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PART I: PARTICIPATORY ERGONOMICS APPROACH TO WASTE CONTAINER HANDLING UTILIZING A MULTIDISCIPLINARY TEAM

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This multidisciplinary team approach to waste container handling, developed within the Grassroots Ergonomics process, presents participatory ergonomic interpretations of quantitative and qualitative aspects of this process resulting in a peer developed training. The lower back, shoulders, and wrists were identified as frequently injured areas, so these working postures were a primary focus for the creation of the workers' training. Handling procedures were analyzed by the team to identify common cycles involving one 5 gallon (60 pounds), two 5 gallons (60 and 54 pounds), 30 gallon (216 pounds), and 55 gallon (482 pounds) containers: lowering from pallet, transporting to/from transport vehicles, loading/unloading on transport vehicles, and loading onto pallet. Eleven experienced waste container handlers participated in this field analysis. Ergonomic exposure assessment tools measuring these field activities included posture analysis, posture targeting, Lumbar Motion Monitor™ (LMM), and surface electromyography (sEMG) for the erector spinae, infraspinatus, and upper trapezius muscles. Posture analysis indicates that waste container handlers maintained non-neutral lower back postures (flexion, lateral bending, and rotation) for a mean of 51.7% of the time across all activities. The right wrist was in non-neutral postures (radial, ulnar, extension, and flexion) a mean of 30.5% of the time and the left wrist 31.4%. Non-neutral shoulder postures (elevation) were the least common, occurring 17.6% and 14.0% of the time in the right and left shoulders respectively. For training applications, each cycle had its own synchronized posture analysis and posture target diagram. Visual interpretations relating to the peak force modifications of the posture target diagrams proved to be invaluable for the workers' understanding of LMM and sEMG results (refer to Part II). Results were reviewed by the team's field technicians and their interpretations were developed into ergonomic training that address the issues originally raised. This training includes intervention methods, ergonomic tools used, data acquired, and effects of waste container handling techniques on lower back, shoulder, and wrists and methods to help proactively reduce injuries associated with this profession.

INTRODUCTION

Low back injuries due to overexertion in lifting, pushing, and pulling of objects are common and costly. In the United States, Bureau of Labor Statistics research indicates that 21% of lost time injuries in 1994 were related to these types of overexertion and 62% of these injuries affected the back, resulting in median times of 6-7 days away from work (BLS 1994). Recent research recommends proper job analysis for characterizing ergonomic risk factors and involving workers in intervention processes for successful ergonomic programs that reduce lost work time. This study combines this information in a unique participatory ergonomics team approach to waste container handling referred to as Grassroots Ergonomics.

Participants in this waste container handler (WCH) ergonomic intervention are employed at the Lawrence Livermore National Laboratory (LLNL) in Livermore, California, USA. LLNL encompasses two sites. The main campus, Site 200, has approximately one thousand waste generators distributed across one square mile. Site 300 has a approximately 60 generators across eleven square miles. The participants are employees of the Environmental Protection Department's Hazardous Waste Management Division. There are approximately 30 WCH technicians within the Division.

These WCH technicians handle from 15 to 150 waste containers each day. Containers can weigh from 25 to over 700 pounds and in the case of initial waste pick-up activities are primarily handled without forklift trucks. Eleven experienced WCH technicians participated in this field analysis. Workers used technical quantitative and qualitative exposure assessment information obtained during field work practices, combined this information with their job-related expertise, and developed their own training and intervention process.

MATERIAL AND METHODS

Participatory Ergonomics Approach

Team Formation. This intervention began when WCH technicians experienced multiple lower back and wrist injuries occurring during the manipulation of heavy waste containers. A team was formed which included five affected WCH technicians and an Industrial Hygienist with a background in participatory ergonomics. One of the technicians served as the leader of the committee.

The initial step involved educating team members about general ergonomic theories. Included in this education process is the need for using correct postures; emphasizing correct lower back, shoulder, and hand positions; the mechanics of manipulating heavy objects; and avoiding extreme body positions and postures that could result in injury. After this initial education process the WCH technicians began analyzing their work tasks to identify procedures that could cause ergonomic-related injuries. The lower back, shoulders, and wrists were identified as frequently injured areas. Procedures that were most likely to cause these injuries were discussed until recurring themes were discovered by the technicians. It was decided that after extensive analysis of these procedures, the goal of this team would be the creation of a technician-developed waste container handling ergonomic training.

Waste Handling Cycles. Waste container handling procedures were reviewed by the team to identify common cycles that could be further analyzed. Since handling of waste containers encompasses such a large area at LLNL, most work stations vary greatly within and between the technicians. Therefore, the five technicians on the team worked to identify the procedures that they all perform. These procedures were broken down into cycles that were the most common for the variety of containers they manipulate.

Cycles for waste container handling are derived from the general procedure of taking a container from one site, placing it on a vehicle bed, and then transferring the container to its next station. This process can be repeated many times during the existence of a given container at LLNL. Handling procedures were analyzed by the team to identify 24 total cycles involving one 5 gallon (60 pounds), two 5 gallons (60 and 54 pounds), 30 gallon (216 pounds), and 55 gallon (482 pounds) containers: lowering from the pallet (breaking), transporting to/from transport vehicles, loading/unloading on transport vehicles, and loading on pallet.

Exposure Assessment Strategy

Multidisciplinary Team. Video analysis techniques were initially chosen for this intervention based on a previous similar participatory ergonomics approach {Zalk 1997}. These techniques include both posture analysis and posture targeting methods focusing on identifying non-neutral postures during actual work practices in the field. Although these techniques are utilized within this study, it was recognized by the team that more field information could be helpful. This required an additional dimension to the analysis strategy that would address muscle load and disc compression information. This intervention was then redesigned to include surface electromyography (sEMG) and three-dimensional motion analysis. To perform these techniques in the field, physicians and an ergonomist were added to the team with professional expertise provided by an sEMG specialist. The ergonomic exposure assessment tools utilized for measuring these field activities included Lumbar Motion Monitor™ (LMM) and sEMG for the erector spinae, infraspinatus, and upper trapezius muscles (refer to Part II).

Test Participants. Eleven experienced waste container handlers, nine male and two female, participated in this field analysis. From this group, two were classified as taller than average, two were classified as shorter than average, and the remaining seven were of average height. This mix of heights is important for correct representation of LLNL WCH technicians and is based on anthropometric data {Pheasant 1986}. Most waste handling containers and equipment are standardized in size. Therefore, individual adaptations to containers, equipment, and procedures were an important aspect to look for as part of the 24 cycles identified above.

Video Analysis

Since video offers both a continuous record of the waste handling cycles, each participant was video taped performing the cycles they perform in the field with the goal of using these results in the creation of the WCH technician's training. Two cameras were used to capture the work activities from different angles. Views from both orthogonal and right angles were taken with hand-held video, however, the cramped outdoor field location limited the usefulness of this approach. All the cycles analyzed in this study were performed in the field under actual field conditions in an operating waste accumulation area. Video-based posture targeting and postural analysis were utilized. The two analyses were performed by stopping the video tape every two seconds, during every distinct cycle, and recording all the necessary information at that interval {Corlett 1979, Ghosh 1993}. This allowed both a random approach to identifying non-neutral postures and also an opportunity to maximize the number of data entry points. The WCH technicians on the team all participated in analyzing the videos. For training applications, each of the 24 cycles had its own synchronized posture analysis and target diagram.

Posture Targeting. A posture targeting method was used to create a three-dimensional picture of every container handling cycle. Posture is an important aspect of interpreting work load and the related possibility of acquiring musculoskeletal injuries {Grandjean 1977}. This is a qualitative visual training tool essential for the technicians' understanding of the technical ergonomic information from this intervention. Corlett's posture targeting diagram is designed to capture three-dimensional postures at specific points in time such as those encountered during a freeze frame analysis. Video taping affords the ability to pause the video and examine the postures at set intervals {Corlett 1979}. The Corlett diagram was modified to identify the left and right shoulder positions and lower back positioning that were recorded for each procedure. Shoulder positioning indicates potential neck stress and pain due to their interrelationship with the trapezius muscle load {Hagberg 1981, Jensen 1993}.

At each pause in the video tape analysis, the appropriate cycle was identified and the three-dimensional posture targeting position was recorded as a dot on the Corlett diagram. Additionally, a special adaptation was made to the diagram to give a visual indication of peak force. If the activity during the video tape's paused interval indicated peak force was applied during that particular frame, an "X" was recorded on the diagram instead of a dot (refer to Figure 1). WCH technician's interpretation of when peak force was applied was utilized.

Postural Analysis. At each video tape analysis interval a separate postural analysis was also performed. In addition to the 24 cycles, a postural analysis chart was also recorded for each individual participant. Therefore, postural information for all 24 cycles, and from all eleven technician participants (see Table 1), was obtained for the five joint categories of the left and right wrist, left and right shoulder, and lower back. The categories of recordable wrist, shoulder, and lower back joint postures for this postural analysis were based on existing experimental data {Baluyutt 1995, Genaidy 1995}. Analyses utilizing postural classification have been useful in interpreting postural stresses {Genaidy 1994, Punnett 1991, Stetson 1991}.

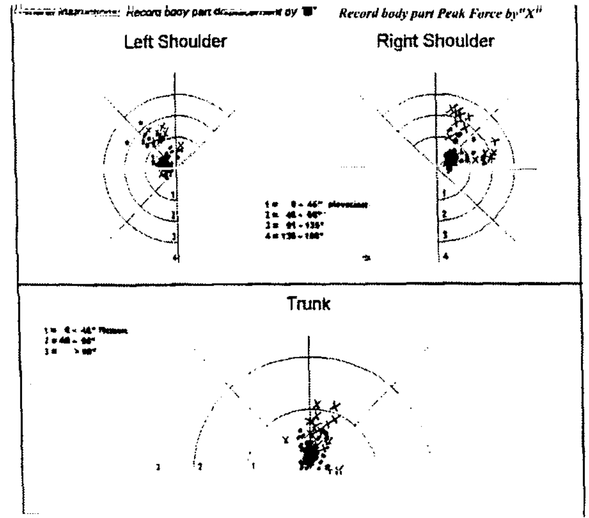
The data points were determined for each category based on that joint's most extreme position. Total data points were accumulated for every joint category, per each cycle and each technician. The percentage of time spent in a joint posture classification was determined by dividing the number of data points per classification by the total number of data points collected per joint category. If a target point was not visible or determinable from the video tape, then a second video camera angle was used. If it was not determinable from either angle, then a data point was not entered for that interval. Working with the technicians during the video analysis allowed for professional interpretation and discussion of each data entry point for both analyses.

Increased Odds Postures. The postural analysis performed as part of this ergonomic study was designed to identify awkward posture trends for LLNL's WCH technicians. In order for the team to study these trends, and optimize the training's benefits, increased odds categories were derived from the original postural classifications {Zalk 1997}. These categories are based on studies indicating non-neutral postures of the wrist {Moore 1995, Genaidy 1995}, shoulders {Sommerich 1993, Genaidy 1995}, and lower back {Boussenna 1982, Punnett 1991, Burdorf 1991, Genaidy 1995} are associated with an increased odds ratio for cumulative trauma injuries and with increases in both objective and subjective stress and pain on the associated joints.

Table 1. Cumulative Posture Analysis Results

JOINT POSTURE	TOTAL MEAN %	INCREASED ODDS
RIGHT WRIST		
Neutral Flexion/Extension (0 - 15°)	61%	
Moderate Flexion/Extension (16 - 45°)	10%	
Severe Flexion/Extension (> 45°)	8%	
Radial Deviation (> 10°)	4%	30.5%
Ulnar Deviation (> 10°)	18%	
LEFT WRIST		
Neutral Flexion/Extension (0 - 15°)	59%	
Moderate Flexion/Extension (16 - 45°)	9%	
Severe Flexion/Extension (> 45°)	7%	
Radial Deviation (> 10°)	5%	31.4%
Ulnar Deviation (> 10°)	19%	
RIGHT SHOULDER		
Neutral Elevation (0 - 15°)	49%	
Light Elevation (16 - 45°)	33%	
Moderate Elevation (46 - 90°)	14%	17.6%
Severe Elevation (> 90°)	3%	
LEFT SHOULDER		
Neutral Elevation (0 - 15°)	49%	
Light Elevation (16 - 45°)	36%	
Moderate Elevation (46 - 90°)	14%	14.0%
Severe Elevation (> 90°)	1%	
LOWER BACK		
Neutral Flexion (0 - 15°)	50%	
Moderate Flexion (16 - 45°)	39%	
Severe Flexion (> 45°)	3%	51.7%
Lateral Bending (> 15°)	3%	
Rotation (> 15°)	5%	

Figure 1. Posture Targeting; 55 gal. On Truck



The percentage of time spent in these identified postures is intended to be used as teaching tool for identifying non-neutral postures with the WCH technicians. Reviewing these results for each cycle of activity assists the technicians in the creation of their training by identifying cycles, and the associated joints, that may be at increased odds for cumulative trauma. This information is taken in concert with the other ergonomic exposure assessment information that is part of this intervention.

RESULTS

Postural analysis cumulative results for the eleven WCH technicians, across all of the 24 cycles, are shown in Table 1. Waste container handlers maintained non-neutral lower back postures (flexion, lateral bending, and rotation) for a mean of 51.7% of the time across all activities. The right wrist was in non-neutral postures (radial, ulnar, extension, and flexion) a mean of 30.5% of the time and the left wrist 31.4%. Non-neutral shoulder postures (defined by upper arm separation from the body, independent of forearm elevation) were the least common, occurring 17.6% and 14.0% of the time in the right and left shoulders, respectively. For training applications, each cycle had its own synchronized posture analysis and posture target diagram. Qualitative results from Corlett posture target diagrams (an example is given in Figure 1), with the modification to identify peak force for shoulders and lower back, were recorded for 24 cycles. The modified diagrams proved to be essential for the workers to create their training. The qualitative, visual information from posture targeting gave the WCH technicians an understanding of peak force and posture that was invaluable for the workers' understanding of LMM and sEMG results (refer to Part II).

DISCUSSION

The postural analyses results were combined with the LMM and sEMG results and presented to the team technicians. The technicians took this information and provided their own interpretations of how the results affected their existing procedures and individual techniques. The training developed by the team's technicians is intended for an audience of other WCH technicians. Suggestions include slowing down when in non-neutral postures, acknowledging training needs, as well as the process of the entire intervention. The fundamental difference is that this training becomes the worker's interpretations of the process and not necessarily that of the health and safety professionals. The training lasts for approximately two hours and includes three sections. The first section is given by a team technician to inform the audience that the genesis of this participatory ergonomic process belongs to technicians such as themselves. This section acknowledges the trust and patience of their management that allowed such a worker-controlled ergonomic process to occur.

The second section is given by the Industrial Hygienist and offers both a basic introduction to ergonomics and some key technician interpretations of how the exposure assessment data in the field pertains to their profession. It initially focuses on neutral postures and general anatomy while indicating what the exposure assessment tools measured. The summary of the technician's interpretations of the sEMG and LMM information focuses on paying attention to the weight they are manipulating and the forces of gravity.that heavy loads equate to increased disc compression, and paying more attention to procedures that require moving containers up a hill or onto a pallet. This section concludes with a discussion of handling 30 and 55 gallon containers. Since most technicians (aged 20 to over 50 years old) tend to roll these containers on their edge, they need to focus on themselves and their limits. This includes deciding when to use mechanical assists and knowing the container's contents and distribution of material.

The third and final section is a hands-on, procedure-specific training for waste container handling. This training is presented by a technician and discusses a variety of appropriate techniques, including placing the drum on edge using both the push and pull techniques. It also includes general guidelines for rolling 55 gallon containers, which makes distances greater than 25 feet require mechanical assists. Rolling 30 gallon containers is not recommended for any distance due to the non-neutral back postures necessary to manipulate these shorter containers. Maximum weight limits were also established for manual manipulation of 55 gallon (500 pounds), 30 gallon (200 pounds), and 5 gallon (50 pounds) containers. Selection of the appropriate tools and equipment is also discussed. During this intervention process the technicians realized that none of their existing mechanical assists (drum dollies) allowed them to consistently maintain neutral postures of the lower back, shoulders, and wrists. So the technicians and the team Industrial Hygienist designed an ergonomically correct dolly (patent pending), with a prototype on display and demonstrated at the training.

CONCLUSION

An increased risk of musculoskeletal related disorders is associated with awkward body postures {Armstrong 1993, Fine 1987, Genaidy 1995}. Some of these awkward postures were identified utilizing video-based posture analyses of LLNL WCH technicians. The WCH technicians on the team were included throughout this participatory ergonomic intervention and all participated in analyzing the videos. Waste container handling procedures were analyzed by the team and identified 24 total cycles for investigation under actual field conditions. For training applications, each of the 24 cycles had its own synchronized posture analysis and posture target diagram.

This participatory ergonomics process assisted these technicians in interpreting the posture analyses, modifying their existing procedures, and creating an ergonomic training. The multidisciplinary team presented exposure assessment results which were reviewed by the team's field technicians. Their interpretations were developed into an ergonomic training that addresses the issues originally raised. This training includes intervention methods, ergonomic tools used, data acquired, and effects of waste container handling techniques on lower back, shoulder, neck and wrists and methods to proactively reduce the risk of injuries in this profession.

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