the pads away. The employee then sprayed the tools with an air nozzle to dry them before putting them on a conveyor back to the tool area.

Figure 9. Collection bin for blocks.

Facility 2 had two different machines for different polishing tasks. Two employees each ran 10 polishing machines. One employee placed pads on the polishing tools and then placed the tools and lenses into the first machine for polishing. These machines required a specially designed rod to release and lock the pads in place. The rod had a pistol grip; however, employees still had flexed and deviated wrists when placing the lenses and tools into the machine. Employees also had neck flexion and deviation while making sure that the machines were set up properly after installing the lenses. Trays were stored on top of the machines during the polishing process causing some employees to reach above shoulder level.

Facility 3 had many different pods of polishing machines. Most of the machines had a shelf to hold the trays during the polishing process but trays were stacked on top of the machine, resulting in extended reaches. We observed an employee using a polishing machine at this facility; that employee held the lens during polishing, resulting in a vibration exposure.

Deblock/Wash

A special cup was used to remove the block from the lens (Figure 3). Employees at all three facilities used a variation of the cup; they held onto the lens and hit the cup on the table. The lens remained in the cup and the block fell to the table. To reduce handling, facility 3 had cut a hole in the table (Figure 9) so the block fell into a bin. The blocks were sent back to the blocking area where they were cleaned before reuse. Employees at facility 2 used a hammer to deblock some lenses, which resulted in vibration exposure. We observed an employee at facility 2 lifting trays up and over an enclosure, resulting in repetitive awkward shoulder postures. Employees removed the tape from the lenses before washing and drying them; all these activities required a pinch grip. Employees at facility 3 had a lens drier that used air to help remove some of the water and reduce the amount of wiping required to dry the lenses.

Finishing Tasks

The finishing tasks described below were similar at each of the three facilities; the tools, storage, and machines at the facilities varied slightly. Table B2 (Appendix B) contains a list of ergonomic hazards in each finishing area. These hazards are detailed in the following paragraphs.

Tinting

We observed tinting tasks at facility 2 and facility 3. Employees placed the lens in a holder that was then placed in a tinting solution. If a gradient of color was requested, the employee attached the lens holder to a machine that dipped the lens at a certain pace. After the lens reached the correct color the employee visually inspected the lens and cleaned it with a rag. These job tasks required pinch grips when attaching the lens to the holder and also when cleaning the lens. Employees did these jobs all day without rotation. Not all locations had dedicated exhaust for these areas; therefore, employees could be exposed to vapors from the heated tinting solution.

Verify/Lining/Chucking

We observed employees at facility 2 attaching chucks and verifying proper alignment. This facility had one standing workstation and one seated workstation. Employees worked for 4 hours at the standing workstation and 4 hours at the seated workstation. The legs on the table of the seated verifier prevented the employee from rotating the chair to the proper position, requiring him or her to twist and rotate his or her back to perform the task. Employees also had to reach across their body for parts when in the seated position.

Edging

For digital edging, employees loaded the trays containing the lenses into the machine. After edging, the machine automatically sent the trays to the assembly area via conveyor. For manual edging, employees loaded each lens into the machine. Trays were stacked and moved to the assembly area. Because this was mostly an automated task we did not observe any employees in the edging area.

Sanding

We observed one employee at facility 1 sanding the edges of the lens before assembly. The employee used a pinch grip to hold the lens while rotating it around the grinder to bevel the edges more precisely.

Assembly

Employees visually inspected the lenses and the frames before assembly. The lenses were cleaned if necessary before they were inserted into the frame. Tools such as screwdrivers, picks, and

Figure 10. Adjustable assembly workstation.

clamps were used, all requiring grip forces. After the lenses were installed, the employee checked that the frame was straight, measured the lenses, and checked the lens with a lensometer. All the assembly tasks required a slight neck flexion and various wrist postures depending on the tools used. Drill mount jobs were more hand intensive and required more tools. Employees at facility 1 were required to assemble 19–20 metal/string/plastic jobs per hour or 10 drill-mount jobs per hour. Employees did not rotate between the two types of assembly. Facility 2 had one "ergonomic" workstation that was being pilot tested (Figure 10); several employees had tried the workstation and made notes in a book about their likes and dislikes. This workstation was height adjustable and had task lighting and a tool holder. Employees at facility 2 were required to assemble 18 jobs per hour. One employee that we spoke to said that she assembled 18 jobs, and then inspected 18 to vary the work. Space was limited at most workstations, and trays were stacked in places that required extended reaches. None of the other workstations were adjustable. Facilities 1 and 2 had only seated workstations; facility 3 had seated workstations, but the tables and chairs were at a height so the employee could choose to stand. One employee at facility 3 suggested magnetic screwdrivers to reduce the amount of pinch force required to hold the screws in place during assembly.

Confidential Medical Interviews

We held confidential interviews with 60 of 235 surfacing and finishing department employees from facilities 1, 2, and 3 who were available during the shifts we selected. Each of the facilities supplied a list of employees who had reported an MSD to their supervisor within a year of our site visit. Most of the interviewed employees were chosen from this list. The remaining employees either requested to be interviewed or were asked to be interviewed at random to provide additional perspectives about jobs where we had fewer employees on the MSD list or requesting interviews. We asked employees, "Do you have any current musculoskeletal problems you think are related to your work?" If they answered "yes," we asked "What do you think your musculoskeletal problems are caused by?" We defined symptoms of WMSDs as persistent pain or soreness of the musculoskeletal system thought to be due to awkward postures, forceful exertions, and repetitive motion tasks at work and not due to slips, trips, or falls. We defined upper extremities to include the shoulder, arm, elbow, forearm, wrist, hand, and finger. Table 1 compares demographic information for interviewed employees by location.

Table 1. Comparison of demographic information among the three facilities

	Facility 1	Facility 2	Facility 3	Total
Number of employees available during interviews	92 (1st, 2nd, and 3rd shifts)	77 (1st and 2nd shifts)	66 (1st shift)	235
Number of employees interviewed (%)	29 (32)	19 (25)	12 (18)	60 (26)
Average age in years (range)	39 (22–67)	38 (22–56)	36 (22–53)	38 (22–67)
Number of males (%)	7 (24)	4 (21)	3 (25)	14 (23)
Average number of years worked at the company (range)	8 (1–26)	8 (1–33)	7 (1–18)	8 (1–33)
Average number of years in current job (range)	6 (0.2–20)	5 (0.3–16)	4.5 (0.1–18)	5 (0.1–20)

Facility 1

We interviewed 29 employees in facility 1: 14 surfacing, 14 finishing, and 1 former finishing employee transferred for medical reasons. Of the 15 current and former finishing employees, 12 reported symptoms of WMSDs; 11 with UE and one with back symptoms. Some employees reported symptoms in more than one body location. Eight of the 12 had seen a doctor. Among the 14 surfacing employees, 12 reported current or recent symptoms of WMSDs, 10 with UE and two with leg and low back symptoms. Six of the 12 had seen a doctor. Some employees reported symptoms in more than one body location. Figure 11 shows the number of facility 1 employees reporting symptoms of WMSDs by body location and job.

Among interviewed employees in facility 1, nearly three fourths in each area reported UE symptoms of WMSDs. Finishing employees reported wrist and shoulder symptoms most commonly, while surfacing employees reported more hand symptoms.

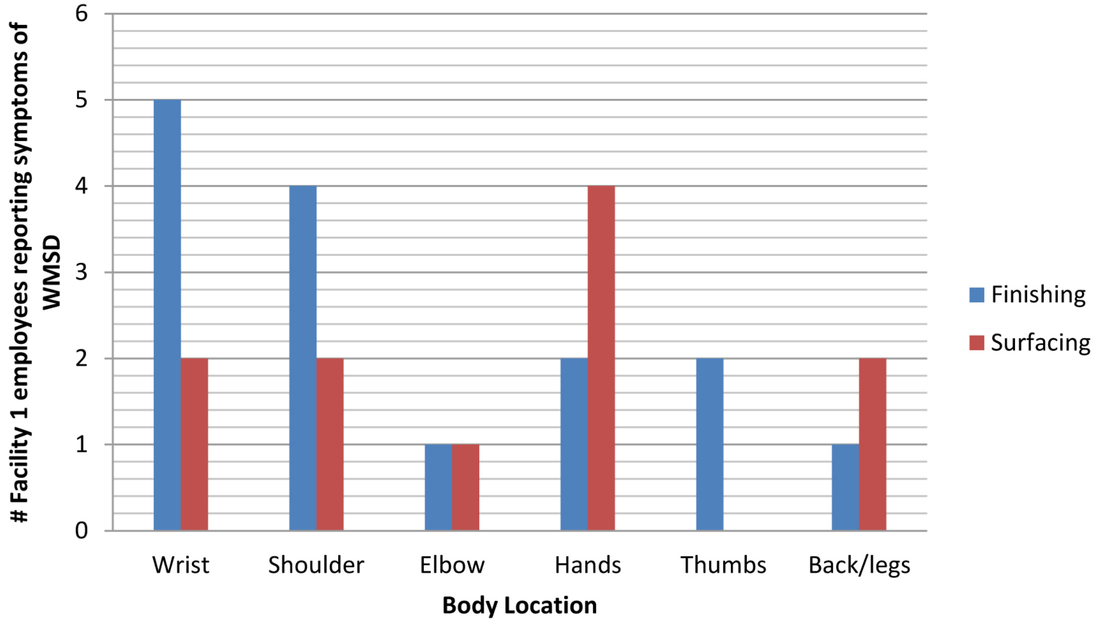

Figure 11. Facility 1 employees reporting symptoms of WMSDs by body location and job.

Facility 2

We interviewed 19 employees in facility 2: 9 finishing and 10 surfacing employees. Among the nine finishing employees, eight reported symptoms of WMSDs, seven with UE and one with back symptoms. Four had seen a doctor. Among the 10 surfacing employees, seven reported symptoms of WMSDs, five with UE and two with back symptoms. Five had seen a doctor. Figure 12 shows the number of facility 2 employees reporting symptoms of WMSDs by body location and job.

Among interviewed employees in facility 2, half of surfacing and more than three fourths of finishing employees reported symptoms of UE WMSDs. Finishing employees reported wrist and shoulder symptoms most commonly, while surfacing employees reported more wrist and back symptoms.

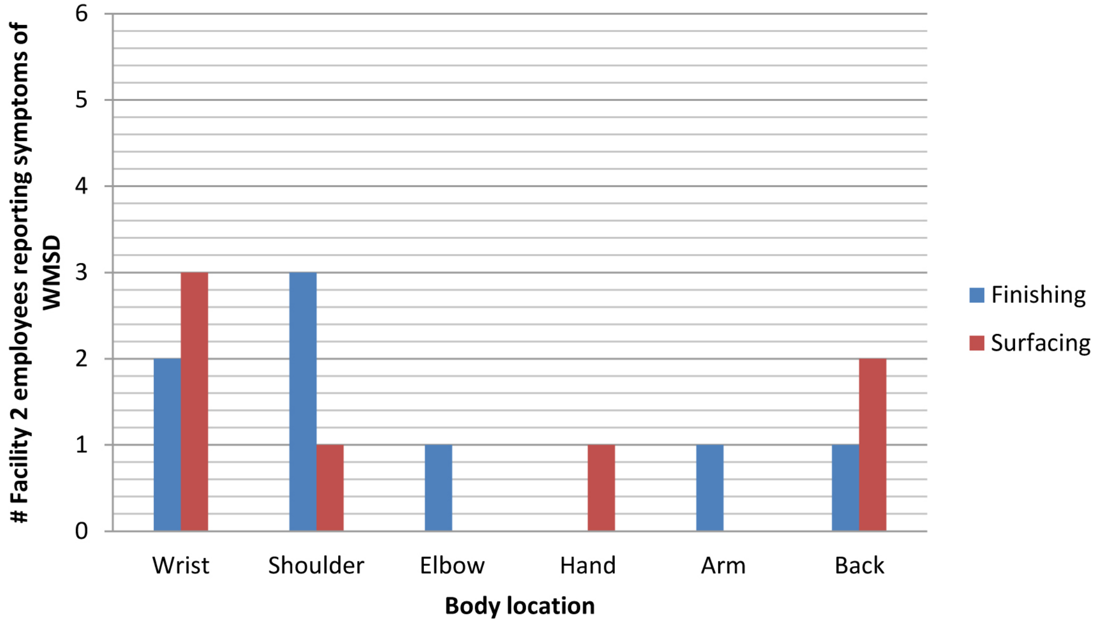

Figure 12. Facility 2 employees reporting symptoms of WMSDs by body location and job.

Facility 3

We interviewed 12 employees in facility 3: 4 surfacing and 5 finishing employees, and 1 former surfacing and 2 former finishing employees who had been transferred to different jobs for medical reasons. Among the seven current or prior finishing employees, six reported current or recent symptoms of WMSDs; all were UE symptoms. Some employees reported symptoms in more than one body location. Three of the six had seen a doctor. Among the five current or past surfacing employees, two reported current shoulder symptoms and one had seen a doctor. Figure 13 shows the number of facility 3 employees reporting symptoms of WMSDs by body location and job.

Among interviewed employees in facility 3, more than three fourths of finishing employees reported symptoms of UE WMSDs. Finishing employees reported shoulder, wrist, and forearm symptoms most commonly; surfacing employees reported only shoulder symptoms.

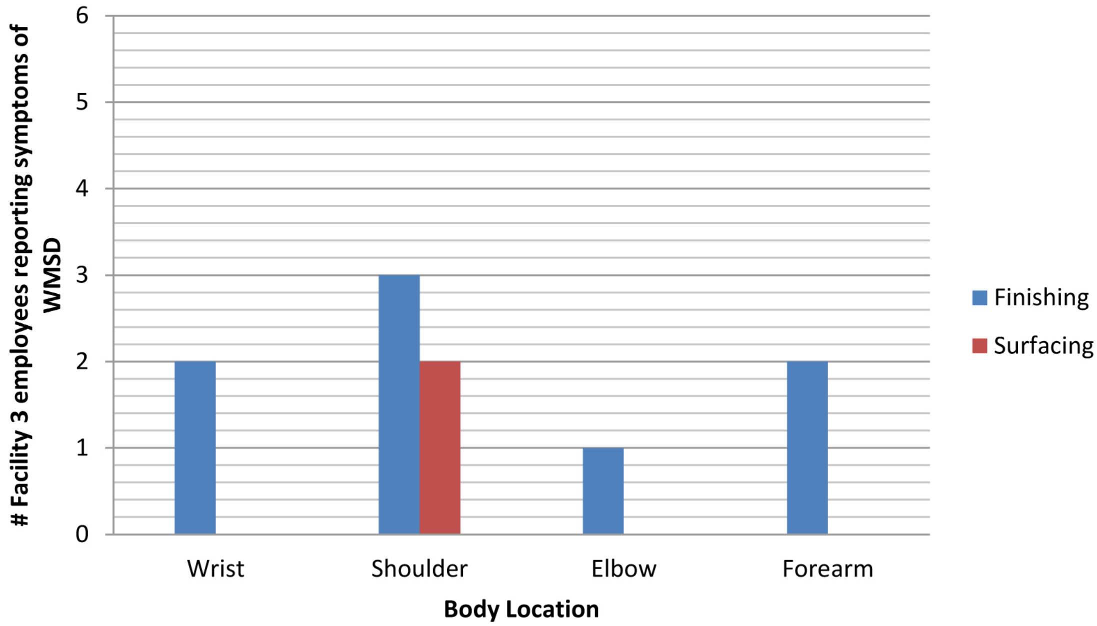

Figure 13. Facility 3 employees reporting symptoms of WMSDs by body location and job.

Employees' thoughts on causes of MSD symptoms

Overall, finishing and surfacing employees from all three facilities thought that bending for; reaching for; grabbing; and lifting trays, tools, and alloys caused symptoms. Finishing employees thought popping lenses; pushing lenses into frames; squeezing, pinching, and gripping tools; screwing and unscrewing; beveling and edging; and washing and wiping lenses were responsible for symptoms. Finishing employees from facilities 2 and 3 reported that overtime and lack of job rotation contributed to symptoms; those from facilities 1 and 2 thought that the job rotation and emphasis on stretching improved their symptoms. Surfacing employees thought that wiping and polishing lenses, gripping handles in fining and deblocking, and being on their feet a lot caused their symptoms. Surfacing employees from facility 3 believed that rotating job tasks helped lessen symptoms.

Review of Medical Records

We reviewed 19 employee medical records: 9 for facility 1 employees, 8 for facility 2 employees, and 2 for facility 3 employees. Table B3 (Appendix B) compares the WMSD diagnoses; number and type of referrals; number that underwent surgery, physical therapy, and joint injections; and number put on permanent work restrictions among surfacing and finishing employees at each facility. Of the 22 WMSDs documented in the 19 employee records, 13 (59%) involved the wrist or wrist and hand, 4 (18%) involved the shoulder, 2 (9%) involved the elbow, 2 (9%) involved the neck or back, and 1 (4.5%) involved the hand. Three of the 19 employees underwent surgery and three were put on permanent work restrictions (one of whom had undergone surgery).

OSHA Form 300 Logs of Work-Related Injuries and Illnesses

We reviewed OSHA Logs for years 2007–2010 and categorized the entries into general types of injuries and illnesses (Table B4 in Appendix B). We categorized entries that included sprains, strains, tears, pain, soreness, and carpal tunnel syndrome into a "sprains, strains, and pains" category. We looked at only these entries that were not associated with a slip, trip, or fall (i.e., those that occurred after bending, climbing, crawling, reaching, twisting, overexertion, or repetition). Sprains, strains, and pains entries accounted for between 40% and 91% of each facility's yearly entries. When we looked at only those sprains, strains, and pains not related to slips, trips, or falls, 80% were UE disorders as shown in Table 2.

Table 2: OSHA Log of sprain, strain, and pain entries not due to slips, trips, and falls, by body location for years 2007–2010

Year	Upper extremity (%)	Back (%)	Lower extremity (%)	Total sprains, strains, pains entries
2007	29 (74)	9 (23)	1 (3)	39
2008	33 (80)	6 (15)	2 (5)	41
2009	18 (78)	5 (22)	0 (0)	23
2010	16 (94)	0 (0)	1 (6)	17
Total	96 (80)	20 (17)	4 (3)	120

Figure 14 shows the number of UE disorder entries by body location and year. Wrist, shoulder, and hand disorders were most commonly logged (see Table B5 in Appendix B for entries by body location and facility).

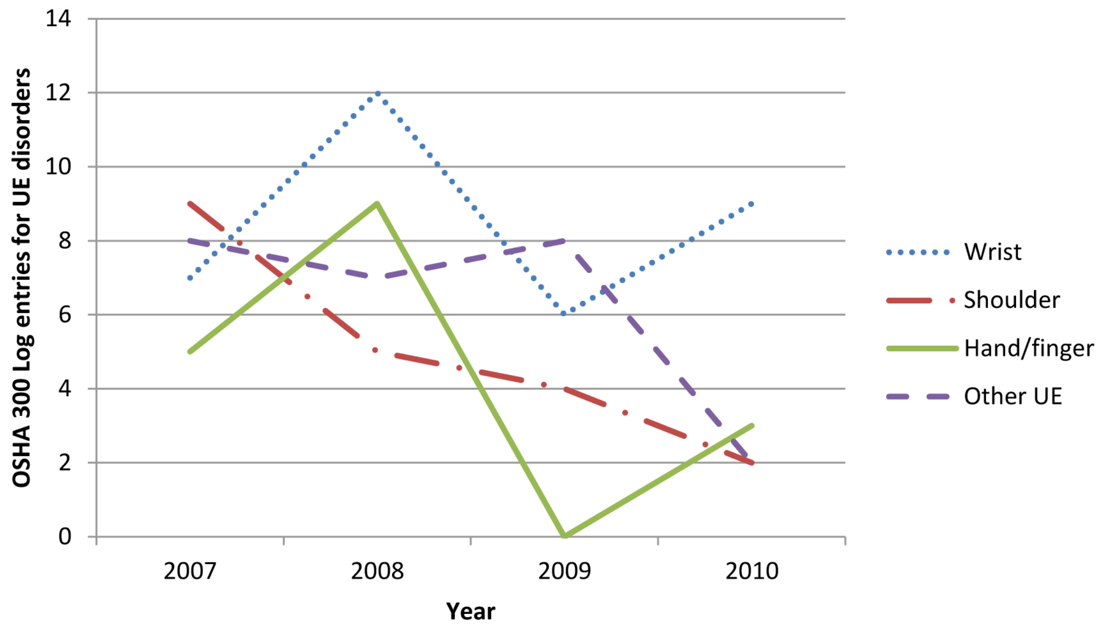

Figure 14. OSHA 300 log entries for UE disorders for years 2007–2010.

Comparing non-fatal injury and illness rates between the company and U.S. industry

We used data from the company's OSHA Logs to calculate and compare incidence rates of nonfatal injury and illness among the three facilities and the U.S. ophthalmic goods manufacturing industry as a whole [http://data.bls.gov/iirc/]. The incidence rates are for nonfatal injuries and illnesses per 100 full-time employees for each year. Figure 15 illustrates the incidence rates for total recordable cases. Figure 16 illustrates incidence rates for total cases involving days away from work, including days of restricted work activity and/or job transfer (Table B6 in Appendix B lists additional incidence rates). These rates can be useful for determining problem areas and progress in preventing work-related injuries and illnesses and benchmarking with similar industries. These rates are calculated using the following formula:

Number of injuries and illnesses × 200,000 / employee hours worked = incidence rate

The 200,000 hours in the formula represents the equivalent of 100 employees working 40 hours a week, 50 weeks a year. From 2007 through 2010, employees at facility 1 and facility 2 averaged slightly below 200,000 work hours per week and employees at facility 3 averaged slightly above. Incidence rates in all categories for facility 3 would be slightly increased and incidence rates in all categories for facility 2 and facility 1 would be slightly decreased if the formula was modified. However, we used the standard number of 200,000 hours to allow comparison to other plants with the same NAICS code throughout the United States.

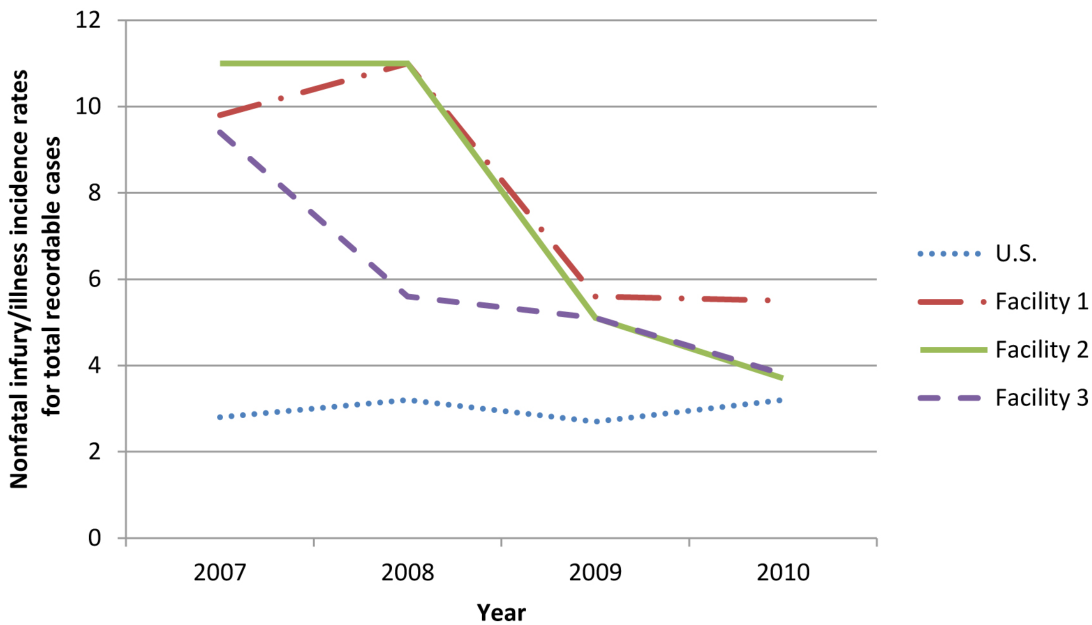

Figure 15. Comparison of nonfatal injury and illness incidence rates (for total recordable cases) for years 2007–2010; facilities 1, 2, and 3 and U.S. private industry plants with U.S. NAICS Code 339115 (Ophthalmic goods manufacturing).

All three facility incidence rates for total recordable cases, cases involving job transfer or restricted work activity only, and total cases involving days away from work (including days of restricted work activity and/or job transfer) were above the U.S. NAICS rates for years 2007, 2008, and 2009. In 2010, these rates decreased to near the U.S. NAICS rates except for facility 1, which had a rate increase in days away from work. These trends in injuries and illnesses during this time period may be due to changes in reporting and documenting or could indicate real differences in injuries and illnesses.

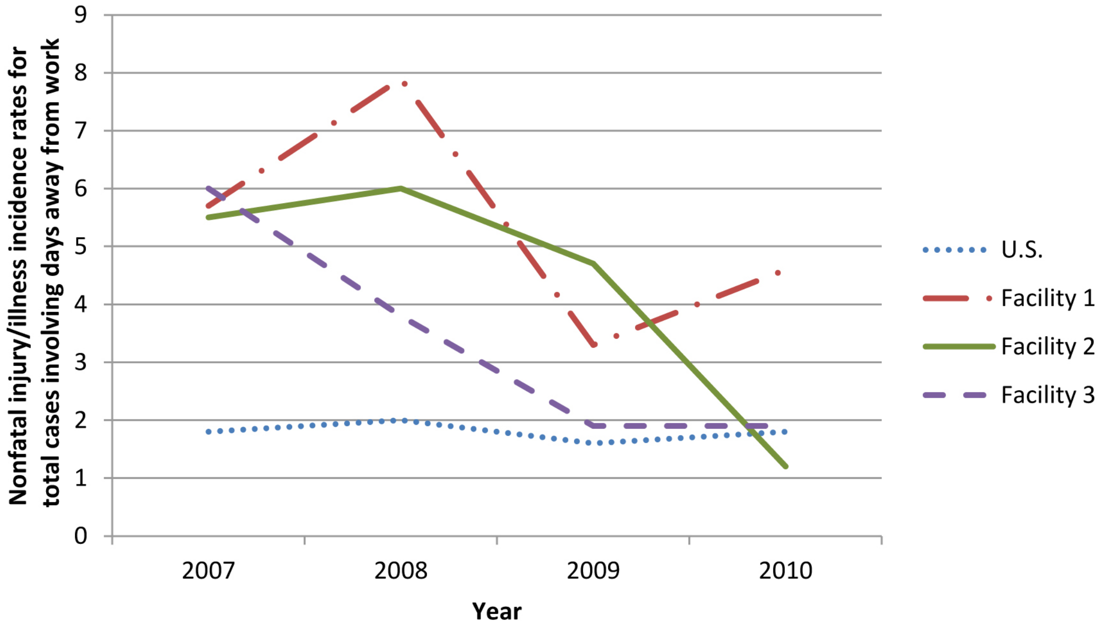

Figure 16. Comparison of nonfatal injury and illness incidence rates (for total cases involving days away from work, including days of restricted work activity and/or job transfer) for years 2007–2010; Facilities 1, 2, and 3 and U.S. private industry plants with U.S. NAICS Code 339115 (Ophthalmic goods manufacturing).

Discussion

Employees were exposed to a combination of risk factors for UE WMSDs, including awkward postures (elevated shoulders and extended reaches), forceful exertions (lifting stacks of trays), and repetitive motions (twisting, reaching, wiping, assembly). Each of the three facilities that we visited had different equipment and different work organization. At the time of our visit, each facility had its own human resource assistant and safety and ergonomic committee. We found preferred practices at each of the facilities, and they are noted in this report. If these facilities met collectively to share best practices and ideas, then some hazards could be reduced or eliminated. Ergonomics programs have been shown to be cost effective, and ergonomic improvements may result in increased productivity and higher product quality. Promoting employee involvement in these efforts can enhance job satisfaction and increases problem-solving capabilities [NIOSH 1997a].

Discussion (continued)

The results of the medical interviews and reviews of employee medical records and OSHA Logs confirmed that symptoms of WMSDs had occurred among surfacing and finishing employees and that the most commonly reported symptoms were for the wrist, shoulder, hand, and back. Rapid, repetitive hand motions, awkward postures, and forceful exertions have been associated with MSDs of the wrist and shoulder. Working at or above shoulder level also has strong associations with shoulder WMSDs. The combinations of work factors leading to neck and shoulder MSDs have been documented in previous studies [Holmstrom et al. 1992; NIOSH 1997b; Miranda et al. 2001]. The types of risk factors reported in these studies for UE and back MSDs were observed at these facilities and are consistent with the reported symptoms. Personal factors such as age, sex, smoking, physical activity, and strength can also influence the occurrence of MSDs [NIOSH 1997b].

One facility had incorporated a stretching program into the work day. Stretching programs alone should not be used as a quick fix, but they can be a component of a comprehensive injury prevention program. An ergonomically optimized work environment, in which hazards are eliminated, is the best solution.

Conclusions

Employees were exposed to a combination of risk factors for UE WMSDs, including awkward postures, forceful exertions, and repetitive motions. The overall rates of OSHA-reportable injuries and illnesses for all three facilities were above those of other plants in the ophthalmic goods manufacturing industry for years 2007–2009, but did trend downward in 2010. We confirmed that WMSDs had occurred among finishing and surfacing employees from all three facilities, with wrist disorders most commonly reported, followed by shoulder, back, and hand disorders.

On the basis of our findings, we recommend the actions listed below to create a more healthful workplace. We encourage the company to use an employee-management health and safety committee or working group, such as the ergonomics committee, to discuss the recommendations in this report and develop a comprehensive action plan that encompasses all three facilities. Those involved in the work can best set priorities and assess the feasibility of our recommendations for your specific situation. Our recommendations are based on the hierarchy of controls approach. This approach groups actions by their likely effectiveness in reducing or removing 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/or personal protective equipment may be needed. We encourage corporate management to work with the management of the facilities and provide resources for these ergonomic improvements.

Engineering Controls

Engineering controls reduce exposures to employees by removing the hazard from the process or placing a barrier between the hazard and the employee. Engineering controls are very effective at protecting employees without placing primary responsibility of implementation on the employee. Many of the recommendations listed below were obtained from *The Handbook of Ergonomic Design Guidelines* [Humantech 2009].

1. Design all work surfaces to be within a height range of 27"–62". Moving the working height toward the middle of the range should reduce the risk for back and shoulder WMSDs.

2. Provide tables with 36" of height adjustability, especially in the blocking and assembly areas. This could also include sit/stand workstations to provide employees the ability to change their posture.

3. Visual display monitors, particularly in blocking, should be 58"–71" (adjustable height) or at 66" (fixed height) for standing workstations and 35"–46" (adjustable height) or 46" (fixed height) for seated workstations. Place screens at a viewing distance of 18"–30" (adjustable distance) or 23" (fixed distance). Monitors should tilt slightly downward to avoid glare. The display should

be in front of the employee, not to the side, and the top of the display should be at or just below the user's eye level.

4. Parts bins (blocks, chucks, etc.) should be placed in front of the employee at a vertical height of 24"–70", not to the side.

5. All work, including parts retrieval or tray locations, should be performed within 22" of the edge of the workstation (horizontal work distance guideline) to eliminate extended reaches. Reposition work, such as the space between the employee and the tray takeaway in blocking, to eliminate extended reaches.

6. Provide cordless scanners or reposition the scanners or work so employees do not have to reach across their body to scan items.

7. Limit the number of trays stacked in all areas to no higher than the employee's shoulder.

8. Place padding on the edge of the facility 2 digital blocking station to eliminate contact stress between the table and the employees' forearms. Investigate other areas where contact stress may be occurring.

9. Provide a handled teapot or pitcher for employees pouring metal into blocking machines.

10. Provide tool bins for the most popular tools, similar to those seen at facility 1, in all facilities. The minimum clearance between levels should be 5" (from top of the bin to the bottom of the next shelf height). The retrieval height should be 38"–49".

11. Conveyors, especially in facility 2 between the grinding and polishing areas, should have a hand working height range of 38"–49".

12. Provide pad dispensers at each facility, similar to the one at facility 1.

13. Modify polishing stations to eliminate placing trays on top of the machine. Consider adding a shelf in the empty space under the equipment at facility 2.

14. Provide cutouts in tables and block collection trays similar to those seen in facility 3 to reduce unnecessary handling of blocks.

15. Provide air-powered lens dryers, as seen in facility 3, to reduce pinch forces and awkward wrist postures during manual lens drying.

16. Evaluate employee exposures to fumes from the heated tinting solution. If necessary, provide local exhaust ventilation in the tinting areas.

17. Perform precision standing work, such as sanding lens edges, on tables that are adjustable to a hand working height of 40"–51" or fixed at 45".

18. Provide precision tools, such as those used for assembly, with the following characteristics: 0.3"–0.9" acceptable handle grip diameter (recommended: 0.3"–0.6"); oval or circular shape; 2.8"–4.6" acceptable handle grip length (recommended: 3.9"); handle long enough so that it does not press into palm at base of thumb; high-friction, non-slip, or slightly etched surface or slightly soft composite or rubber surface.

19. Provide magnetic screwdrivers to eliminate pinch grip forces while holding screws during insertion.

20. Use lensometers at the optimal seated eye height, 35"–46" above the floor surface or 46" if fixed. The eyepiece should have 4" or more of height adjustability. These recommendations were designed for microscope work, but the work is similar.

21. Provide industrial mats for employees who stand for 90% or more of their working hours. Mats should be ≥ 0.5" thick, have an optimal compressibility of 3%–4%, have beveled edges to minimize trip hazards, and be placed at least 8" under a workstation to prevent uneven standing surfaces. Mats should cover the entire area that employees move on while performing their work task and be replaced when they appear worn out or are damaged.

22. Implement a preventative maintenance program for machines. At facility 3, a blocking machine seemed to have a stuck release mechanism and exposed the employee to additional pinch forces, and a polishing machine exposed employees to vibration while they held the lens during polishing.

Administrative Controls

Administrative controls are management-dictated work practices and policies to reduce or prevent exposures to workplace hazards. The effectiveness of administrative changes in work practices for controlling workplace hazards is dependent on management commitment and employee acceptance. Regular monitoring and reinforcement is necessary to ensure that control policies and procedures are not circumvented in the name of convenience or production.

1. Rotate employees through several jobs with different physical demands to reduce the stress on limbs and body regions. Rotate every 2 hours to increase job variability; use the same rotation pattern for all employees.

2. Cross-train employees for different jobs so that one person does not work at a particular job all day, tinting in particular.

3. Limit the number of trays employees carry to reduce contact stress from the tray edges; the use of carts for transportation would eliminate this hazard. Ensure that employees are not carrying so many trays that their vision is blocked.

4. Evaluate the effectiveness of the implemented engineering and administrative controls. Develop a system for employees to provide information and feedback on work equipment and procedure modifications.

5. Schedule short breaks of 3–5 minutes every hour to allow the body to rest and to reduce discomfort.

6. Train employees on adjustability features of their equipment and workspace and ensure that they are using them.

7. Manage overtime work to avoid muscle overuse and to give time for muscles to rest between work shifts.

8. Train employees on MSDs and ergonomics covering specific operations that have been identified by NIOSH or the company as causing or likely to cause MSDs.

Recommendations (continued)

9. Routinely analyze data from the OSHA Logs and company injury/illness logs to identify jobs that need intervention to reduce or eliminate ergonomic hazards.

10. Encourage employees to report symptons of discomfort or pain associated with work tasks. Early reporting allows intervention measures to be implemented before the effects of a job problem worsen.

11. Encourage injured employees to seek care from a medical provider with experience in occupational medicine.

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Appendix A: Ergonomic Evaluation Criteria

Musculoskeletal disorders are those conditions that involve the nerves, tendons, muscles, and supporting structures of the body. They can be characterized by chronic pain and limited mobility. WMSD refers to (1) musculoskeletal disorders to which the work environment and the performance of work contribute significantly, or (2) MSDs that are made worse or longer lasting by work conditions. A substantial body of data provides strong evidence of an association between MSDs and certain work-related factors (physical, work organizational, psychosocial, individual, and sociocultural). The multifactorial nature of MSDs requires a discussion of individual factors and how they are associated with WMSDs. Strong evidence shows that working groups with high levels of static contraction, prolonged static loads, or extreme working postures involving the neck/shoulder muscles are at increased risk for neck/shoulder MSDs [NIOSH 1997]. Further strong evidence shows job tasks that require a combination of risk factors (highly repetitious, forceful hand/wrist exertions) increase risk for hand/wrist tendonitis [NIOSH 1997]. Finally, strong evidence shows that low-back disorders are associated with work-related lifting and forceful movements [NIOSH 1997]. A number of personal factors can also influence the response to risk factors for MSDs: age, sex, smoking, physical activity, strength, and body measurements. Although personal factors may affect an individual's susceptibility to overexertion injuries/disorders, studies conducted in high-risk industries show that the risk associated with personal factors is small compared to that associated with occupational exposures [NIOSH 1997].

In all cases, the preferred method for preventing and controlling WMSDs is to design jobs, workstations, tools, and other equipment to match the physiological, anatomical, and psychological characteristics and capabilities of the employee. Under these conditions, exposures to risk factors considered potentially hazardous are reduced or eliminated.

Workstation design should directly relate to the anatomical characteristics of the employee. Because a variety of employees may use a specific workstation, a range of work heights should be considered. On the basis of functional anthropometry, working heights should be within a range of 27" to no higher than 62" [Humantech 2009]. These heights correspond to a range of employees, between smallest (5th percentile female) and largest (95th percentile male).

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Table B1. Significant ergonomic hazards for surfacing tasks

Taping	Blocking	Grinding	Tool/Pad	Polish	Deblock/Wash
Workstation not adjustable	Parts bins not placed in front of employee	Trays placed on top of machines, above recommended height	Tool rounds and compartments required reaches above and below the recommended range	Loading and unloading machines required awkward wrist postures	Vibration exposure when deblocking
Hand working height at tape machine is above fixed height recommendation of 42”	Horizontal reach distance outside the recommended range	Conveyor height above suggested hand working height range	No pad dispenser at each workstation, caused pinch forces	Removal of pads required pinch forces	Tape removal and drying caused pinch forces
Tray heights above shoulder level for some employees	Display monitor not directly in front of employee		Pads stored overhead, required reaches above the recommended height	Trays placed above the recommended height	No lens drier at many locations
	Contact stress on edges of some workstations			Vibration exposure while holding the lens during the polishing process	No deblock bin at every workstation
	Some workstations not height adjustable				
	Stacks of trays above shoulder level				
	Scanner location caused reaches in front of the body				

Appendix B: Tables (continued)

Table B2. Significant ergonomic hazards for finishing tasks

Tinting	Verify/Lining/Chucking	Sanding	Assembly
Placing the lens in the holder and wiping the lens caused pinch grips	Twisted back postures due to improper chair clearance	Holding the lens required pinch grips	Tools required grip forces
No rotation to other job tasks	Parts bins not located in front of the employee	Workstation not adjustable	Lensometer use and assembly required awkward neck postures
Possible exposure to tint fumes	Scanner location caused reaches in front of the body		Workstations not height adjustable
			No rotation to other job tasks
			Limited space; trays stacked in various locations that required extended reaches

Table B3. Results of medical record review of 19 employees by job title and facility

	Finishing employees			Surfacing employees			Total (%)
	F1*	F2†	F3‡	F1	F2	F3	
Employees with records reviewed	5	4	2	4	4	0	19
Referred to orthopedic	1	3	0	1	3	0	8 (42)
Referred to physical therapy	2	2	1	1	3	0	9 (47)
Underwent joint injection	1	2	0	1	1	0	5 (26)
Underwent surgery	1	1	0	0	1	0	3 (16)
Put on permanent work restrictions	0	2	0	1	0	0	3 (16)
Diagnosis/Location of WMSD							
De Quervain tenosynovitis (wrist/hand)	2	1	—	1	—	—	4
Carpal tunnel syndrome (wrist/hand)	1	1	—	1§	—	—	3
Superior labral tear from anterior to posterior (shoulder)	—	2	—	—	—	—	2
Ulnar nerve neuropathy (elbow)	1	—	1	—	—	—	2
Scaphoid nonunion (wrist)	—	—	—	—	1	—	1
Triangular fibrocartilage complex tear (wrist)	—	—	—	1	—	—	1
Wrist pain/strain	2	—	—	1	1	—	4
Shoulder pain/strain	—	—	—	—	2	—	2
Hand pain/strain	—	—	1	—	—	—	1
Neck/back strain	1	—	—	—	1	—	2

*Facility 1
†Facility 2
‡Facility 3
§Pending more tests

Table B4. OSHA Log of work-related injury and illness entries by facility, 2007–2010

		Sprains, strains, pains not due to slip, trip, fall (%)	Contusion, abrasion, or laceration	Slip, trip, fall injury	Other	Total entries
2007	F1*	12 (63)	2	3	2	19
	F2†	17 (68)	2	5	1	25
	F3‡	10 (91)	1	0	0	11
2008	F1	18 (58)	5	4	4	31
	F2	18 (75)	3	0	3	24
	F3	5 (56)	0	3	1	9
2009	F1	7 (58)	1	4	0	12
	F2	11 (85)	1	0	1	13
	F3	5 (63)	1	1	1	8
2010	F1	8 (67)	3	0	1	12
	F2	6 (67)	2	0	1	9
	F3	3 (50)	1	1	1	6

*Facility 1
†Facility 2
‡Facility 3

Table B5. OSHA Log of sprain, strain, and pain entries not due to slips, trips, and falls, by body location and facility for years 2007–2010

		Shoulder	Wrist	Hand and finger	Other upper extremity	Back	Lower extremity	Total upper extremity* (%)	Total sprains, pains, strains entries
2007	F1†	3	3	0	2	4	0	8 (67)	12
	F2‡	4	2	4	3	3	1	13 (76)	17
	F3§	2	2	1	3	2	0	8 (80)	10
2008	F1	4	3	7	1	2	1	15 (83)	18
	F2	1	7	2	4	3	1	14 (78)	18
	F3	0	2	0	2	1	0	4 (80)	5
2009	F1	2	1	0	3	1	0	6 (86)	7
	F2	2	4	0	1	4	0	7 (64)	11
	F3	0	1	0	4	0	0	5 (100)	5
2010	F1	0	4	1	2	0	1	7 (88)	8
	F2	2	3	1	0	0	0	6 (100)	6
	F3	0	2	1	0	0	0	3 (100)	3
Totals		20	34	17	25	20	4	96 (80)	120

*Upper extremities include shoulder, arm, elbow, forearm, wrist, hand, and finger.
†Facility 1
‡Facility 2
§Facility 3

Table B6. Comparison of nonfatal injury and illness incidence rates for years 2007–2010; facility 1 (F1), facility 2 (F2), and facility 3 (F3) and U.S. private industry plants with U.S. NAICS code 339115 (Ophthalmic goods manufacturing)

Year	2007		2008		2009		2010	
Case Type	U.S.	Company	U.S.	Company	U.S.	Company	U.S.	Company
Total*	2.8	F1: 9.8 F2: 11.0 F3: 9.4	3.2	F1: 11.0 F2: 11.0 F3: 5.6	2.7	F1: 5.6 F2: 5.1 F3: 5.1	3.2	F1: 5.5 F2: 3.7 F3: 3.8
Days away†	0.7	F1: 1.5 F2: 2.8 F3: 0.9	0.8	F1: 3.1 F2: 2.3 F3: 0.0	1.0	F1: 1.4 F2: 1.6 F3: 0.0	0.5	F1: 0.9 F2: 0.0 F3: 0.0
Job transfer‡	1.0	F1: 4.1 F2: 5.5 F3: 5.1	1.2	F1: 4.8 F2: 3.7 F3: 3.8	0.7	F1: 1.9 F2: 3.1 F3: 1.9	1.3	F1: 3.7 F2: 1.2 F3: 1.9
DART§	1.8	F1: 5.7 F2: 5.5 F3: 6.0	2.0	F1: 7.9 F2: 6.0 F3: 3.8	1.6	F1: 3.3 F2: 4.7 F3: 1.9	1.8	F1: 4.6 F2: 1.2 F3: 1.9

*Total recordable nonfatal injury and illness cases
†Cases involving days away from work
‡Cases involving job transfer or restricted work activity only
§Total cases involving Days Away from work, days of Restricted work activity, and/or job Transfer

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