ELSEVIER

International Journal of Industrial Ergonomics 29 (2002) 263–273

International Journal of
Industrial
Ergonomics

www.elsevier.com/locate/ergon

Ergonomic interventions for the furniture manufacturing industry. Part I—lift assist devices

Gary A. Mirka*, Christy Smith, Carrie Shivers, James Taylor

The Ergonomics Laboratory, Department of Industrial Engineering, North Carolina State University, Box 7906, Raleigh, NC 27695-7906, USA

Received 10 April 2001; received in revised form 18 June 2001; accepted 29 August 2001

Abstract

The objectives of this intervention research project were to develop and evaluate engineering controls for the reduction of low back injury risk in workers in the furniture manufacturing industry. An analysis of injury/illness records and survey data identified upholsterers and workers in the machine room as two occupations within the industry at elevated risk for low back injury. A detailed ergonomic evaluation of the activities performed by these workers was then performed and the high risk subtasks were identified. The analysis for upholsterers revealed: (1) high forces during the loading and unloading of the furniture to and from the upholstery bucks, (2) static awkward postures (extreme flexion > 50°, lateral bending > 20°, twisting > 20°) during the upholstering of the furniture, and (3) repetitive bending and twisting throughout the operation. For machine room workers, this ergonomic evaluation revealed repetitive bending and twisting (up to 5 lifts/min and sagittal flexion > 80°, lateral bending > 15°, twisting > 45°) when getting wooden components from or moving them to the shop carts that are used to transport these materials. Engineering interventions were then developed and evaluated in the laboratory to document the reduction of exposure to these stressors. The height-adjustable upholstery buck system eliminated the lifting and lowering requirements and affected trunk kinematics during the upholstery operation by reducing peak sagittal angles by up to 79% (average: 52%; range: 27–79%), peak sagittal accelerations by up to 42% (average: 71%; range: 0–74%) and peak lateral position by up to 31% (average: 20%; range: 12–31%), and showed no impact on time to complete the task. The machine room lift reduced peak sagittal angle by up to 90% (average: 76%; range: 64–90%), peak sagittal accelerations by up to 86% (average: 72%; range: 59–86%) and had a positive impact on the time to complete the task (average reduction: 19%).

Relevance to industry

The ergonomic intervention research documented in this report shows the impact of engineering controls for the furniture manufacturing industry on the risk factors for work-related low back injuries.

Keywords: Low back injury; Intervention research; Furniture industry; Trunk motion; Trunk posture

1. Introduction

The furniture manufacturing industry is of great importance to the economy of the southeastern

*Corresponding author. Tel.: +1-919-515-6399; fax: +1-919-515-5281.

E-mail address: mirka@eos.ncsu.edu (G.A. Mirka).

0169-8141/02/$ - see front matter
PII: S0169-8141(01)00067-1

United States. In North Carolina alone, there are over 75,000 people employed by the industry (Standard Industry Code (SIC): 25) ranking it second in the state's manufacturing sector employment. This constitutes about 9.7% of the state's manufacturing workforce. About 75% of these establishments are producers of household furniture (SIC 251) making up 88% of the furniture manufacturing workforce (NC ESC, 2000).

As with many manufacturing industry sectors, the furniture manufacturing industry has struggled with problems associated with work-related low back pain and other musculoskeletal illnesses. Bureau of Labor Statistics data from the years 1992–1996 indicate that the incidence rate for low back pain cases involving days away from work was 21.98/10,000 workers (BLS, 1992, 1993, 1994, 1995, 1996). This is compared to the incidence rates of low back pain cases of 15.94 for private industry as a whole and 15.6 for general manufacturing industry. The residential furniture manufacturing industry can be broken into three separate categories: (1) upholstered furniture (sofas, chairs, loveseats, etc.), (2) casegoods (tables, desks, bookshelves, dressers, etc,) and (3) hardwood chairs (such as dining room chairs—sometimes upholstered, sometimes not). All three have historically high rates of musculoskeletal disorders, but the specific risk factors in each sector vary.

A review of the recent literature with regard to safety and health research in the furniture industry illustrates that the majority of the previous work has focused on issues of exposure to sawdust (Demers et al., 1997; Goldsmith and Shy, 1988; Piasaniello et al., 1991, 1992; Scheeper et al., 1995; Vinzents, 1988), chemical exposure (Estill and Spencer, 1996; Goldsmith and Shy, 1988; Vinzents and Laursen, 1993; Voog and Jansson, 1992), noise (Vinzents and Laursen, 1993), and acute injury (Aaltonen, 1996). While these topical areas are clearly important, it is also recognized that furniture workers have known exposures to a number of recognized occupational risk factors for low back injury/illness: physically heavy work, highly repetitive bending and twisting, pushing, twisting, frequent lifting over 25 pounds, sustained awkward postures of the torso, and dynamic movements of the torso (Andersson, 1981; Damkot et al., 1984; Frymoyer et al., 1983; Kelsey et al., 1984; Magora, 1970; Marras et al., 1993; Pope et al., 1984). Surprisingly, there is little literature specifically related to work-related musculoskeletal injuries/illnesses among furniture industry jobs or related to interventions aimed towards the prevention of these disorders among these workers. One study that did consider musculoskeletal problems in the furniture manufacturing industry was conducted by Christensen et al. (1995). In their study, they considered body posture and manual material-handling activities in the wood and furniture industry. They report that 75% of the employees experienced symptoms of pain, ache or discomfort from the musculoskeletal system during the previous year. They found a 1-year prevalence of low back symptoms of 42% (13% reported pain within the last week and 6% reported daily symptoms), a 1-year prevalence of shoulder pain of 28% and a 1-year prevalence of hand/wrist symptoms of 24%. In their biomechanical assessment of the manual materials handling tasks, they cited repetitive lifting, awkward postures, static muscle loads and high external loads as critical components to be considered in ergonomic intervention development. They conclude by noting that "Optimal strategies for job redesign including more variation between the work tasks may be worked out using this information in order to reduce the high prevalence of occupational musculoskeletal disorders seen in this industry" (p. 803). A review of the scientific literature has revealed little progress towards this goal through either administrative or engineering controls. The objectives of this current research were to develop and evaluate engineering controls for the reduction of low back injury risk in workers in the furniture manufacturing industry.

2. Methods

2.1. OSHA Form 200 Log analysis and survey

The first step in this ergonomic intervention process was to identify those jobs that posed the greatest risk for low back injury. This was

accomplished in two ways: passive surveillance (OSHA Form 200 Log analysis and surveys) and active surveillance (on-site ergonomic assessments). Incidence and severity rate data from OSHA Form 200 Logs were gathered from a group of 29 casegoods facilities and 11 upholstered furniture facilities. The review of the OSHA Log data from upholstery facilities indicated that a significant percentage of the low back problems in these facilities were located in the upholstery department. The OSHA Log data from the casegoods facilities indicated that the low back injury problem was a little bit more dispersed but one high-risk area was the "machine room", where the large pieces of wood are cut down into smaller pieces removing the imperfections in the piece and then machined to the correct size for a particular component.

In addition to the analysis of the OSHA Logs, a survey of experienced furniture industry personnel was also undertaken. This survey simply asked the respondents to list top jobs that, in their experience, posed the greatest risk of injury from overexertion/repetitive motion. The results of these surveys generated data that closely matched the OSHA Form 200 Log data. It is interesting to note, however, that the subjective impressions of the survey respondents were much more consistent across respondents than results of the OSHA Log data indicating that there were a few high-profile jobs that everyone recognized as high risk.

2.2. On-site ergonomic assessments

Fourteen different furniture manufacturing facilities (both casegoods and upholstered furniture) were visited over a period of six months to conduct a high-level ergonomic task analysis of the work activities performed in these facilities. The differences in equipment and work technique among the facilities manufacturing the same product type were documented. Based on the results of this preliminary ergonomic task analyses, the review of the OSHA Logs (both incidence and severity measures) and the compilation of survey results, two specific occupations were identified as areas of concern for low back injury: machine operators in casegoods facilities and the upholsterers in upholstered furniture facilities. A more comprehensive task analysis of each of these occupations was then performed to identify the levels of exposure to the specific risk factors for low back injury.

There are a variety of workers who fall under the general category of "machine operators" in a casegoods facility. The first group of operators works in the rough cut area, where the defects in the wood are eliminated: (1) loaders and unloaders (offbearers) on the large rip saws and (2) the cutoff saw operators. The second group of machine operators works to refine individual components on a single machine (bandsaws, sanding machines, drill presses, etc.). The former group often deals with large awkward loads, while the latter does a great deal of repetitive twisting and bending. The ergonomic evaluation of the activities in both groups revealed that repetitive bending and twisting (up to 5 repetitions/min) and extreme awkward postures (extreme flexion $> 80^\circ$, lateral bending $> 15^\circ$, and twisting $> 45^\circ$) are of greatest concern. These risk factors are present as the machine operator gets parts from, and delivers parts to, the standard shop carts that are used to transport materials throughout the machine room area.

The work activities of the upholsterers are fairly consistent across companies. While they have different sizes of the pieces that they upholster (sofas vs. chairs), and different materials (fabric vs. leather), their task is to lift a piece of furniture onto their upholstery bucks (small saw horses) and then secure the fabric/leather to the frame. Ergonomic analysis of the upholsterer position revealed several known risk factors for low back injury. These risk factors included: (1) high forces during the loading and unloading of the furniture to and from the upholstery bucks (saw horses), (2) static awkward postures (extremeflexion $> 50^\circ$, sidebending $> 20^\circ$, twisting $> 20^\circ$) during the upholstering of the furniture, and (3) repetitive bending and twisting throughout the operation.

2.3. Engineering design of prototypes

The research and design team employed an iterative prototyping process, wherein each ergonomic intervention prototype was subjectively

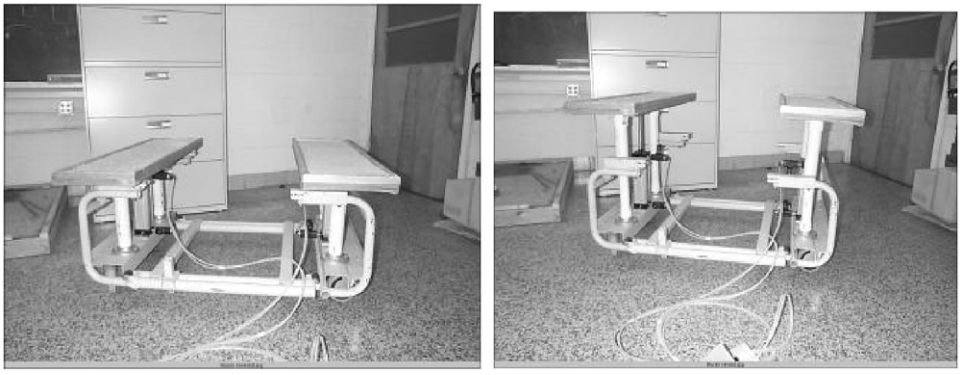

Fig. 1. Height-adjustable upholstery bucks.

evaluated in the lab by the research team and in the field by furniture workers and the results of these assessments were used to improve on the design of the intervention. The principle component of the intervention for the upholstery operation is a height-adjustable upholstery buck system. This intervention utilizes existing upholstery carts that are commercially available but then adds pneumatic cylinders into the structure so that the work surface moves vertically at the users' discretion (Fig. 1). The overall function of the system is as follows. The upholsterer brings the un-upholstered piece (wooden frame) to his workstation via a rolling cart and slides the frame from the rolling cart onto the height-adjustable bucks. S/he then uses a foot pedal to control the airflow into the pneumatic cylinders to adjust the height of the piece during the upholstery process. When the upholstery activities are complete, the upholsterer slides the upholstered piece from the bucks back onto the cart and rolls the cart away. This system is designed to eliminate the heavy, awkward lifts to and from the bucks and to control the awkward movements and static postures of the low back during the upholstery process.

The intervention developed for the machine room in casegoods facilities is a lift system that allows for a safe, quick and easy way of raising and lowering the standard shop carts that transport the materials within the machine room. A stationary forklift system was designed such that forks of the lift matched the undercarriage profile of these standard shop carts (Fig. 2). As the operator takes away blanks from the raw materials cart, it can be raised, and as s/he adds parts to the finished product cart, it can be lowered. This allows the operator to maintain a more upright and neutral back posture throughout the process

Fig. 2. Shop cart lift.

and increase productivity through improvements in the economy of motion (fewer trunk motions required). It should be noted that similar lift-assist devices are commercially available for general applications in other industries, but this intervention has been designed specifically to work with the standard shop carts used in most furniture manufacturing facilities.

2.4. Laboratory evaluation of prototypes

2.4.1. Subjects

Twelve subjects (seven men and five women) were recruited from the university population and provided written informed consent before participation. All subjects were in good health and had no serious musculoskeletal problems. The mean (standard deviation) of pertinent anthropometric variables is as follows: stature—172.8(8.01), acromion height—140.9(7.46), standing elbow height —110.2(5.76), and iliac crest height—104.0(5.55).

2.4.2. Apparatus

The Lumbar Motion Monitor (LMM) (Marras et al., 1992) was used to capture the trunk kinematics as the subjects performed the experimental tasks. The time-dependent (60 Hz), three-dimensional angular data were then used to create time-dependent, three-dimensional velocity and acceleration profiles for each trial (Marras et al., 1992). A standard stopwatch was used to measure the time to complete each task.

2.4.3. Experimental Task 1

Experimental Task 1 was performed to evaluate the effects of the height-adjustable upholstery bucks. The fabric was stapled to a sofa frame such that the loose ends of the fabric were hanging in the locations that the fabric would typically be hanging before the upholsterers begin their task. Videotapes of experienced upholsterers working on a sofa frame were reviewed to determine representative locations and the number of times an upholsterer would grasp the fabric during an upholstery task. The following locations were used: (1) front bottom of frame: 10 pulls, (2) top of arms: 6 pulls/side, (3) inside front (pushing fabric along seat pan): 6 pushes, (4) back sides: 6 pulls each side, (5) top back of frame: 10 pulls, and (6) bottom sides of frame: 6 pulls each side.

The subject simulated the upholstery operation by reaching and grasping the fabric at these points with the non-dominant hand while holding a staple gun in the dominant hand and simulating a stapling motion.

The task was performed under two conditions. In one condition, the height of the buck remained in the lowest position (simulating the existing, non-adjustable system found in most facilities). In the other condition, the height-adjustability of the upholstery bucks was utilized (Fig. 3). The independent variables in this study were: (1) type of upholstery buck (2 levels: stationary buck and height-adjustable buck) and (2) location of work activity (6 levels (described above)). The dependent variables were: (1) trunk kinematic parameters (position, velocity and acceleration in the sagittal, coronal and transverse planes), and (2) time to complete the task.

The presentation order of the two conditions (stationary buck vs. height-adjustable buck) was counterbalanced across subjects to minimize the order effects. The subject performed each of the six upholstery activities twice in each condition. Before and after each trial set, LMM data were collected while the subject stood upright (0°) and then flexed 90° at the waist. These collections served as calibration points for the LMM data. During each trial, the LMM data were collected continuously. The time taken to complete each work activity task was recorded.

2.4.4. Experimental Task 2

Experimental Task 2 was performed to evaluate the effects of the shop cart forklift intervention. The subjects simulated work at a machine by picking up a 30 cm length of $2'' \times 4''$ lumber from different locations on the surface of a shop cart and then placing it on a table that was set to their elbow height, as if they were going to work on the piece. This task was performed at three different shop cart surface heights and the wood piece was placed in five different positions on the shop cart surface (Fig. 4). After each lift/place task was completed, the research assistant moved the wood piece and/or platform height before starting the

Fig. 3. Experimental apparatus to test the effects of height-adjustable upholstery bucks.

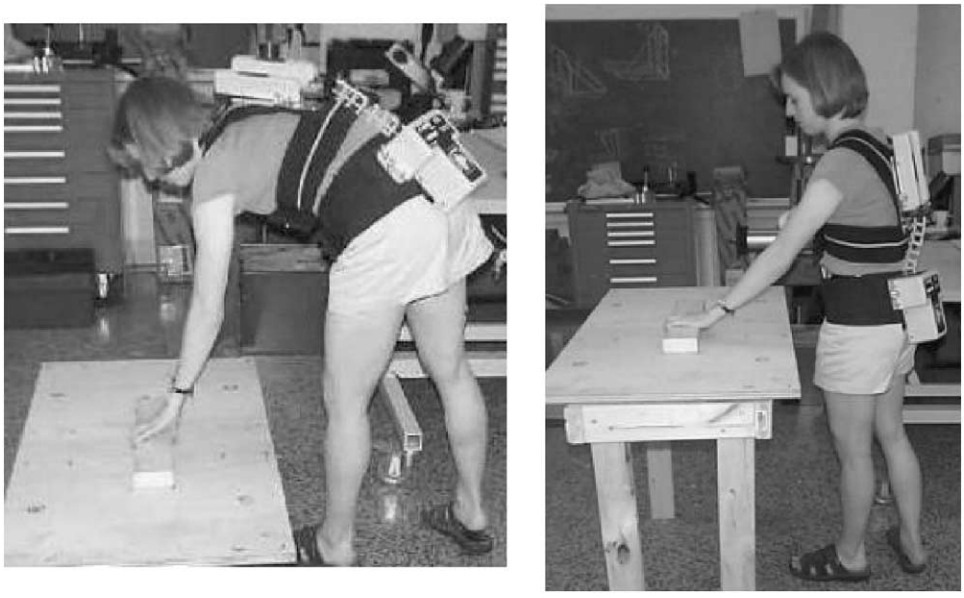

Fig. 4. Experimental apparatus to test effects of shop cart lift.

next task. The platform was located to the left of the subject, perpendicular to the subject's body. The subject picked the piece of wood off the platform and placed it on the table. The subject started in the same position before each lift (facing the table), but was allowed to move in any way to pick up and place the wood piece.

The independent variables in this study were: (1) height of the platform (low (33 cm), medium (65 cm), and high (85 cm)) and (2) position of the wood piece (upper right-hand corner (position "D"), upper left-hand corner (position "A"), center (position "C"), lower right-hand corner (position "E"), and lower left-hand corner

(position "B")) (Fig. 4). The "high" position of the cart surface represented the intervention condition while the "medium" and "low" positions represented the half-full and almost-empty conditions of the standard shop cart, respectively. The dependent variables were: (1) trunk kinematic parameters (position, velocity and acceleration in the sagittal, coronal and transverse planes) and (2) time to complete the task.

The presentation order of the platform heights and wood-piece position was randomized. The subject lifted the wood from each of the five positions at a given platform height, then the height was changed for the next trial. A lift at each combination of the platform height and position was performed twice for a total of 30 lifts/subject.

2.4.5. Complete experimental procedure

After the subject signed the informed consent forms (one for each task), anthropometry measurements were taken of stature, standing acromion height, standing elbow height and standing iliac crest height. The LMM was placed on the subject's back, and each task was explained and demonstrated to the subject. The subject performed the simulated upholstery activity first and then, after a 5 min break, moved to the simulated machine shop activity. The total experimentation time was 1 h.

2.4.6. Data reduction and statistical analysis

The first step in data reduction was to take each individual file containing the LMM data and eliminate those points in time wherein the subject was not performing the designated task. The stopwatch data were used to demark these endpoints. The remaining time-dependent position data were then normalized relative to the 0–90 range as defined by the calibration data sets described above. After this normalization procedure, each file was reduced to the minimum, maximum and average for each of the nine variables (position, velocity and acceleration in the sagittal, coronal and transverse planes). For the purpose of this report, the dependent variables will be limited to: (1) peak sagittal position (greatest forward flexed posture), (2) peak sagittal acceleration, (3) maximum lateral position (greatest deviation from neutral in the coronal plane), and (4) time to complete the task. The final statistical analyses were then performed on these variables.

ANOVA procedures were performed on this data set to identify the significant effects of the independent variables. Since this was a mixed model (both fixed and random effects), the appropriate expected mean square ratios were used to calculate the appropriate *F*-statistics. Derivation of test statistics is shown in the appendix. The analysis used "subject" as a blocking variable to control for the differences between individuals.

3. Results

As was hypothesized, the height adjustability provided by the two interventions had a considerable impact on the trunk kinematics required to perform these simulated furniture manufacturing activities (Table 1). The results of the laboratory evaluation of the height-adjustable bucks show considerable reductions in the required sagittal range of motion of the torso (Fig. 5), peak sagittal acceleration of the torso (Fig. 6), and lateral range of motion of the torso (Fig. 7), while maintaining productivity (Fig. 8). The significant interaction effects imply that the height adjustability had a greater impact when the subjects were working on the lower locations on the piece of furniture (front, lower part of arm, etc.).

Similarly, the results of the laboratory evaluation of the shop cart lift show consistent improvements in trunk posture (Figs. 9 and 10) as well as significant changes in the dynamics of the lifting activity (Fig. 11). The lift also showed a significant decrease in the movement times required to perform the activity (Fig. 12), a productivity benefit that we anticipate will increase the likelihood that the intervention is adopted by the industry.

4. Discussion

Trunk posture and trunk dynamics play an extremely important role in the loading characteristics of the spine and, therefore, are important

Table 1
ANOVA for the ergonomic interventions

ANOVA for height-adjustable upholstery bucks (Experiment 1)

	Part of furniture	Buck type	Interaction
Peak sagittal position	$F(5,55) = 52$[a]	$F(1,11) = 25$[a]	$F(5,55) = 5.84$[a]
Peak sagittal acceleration	$F(5,55) = 2.45$[b]	$F(1,11) = 13$[a]	$F(5,55) = 6.75$[a]
Peak lateral position	$F(5,55) = 11.2$[a]	$F(1,11) = 19.8$[a]	$F(5,55) = 0.6$ NS
Time to complete	$F(5,55) = 80.8$[a]	$F(1,11) = 2.75$ NS	$F(5,55) = 5.36$[a]

ANOVA for the shop cart lift (Experiment 2)

	Position on cart	Height of cart surface	Interaction
Peak sagittal position	$F(4,44) = 13.3$[a]	$F(2,22) = 115$[a]	$F(8,88) = 4.0$[a]
Peak sagittal acceleration	$F(4,44) = 3.06$[b]	$F(2,22) = 54$[a]	$F(8,88) = 4.67$[a]
Peak lateral position	$F(4,44) = 11.1$[a]	$F(2,22) = 67$[a]	$F(8,88) = 14$
Time to complete	$F(4,44) = 71$[a]	$F(2,22) = 20$[a]	$F(8,88) = 2.1$ NS

[a] Significant at the $p = 0.01$ level.
[b] Significant at the $p = 0.05$ level.
NS—not significant.

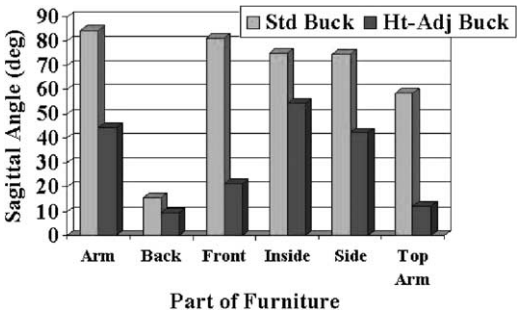

Fig. 5. Effect of height-adjustable bucks on the peak sagittal angle of the torso during upholstery work.

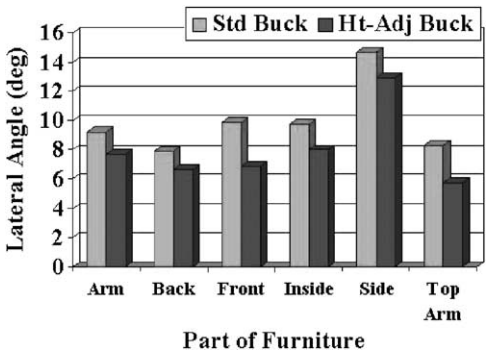

Fig. 7. Effect of height-adjustable bucks on the peak lateral (coronal) angle of the torso during upholstery work.

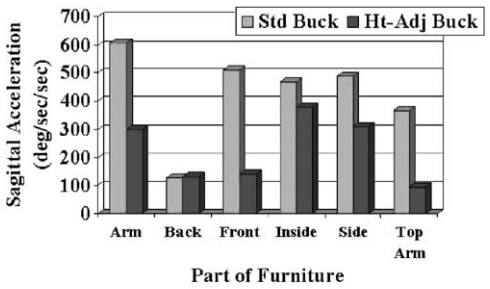

Fig. 6. Effect of height-adjustable bucks on the peak sagittal acceleration of the torso during upholstery work.

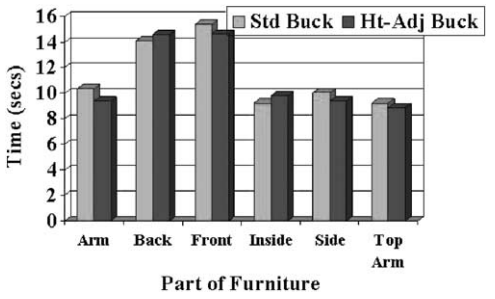

Fig. 8. Effect of height-adjustable bucks on the time to complete upholstery task.

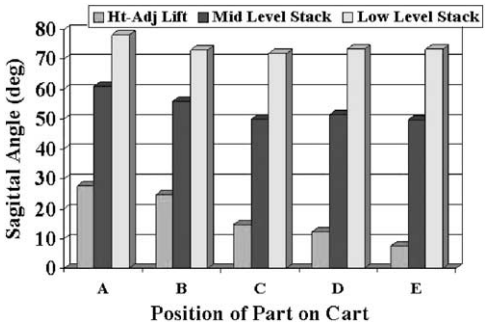

Fig. 9. Effect of shop cart lift on peak sagittal angle during simulated machine shop work.

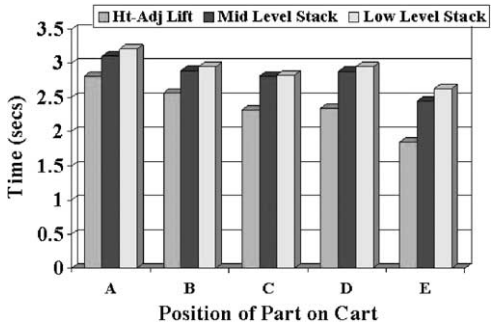

Fig. 12. Effect of shop cart lift on time to complete task during simulated machine shop work.

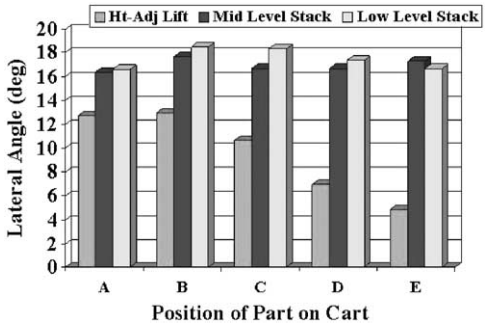

Fig. 10. Effect of shop cart lift on peak lateral (coronal) angle during simulated machine shop work.

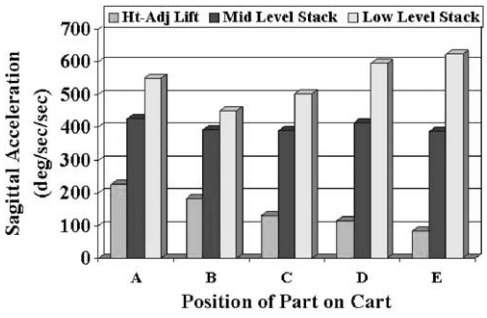

Fig. 11. Effect of shop cart lift on peak sagittal acceleration during simulated machine shop work.

effects to consider when developing interventions for the prevention of low back injury. The static/postural characteristics play a major role in determining the moment created by the force of gravity acting on the center of mass of the torso (when considering the posture in the sagittal plane) and they play a major role in determining the muscle forces required to hold off-plane static postures against the spring-like forces provided by the passive tissue of the torso (when considering the posture in the transverse and coronal planes). Ergonomic interventions designed to reduce the internal muscle forces required to perform a job need to consider both of these non-optimal conditions as potential sources of improvement in the redesign of a manual materials-handling task. The results of the current intervention study have shown considerable improvements in both the peak and mean back postures with the introduction of each intervention.

In addition to the static and postural loads, a number of studies (e.g. Marras et al., 1993; Marras and Mirka, 1993; Mirka and Marras, 1993) have emphasized the importance of considering the torso dynamics in assessing the risk of low back injury. In their multiple logistic regression model of low back risk, Marras et al. (1993) illustrated that one should consider not only the sagittal acceleration (which results in inertial forces) but also the dynamics in the transverse and coronal planes as potential sources of risk. The current study clearly showed that the interventions had a considerable impact not only on the static postures required by the tasks, but also on the trunk kinematics, which will also reduce the risk of injury.

While the ergonomic benefits of an intervention like those described in this paper are evident, there is often some resistance to their adoption in industry because of concerns regarding their effects on productivity, inertia of management, inertia of the workers, etc. One of the key

aspects of our intervention efforts has been to quantitatively assess productivity effects of the developed interventions at every stage of the development process so that we can address these concerns. In a laboratory study, such as the one described in this paper, wherein college students are asked to perform a relatively unfamiliar task, one should be careful not to place too much emphasis with regard to productivity assessment. Having said this, it is noteworthy that generally positive productivity benefits were gained by these interventions, in this sample of subjects. Ultimately though, productivity will only be truly assessed in the field assessment phase of this project.

In addition to the limitation described above with regard to the subject population, there are other limitations of the current study that need to be considered. First, the environment of the laboratory is considerably more uncluttered than the average furniture industry workstation, particularly as compared with upholstery workstations. Second, many of the jobs in industry are production jobs, meaning that they are being paid by the amount of product produced, not by the number of hours worked. This may influence the postures and motions adopted by these workers. It can be hypothesized, however, that the effects shown in this study with regard to both trunk postures/kinematics and productivity could be amplified by a worker focused on generating the highest levels of productivity. These workers will gravitate to the most motion-efficient work methods and the ergonomic interventions described in this work also generate improvements in worker-motion economy. The challenge facing our research team is to encourage the management and the workers to consider changing their standard work methods to take advantage of the benefits (both ergonomic and productivity) that will come from these interventions.

5. Conclusions

This paper describes two lift-assisting interventions for the furniture manufacturing industry. Both generated considerable improvements in the trunk postures and trunk kinematics required to perform the requisite tasks. Productivity benefits from these interventions were also found, but it is felt that these productivity improvements may only be a fraction of those that may come from the long-term utilization of these interventions by skilled workers attempting to maximize their productivity.

Acknowledgements

This work was supported by Grant No. R01-OH03701 from the National Institute for Occupational Safety and Health (NIOSH) and a Grant from The Furniture Manufacturing and Management Center (FMMC) at the North Carolina State University. The contents are solely the responsibility of the authors and do not necessarily reflect the views of the NIOSH or the FMMC.

Appendix A. Derivation of test statistics

Experiment 1: Height-adjustable bucks

A—buck type (2 levels) (fixed effect)
B—part of furniture (6 levels) (random effect)
S—subject (12 levels) (random effect)

To test the effect of buck type

$$F\text{-ratio} = (MS_A/df_A)/[(MS_{SA}/df_{SA}) + (MS_{AB}/df_{AB}) - (MS_{ABS}/df_{ABS})]$$

To test the effect of part of furniture

$$F\text{-ratio} = (MS_B/df_B)/(MS_{SB}/df_{SB})$$

To test the effect of buck type × part of furniture

$$F\text{-ratio} = (MS_{AB}/df_{AB})/(MS_{SAB}/df_{SAB})$$

Experiment 2: Shop Cart Lift

A—height of cart surface (3 levels) (random effect)
B—position on cart (5 levels) (random effect)
S—subject (12 levels) (random effect)

To test the effect of height

$$F\text{-ratio} = (MS_A/df_A)/(MS_{SA}/df_{SA})$$

To test the effect of location

$$F\text{-ratio} = (MS_B/df_B)/(MS_{SB}/df_{SB})$$

To test the effect of height × location

$$F\text{-ratio} = (MS_{AB}/df_{AB})/(MS_{SAB}/df_{SAB})$$

References

Aaltonen, M.P., 1996. Occupational injuries in the Finnish furniture industry. Scandinavian Journal of Work Environment and Health 22 (3), 197–203.

Andersson, G.B.J., 1981. Epidemiologic aspects of low back pain in industry. Spine 6, 53–60.

BLS, 1992. Table R5: incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by industry and selected natures of injury or illness, 1992. Bureau of Labor Statistics.

BLS, 1993. Table R5: incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by industry and selected natures of injury or illness, 1993. Bureau of Labor Statistics.

BLS, 1994. Table R5: incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by industry and selected natures of injury or illness, 1994. Bureau of Labor Statistics.

BLS, 1995. Table R5: incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by industry and selected natures of injury or illness, 1995. Bureau of Labor Statistics.

BLS, 1996. Table R5: incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by industry and selected natures of injury or illness, 1996. Bureau of Labor Statistics.

Christensen, H., Pedersen, M.B., Sjogaard, G., 1995. A national cross-sectional study in the Danish wood and furniture industry on working postures and manual materials handling. Ergonomics 38 (4), 793–805.

Damkot, D.K., Pope, M.H., Lord, J., Frymoyer, J.W., 1984. The relationship between work history, work environment and low-back pain in men. Spine 9 (4), 395–399.

Demers, P.A., Teschke, K., Kennedy, S.M., 1997. What to do about softwood? A review of respiratory effects and recommendations regarding exposure limits. American Journal of Industrial Medicine 31 (4), 385–398.

Estill, C.F., Spencer, A.B., 1996. Case study: control of methylene chloride exposures during furniture stripping. American Industrial Hygiene Association Journal 57 (1), 43–49.

Frymoyer, J.W., Pope, M.H., Clements, J.H., 1983. Risk factors in low back pain. Journal of Bone and Joint Surgery (American) 65A, 213.

Goldsmith, D.F., Shy, C.M., 1988. An epidemiologic-study of respiratory health-effects in a group of North Carolina furniture workers. Journal of Occupational and Environmental Medicine 30 (12), 959–965.

Kelsey, J.L., Githens, P.B., White, A.A., Holford, T.R., Walter, S.D., O'Connor, T., 1984. An epidemiologic study of lifting and twisting on the job and risk for acute prolapsed lumbar intervertebral disc. Journal of Orthopedic Research 2 (1), 61–66.

Magora, A., 1970. Investigation of the relation between low back pain and occupation. Industrial Medicine 39, 31–37.

Marras, W.S., Mirka, G.A., 1993. Electromyographic studies of the lumbar trunk masculature during the generation of low level trunk acceleration. Journal of Orthopaedic Research 11 (6), 811–817.

Marras, W.S., Fathallah, F.A., Miller, R.J., Davis, S.W., Mirka, G.A., 1992. Accuracy of a three-dimensional lumbar motion monitor for recording dynamic trunk motion characteristics. International Journal of Industrial Ergonomics 9, 75–87.

Marras, W.S., Lavender, S.A., Leurgans, S., Rajulu, S., Alread, G., Fathallah, F., Ferguson, S., 1993. The role of dynamic three-dimensional trunk motion in occupationally related low back disorders: the effects of workplace factors, trunk position and trunk motion characteristics on risk of injury. Spine 18, 617–628.

Mirka, G.A., Marras, W.S., 1993. A stochastic model of trunk muscle coactivation during trunk bending. Spine 18 (11), 1396–1409.

NC ESC, 2000. Employment Data 2000. Employment Security Commission of North Carolina.

Pisaniello, D.L., Connell, K.E., Muriale, L., 1991. Wood dust exposure during furniture manufacture—results from an Australian survey and considerations for threshold limit value development. American Industrial Hygiene Association Journal 52 (11), 485–492.

Pisaniello, D.L., Tkaczuk, M.N., Owen, N., 1992. Occupational wood dust exposures, life-style variables, and respiratory symptoms. Journal of Occupational and Environmental Medicine 34 (8), 788–792.

Pope, M.H., Frymoyer, J.W., Andersson, G.B.J., 1984. Occupational Low Back Pain. Praeger, New York.

Scheeper, B., Kromhout, H., Boleij, J.S., 1995. Wood-dust exposure during wood-working processes. Annals of Occupational Hygiene 39 (2), 141–154.

Vinzents, P., 1988. Personal sampling of total and inspirable dust—results from a survey in the Danish wood industry and furniture. Industry Journal of Aerosol Science 19 (7), 1437–1439.

Vinzents, P., Laursen, B., 1993. A national cross-sectional study of the working environment in the Danish wood and furniture industry—air-pollution and noise. Annals of Occupational Hygiene 37 (1), 25–34.

Voog, L., Jansson, B., 1992. Identification and control of contact-dermatitis from polyfunctional acrylicmonomers in 5 Swedish furniture companies. Journal of Environmental Science and Health 27 (7), 1925–1938.