ERGONOMIC HAND TOOL INTERVENTIONS FOR THE FURNITURE MANUFACTURING INDUSTRY

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This project focused on the development of ergonomic interventions to reduce the incidence of musculoskeletal problems in the furniture manufacturing industry. The results of an industry-based survey provided a list of the high priority jobs to be addressed with ergonomic interventions. This paper focuses on the development and evaluation of two of these interventions: an upholstery hand tool and an ergonomic interface for a random orbital sander. Laboratory testing was performed to examine the ergonomic issues with use of each intervention. A reduction in risk factors was found with use of the interventions. The upholstery hand tool reduced grip force from 36 to 18 N, improved hand posture by changing from a pinch grip to a power grip, and reduced the repetition rate from 40 to 24 repetitions per minute. EMG analysis of intrinsic and extrinsic muscles showed a reduction in overall muscle activity and a shift from the intrinsic muscles to the extrinsic finger flexor muscles. The ergonomic interface for the random orbital sander was designed to reduce exposure to vibration and eliminate the need for sustained, static grip force. A subjective survey of users revealed both a short and long term improvement in user comfort and fatigue, while a pre-post study design revealed no significant change in grip strength.

INTRODUCTION

Workers in the furniture industry have exposure to a number of recognized occupational risk factors for upper extremity cumulative trauma disorders, including pinch grips, vibrating hand tools, awkward wrist postures (both radial/ulnar deviation and flexion/extension), high grip force and repetitive hand/wrist motions (Bovenzi et al, 1991; Osorio et al, 1991; Silverstein et al, 1987; Sommerich et al, 1993; Tanaka et al, 1995). Bureau of Labor Statistics data from the years 1992-1996 indicate that incidence rates for carpal tunnel syndrome (CTS) and tendinitis show the furniture manufacturing industry as a high risk industry. On average, CTS rates are 10.64 / 10,000 workers (as compared to 8.8 for manufacturing industry and 4.36 for all private sector industry) and tendinitis incidence rates are 7.72 / 10,000 workers (as compared to 6.56 for manufacturing industry and 2.88 for all private sector industry) (BLS, 1992-1996).

Despite these statistics, a review of the ergonomics literature revealed that there has been little work specifically related to work-related musculoskeletal injuries/illnesses among furniture industry jobs or related to interventions aimed toward the prevention of these disorders among these workers.

The purpose of the current study was to develop ergonomic solutions to reduce the risk of upper extremity musculoskeletal injury/illness in the furniture manufacturing industry and then to evaluate the effectiveness of these solutions for the reduction of recognized risk factors. Two ergonomic hand tool interventions were developed, one for use in upholstery processes and one for use in case goods operations.

METHODS

A small-scale survey of experienced furniture industry employees (line workers, line supervisors, safety specialists and management) was conducted asking them to identify the most physically demanding/stressful jobs that they had encountered in the furniture manufacturing industry. These surveys were administered in both upholstery and casegoods facilities. Subsequent on-site and video ergonomic analyses of the resulting prioritized list of jobs were performed. The end result of this ergonomic analysis was a list of four jobs to be addressed in an ergonomic intervention process. Two of the jobs required the extensive use of a handtool and the interventions for these jobs will be discussed in this paper.

Ergonomic Upholstery Handtool

The upholstery process involves stretching fabric or leather over a wood frame and securing the fabric with a staple gun. The fabric or leather must be manually stretched tightly across the springs and frame to prevent wrinkles. Workers typically perform this task manually using repetitive pinch grips (using the thumb, index and middle finger) to pull the fabric for stapling. Workers in these positions are typically paid on the piece-rate system and perform the task very quickly. The task requires a substantial amount of pinch force (20 - 50 N) in order to keep the fabric tight against the frame. Because only a small section of fabric can be grasped with a pinch grip, the task is highly repetitive, requiring approximately 40 repetitions per minute. In summary, the process of upholstering a piece of furniture requires awkward hand postures (pinch grip), high pinch forces and high repetition rates.

A new handtool was developed to reduce the levels of each of these risk factors (Figure 1). The handtool has a spring loaded clamping mechanism so that the operator opens the jaws against resistance and then relaxes their grip, thus allowing the teeth of the tool to puncture the fabric and secure the grip of the tool on the fabric. To reduce repetition rates, the nose plate of the clamping mechanism was designed to be 12.5 cm wide, so that a wider region of fabric could be grabbed as compared to the traditional pinch grip. Once the tool has grabbed the fabric, the user's power grip can be relaxed and the operator can pull against the flange at the base of the handle to provide the required pull force. This is an advantage over the pinch grip, which requires the worker to squeeze the fabric until the staple is in place. To summarize, 1) the use of the handtool changes the pinch grip to a power grip, 2) the mechanical advantage of the tool reduces the required hand-generated forces, 3) the wide nose plate reduces the repetition rates, and 4) the spring-loaded design of the tool eliminates the sustained grip force requirements.

A mock upholstery workstation was built to simulate the conditions that an upholsterer would encounter on the job. Five subjects performed a simulated upholstery task with the non-dominant hand

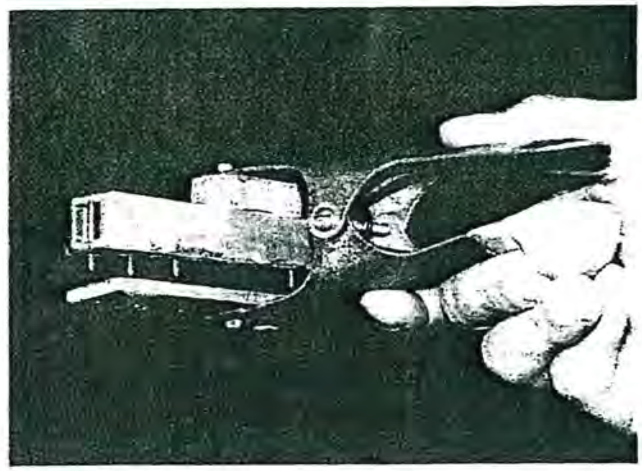

Figure 1: Fabric pulling tool

pulling the fabric while a staple gun was in the dominant hand. Fabric pulling technique (pinch grip vs. handtool) was the principle independent variable in the study. To better understand the impact that pull force might have on the effectiveness of the intervention, three different pull force levels were used: 20, 40, and 50 Newtons. Normalized integrated electromyography (NIEMG) was used to assess the muscular activity of three muscle groups of the non-dominant (fabric pulling) hand during each condition: first dorsal interosseous, generalized thenar group, and flexor digitiorm superficialis. Number of repetitions to complete the task and time to completion were also dependent measures employed to evaluate the intervention.

Interface for a Random Orbital Sander

The casegoods sector of the furniture manufacturing industry involves the production of solid wood furniture such as cabinets, tables and dressers. These large items often require a great deal of sanding of components and final products to produce a smooth surface prior to the application of stain and other surface coatings. In some locations along the production line, workers are asked to use a random orbital sander for their whole workday. The use of the random orbital sander requires the user to exert a continuous static grip force on the handtool. The survey respondents identified this as an activity that caused considerable fatigue and pain in the wrist and forearm region. In addition, the sanders produce vibration, which is transmitted to the worker and has been identified as an irritant to many workers. Thus, the stressors to be addressed in the development of the ergonomic intervention for this task were continuous static grip force and exposure to vibration.

Figure 2: Ergonomic interface for the random orbital sander

An ergonomic interface that attaches to the orbital sander was developed to reduce the exposures to these risk factors. This interface has two components: a harness that secures the hand to the tool and a vibration- absorbing glove. The harness system consists of two adjustable straps that cross across the back of the hand and secure the sander to the hand without constriction of blood flow. The glove has vibration-absorbing material sewn into the palm and proximal phalanges of the glove. With this ergonomic interface, the necessity of the static hand grip force is eliminated because the hand is harnessed to the sander and the amount of direct hand contact with the sander is reduced (Figure 2).

The laboratory test for this intervention consisted of a continuous sanding activity using the random orbital sander. Four subjects sanded a horizontal piece of wood and another 4 sanded the horizontal and vertical surfaces of a wood box. All subjects performed 2 trials, each lasting 15 minutes. One trial involved using the sander in the traditional method of gripping the tool. In the other trial, the subject used the ergonomic interface. At the end of each trial, the subject performed maximum grip strength tests using a handgrip dynamometer and completed a survey exploring subjective levels of fatigue, discomfort and level of control. The survey also asked the subjects to estimate their responses for an eight hour workday. The survey scale for discomfort and fatigue ranged from "0" (none) to "5" (high levels), with "3" indicating uncomfortable levels. Therefore, a low score is positive with these variables. Control of the sander was rated using the same increments, with "0" indicating no control and "5" indicating complete control.

RESULTS

The results of this analysis revealed that there were several advantages to using the upholstery hand tool as compared to the traditional method of pulling fabric. Along with assisting the worker in grasping and pulling fabric, use of the tool reduces 3 risk factors for hand and wrist cumulative trauma disorders: force, posture, and repetition. On average, the required grip force was reduced from 36 N when employing the manual pinch grip to just over 18 N when using the upholstery handtool. The change from pinch grip to power grip translated into a significant decrease in the use of the intrinsic hand muscles (first dorsal interosseus and thenar group) and a slight increase in the use of the extrinsic flexor digitorum superficialis (Figure 3). The tool was also shown to reduce the repetition rate of the fabric pulling activity. Grasping the fabric with a pinch grip required approximately 40 repetitions per minute, while use of the fabric-pulling tool required approximately 24 repetitions per minute.

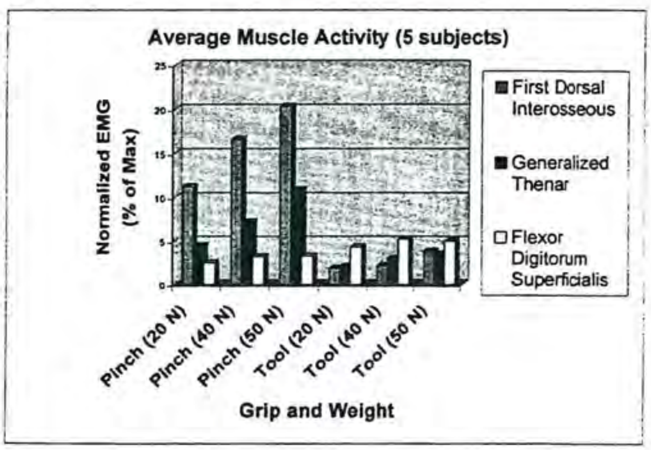

Figure 3: Muscle activity while pulling fabric

The reduction of several risk factors was also found in the ergonomic analysis of the interface for the random orbital sander. The padded glove reduces vibration transmitted to the hand, while the harness device eliminates the necessity for continuous static contraction of the finger flexor muscles. Along with reducing grip force, the attachment device also reduces vibration exposure, as the fingers are no longer in contact with the tool.

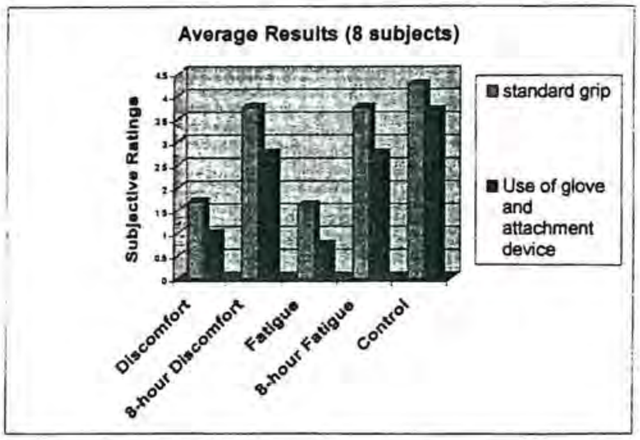

Figure 4: Subjective assessment of sanding with and without the ergonomic interface

The results from the subjective survey confirm the predictions of the ergonomic analysis and show a decrease in discomfort, fatigue and 8-hour estimated discomfort and fatigue with use of the intervention. (See Figure 4). Although the control rating also shows a decrease with use of the device, 7 of 8 subjects gave the device a "4" rating, indicating good control of the sander. Seven of the subjects stated that they would prefer to use the glove and attachment device if their jobs required long periods of sanding. Grip strength measurements were not affected by the intervention, a result which may be a function of the relatively short trial duration.

DISCUSSION

The interventions described in this presentation are first-level prototypes. Although initial testing has shown positive results, more extensive laboratory and field testing is needed to determine the feasibility of implementing the devices into the workplace. Future work with this project will involve taking the developed prototypes into more furniture manufacturing facilities to obtain worker feedback. This feedback will be used to modify the prototypes to address usability and productivity concerns. One of the greatest obstacles faced in doing ergonomic intervention research is inertia, particularly in jobs where the operators are paid on an incentive system of compensation. Our plan to overcome this obstacle is to develop a participatory ergonomics approach allowing the operators to develop design and redesign criteria throughout the project.

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