ERGONOMIC INTERVENTIONS FOR THE HOME BUILDING INDUSTRY

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Workers on framing carpentry crews in the home building industry are exposed to many of the recognized occupational risk factors for low back disorders. The focus of the current project was the design, fabrication and evaluation of a set of engineering controls designed to reduce the exposure to these risk factors. A biomechanical evaluation of the work activities of the workers on a framing crew was performed using the CABS methodology which employs three well-established low back stress assessment tools. From this evaluation a prioritized list of high-risk activities was developed. An iterative, participative engineering development process was employed to develop efficacious, cost-effective engineering controls. Described in this paper are three of these solutions: an extension handle for a nailgun, a pneumatic wall lift and a vertical material lift. A description of the impact that these tools had on low back stress and productivity are presented.

INTRODUCTION

Workers on framing carpentry crews have exposure to many of the recognized occupational risk factors for low back pain including extensive manual materials handling, pushing/pulling, repetitive bending/twisting, frequent lifting over 25 pounds, requirements for sudden unexpected maximal effort, and sustained awkward/extreme trunk postures (Bernold, 1993; Schneider and Susi, 1994)). Despite this fact there is little published literature specifically related to occupational low back problems in this trade or about interventions designed to reduce biomechanical stress. The goal of this study was to develop and evaluate ergonomic interventions for the reduction of low back injuries in framing carpenters.

METHODS

There were three distinct phases to this study: 1) ergonomic analysis of the work activities of framing carpenters, 2) development of ergonomic interventions for the reduction of low back stress and 3) ergonomic and productivity evaluations of these solutions.

Ergonomic Analysis

In Phase I of this project, the objective was to evaluate all work activities performed by these workers and then develop a prioritized list of jobs for intervention. To accomplish this, videotape footage of the work activities of these workers was gathered at 12 different home sites. All phases of the framing activity were videotaped. This included floor joists/floor trusses, sub-flooring, building and raising interior and exterior walls, rafters/trusses, roof sheeting. All workers from each crew (crew leader, tradesman, material handler) were videotaped. In total, over 350 man-hours of videotape were collected.

These data were used to develop distributions describing the time spent at different levels of biomechanical stress. Three well-established low back stress analysis tools: NIOSH Revised Lifting Equation (Waters et al, 1993), The University of Michigan 3D Static Strength Prediction Program (3DSSPP^{TM}) and Lumbar Motion Monitor Model (Marras et al, 1993) were used to describe the low back stress/risk. These three assessment tools were used because it was recognized that each takes a slightly different perspective on quantifying the biomechanical stress. For a more complete description of this assessment technique see Mirka et al (1998). The output from these assessments were distributions quantifying the amount of time the workers spent at different levels of biomechanical stress. Figure 1 shows the resulting distribution of spine compression averaged across workers and sites. Similar distributions were developed for the NIOSH Lifting Index (Revised NIOSH Lifting Equation) and Probability of High Risk Group Membership (OSU Lumbar Motion Monitor Model).

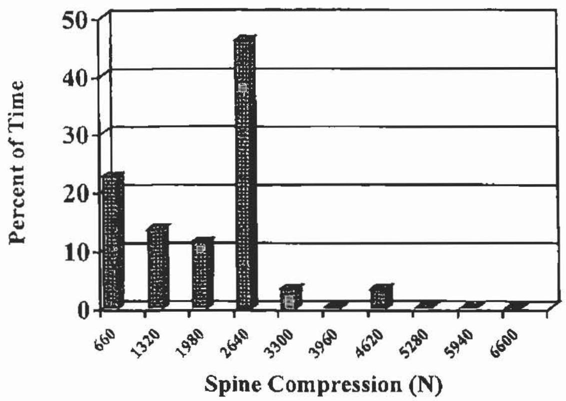

Figure 1. Distribution of spine compression for workers from framing crews

Development of Ergonomic Interventions

From this biomechanical analysis the high risk tasks were identified. Of these, three are described in this paper: erecting interior and exterior walls, moving lumber from ground level to the second and third stories and continuous use of nail gun at ground level. A more detailed description of each of these activities along with the proposed solution and evaluation of the proposed solution are presented below.

Pneumatic wall lift. One the tasks most easily identified as high risk, was the lifting of assembled walls. The current method used by framing crews is to build the wall on the floor and then gather the rest of the crew together and manually lift the wall to the vertical position. The risk factors identified in this process were extreme flexion of the torso and large moments about the lumbar spine placing it in a high risk category for acute trauma (i.e. right hand tail of the distribution shown in Figure 1).

The solution to this problem was to develop a pneumatic lift assist device that could provide the majority of the lift force required from ground level up to shoulder height. Once it gets to shoulder height the worker can exert force in a more neutral spine posture and only be required to generate a fraction of the original force required to lift/push the wall to its vertical position. Figure 2 shows the device. The pneumatic wall lift device employs a 2m cable cylinder (GreenCo, Tampa FL) that provides the lifting force The cylinder is secured (using two nails) to the floor through a hinged baseplate. An attachment element is secured to the cable of the pneumatic cylinder, which locks onto the header plate of the wall. One of the workers then pushes

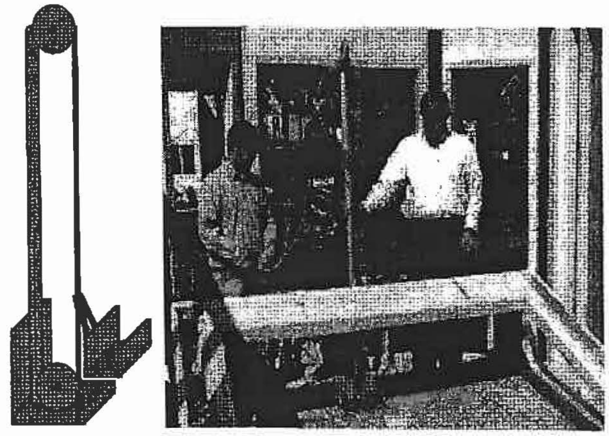

Figure 2. Pneumatic wall lift device for lifting interior and exterior walls

the lever of the hand-held control and the wall is then lifted to slightly greater than shoulder height. From this position the workers lift the wall and the attachment element releases and they push the wall to the vertical position. When lifting long walls (>5m) a person on each end is suggested to keep the deformation of the wall to a minimum. This device has lifted walls up to 10m.

Vertical Material lift. Another task that was identified as high risk, was the movement of raw material from the stacks to the upper stories of the home. The observed method used by framing crews is to have one person manually transport a quantity of materials to the side of the home and then hand them up, one by one, to a co-worker on the upper level. If the materials are for work on a third floor, the process is then repeated. Materials that were delivered this way include 2x10s, 2x4s, 1x6s and sheets of plywood. The repetitive lift and carry from the stack to the structure and then the repetitive overhead lifts for the low man and the repetitive lifts from ground level for the high man were found through this analysis to be problematic.

The solution to this problem was to develop a motorized vertical lift device that could move large quantities of material from the ground to the second or third story. We identified an existing product that was designed to lift roofing materials. The Safety Hoist™ (Safety Hoist, Lafayette Hill, PA) is essentially a ladder with pulleys on the top and bottom. A motor attached at the base of the ladder then pulls a cable that runs through the pulleys and attaches to the carriage. Our approach was simply to modify the carriage of the device so that it could transport larger items like plywood and 4m lengths of 1x6s. (See Figure 3)

Figure 3. Vertical material lift to move materials to the second and third stories of a structure

In one mode of operation with the intervention the worker on the ground simply carried the material to the carriage and then engaged the motor which lifted the load and deposited it on the appropriate level. In another mode we integrated a skate wheel conveyor from the stack to the lift, thus eliminating the carry portion of the task.

Nailgun extension. Investigation of tasks that made up the more central regions of the distribution shown in Figure 1 revealed that these were primarily from working at or near ground level with small amounts of weight held in hands. Review of the videotapes revealed that there were long stretches of time where the framers would be in relatively static, fully flexed spine postures as they nailed the subflooring to the floor joists/trusses. Interviews with these workers revealed a lasting stiffness of the low back that came with this task. Combining these results with some of the observations of Adams and Dolan (1995) and McGill (1997) regarding the effects of static flexed torso postures, this was also identified as a priority area for intervention. The specific risk factors included extreme forward flexion postures and static loading.

The solution to this problem was to develop an extension (Figure 4) that is attached to the nailgun. The handle of this extension would be located at about waist height, eliminating the need for the continuous, extreme forward flexion of the torso. The trigger mechanism is likewise moved to the new handle on the extension and is connected through cable to the nailgun trigger.

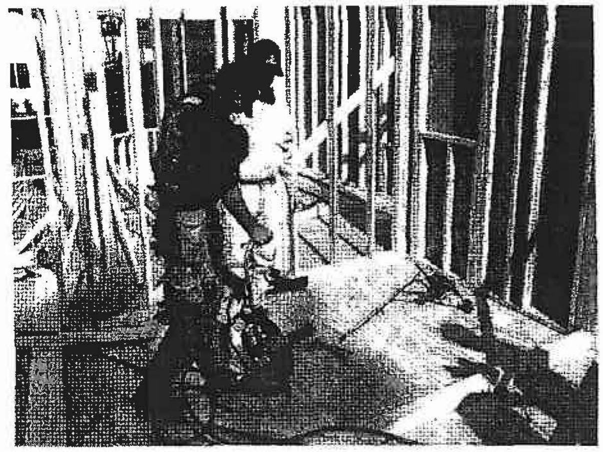

Figure 4. Nailgun extension to reduce static loading and extreme forward bending torso posture

Ergonomic and Productivity Evaluations

Each of these tools was evaluated on three home building sites and two framing crews. Our approach to introducing the tools was to describe how the tool works, when it could be used and the different safety related issues with each device. Similar to the data collection procedures in the Ergonomic Analysis phase of this project, the workers were videotaped as they used their normal work methods to perform the work activities that these interventions were developed to aid. Once this baseline data was collected (usually about half of the activity completed) the interventions were introduced and the workers used them for the remainder of the task. This intra-site comparison approach was taken to try and control for site related variables such as distance of stacks of raw materials from the structure, different types of flooring material used, different wall heights etc.

Pre- and post-intervention biomechanical stresses were evaluated using the same methodology used in the Ergonomic Analysis phase of the project. Productivity was quantified by describing the time spent performing the specific activity and these measures were typically described in terms of man-seconds per piece or pieces per second. In an effort to reduce extraneous variability only those activities directly related to the use of the intervention were quantified.

Intervention / Task	Pre Intervention (Productivity) (Avg/Peak Spine Comp)	Post Intervention (Productivity) (Avg/Peak Spine Comp)
Vertical Material Lift		
Lifting 4' x 8' sheets of OSB from ground to 2nd floor*	59.4 man-seconds/sheet 743 N / 4357 N	39.0 man-seconds/sheet 526 N / 1298 N
Lifting 4'x8' sheets of plywood from ground to 3rd story*	58.8 man-seconds/sheet 1058 N / 4594 N	44.7 man-seconds/sheet 608 N / 3332 N
Lifting 8', 2"x4" boards to 2nd floor*	21.3 man-seconds/board 671 N / 2762 N	14.0 man-seconds/board 1186 N / 2653 N
*Each of the above include lift and carry from stack activities		
Nail Gun Extension		
Nailing nails across floor joists	1.6 nails/second	1.1 nails/second
Loading nails into nail gun	10.6 seconds/loading	13.8 seconds/loading
Combined nailing and loading spine compressions	1738 N / 2437 N	464 N / 1868 N
Pneumatic Wall Lift		
Lifting inner walls (not OSB covered)	23.6 man-seconds/wall 1267 N /4664 N	95.2 man-seconds/wall 538 N / 1492 N
Lifting outer walls (covered with OSB)	33.8 man-seconds/wall 1472 N / 5600 N	142.5 man-seconds/wall 655 N / 2081 N

RESULTS AND DISCUSSION

Table 1 summarizes the ergonomic and productivity effects of these interventions. In developing the solutions in this project it was recognized that in addition to reducing loading on the low back, another objective was to maintain current productivity levels. The vertical lift was the only intervention that achieved that goal consistently. However, the feedback from the workers with regard to the pneumatic wall lift was that it was worth the extra time. Further, what is not shown in these data is the extra time it would take for the framers to attach the exterior sheeting, a task that would certainly increase the time on the pre-intervention side. The productivity data from the nailgun extension may also be misleading in that 75% of the users felt that their productivity levels would increase with continued use. Our research continues in this area.

ACKNOWLEDGMENTS

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