

OCCUPATIONAL LOW BACK PAIN IN RESIDENTIAL CARPENTERS: OWAS CATEGORIES AND FORCES OF COMPRESSION AND SHEAR

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ABSTRACT

Occupational low back pain (LBP) remains the leading safety and health challenge for many industries. This study was a cross-sectional investigation measuring the prevalence of occupational LBP in residential carpenters in the Denver Metro area of Colorado. Evaluation of ergonomic factors that may contribute to the occurrence of LBP were also investigated. Ninety-four framing carpenters were investigated for the presence of LBP and associated personal and workplace risk factors. Ten major carpentry job-tasks were evaluated using the Ovako Working Posture Analysis System (OWAS[®]) and ErgoMaster 2-D[®] software to measure elements of posture, stress, and risk. Job-tasks were found to differ significantly ($p < 0.001$) in the 21 parameters measured; specifically, total lumbar compression and shear at peak loading varied significantly ($p < 0.001$) ranging from 2956 N to 8606 N and 802 N to 1974 N. Slight risk for injury was found in all 10 job-tasks evaluated using OWAS while distinct risk was found in seven of the 10 job-tasks assessed. Seven of the 10 job-tasks exceeded the NIOSH action limit (AL) of 3,425 N for low back loading. Framing carpenters experienced higher levels of point and 12-month period prevalence of LBP (14% and 38%, respectively) than the general population. Results add to the understanding of LBP problems in framing carpenters.

INTRODUCTION / BACKGROUND

Occupational low back pain (LBP) is America's number one workplace safety challenge (OSHA, 1993). LBP is a leading cause of lost work time, second only to the common cold, and it accounts for up to 240 million lost workdays per year (Deyo and Weinstein, 2001; NIOSH, 1997a; Kahlil et al., 1993; Center to Protect Workers' Rights, 1997). LBP is credited as the leading cause for physician visits each year (CPWR, 1997; Kahlil et al., 1993; NIOSH, 1997a). LBP is ubiquitous in modern society. It affects 60% to 90% of all people at some time in their lives and affects 4% to 31% of the population at any given time (Cassidy and Wedge, 1988; Cassidy et al., 1998; Cote et al., 1998; Kelsey and White, 1980; Kelsey and Gordon, 1987;

Linton et al., 1998; NIOSH, 1996; Riihimaki et al., 1989). Back injuries comprise 16% to 27% of all reported claims totaling more than 1.2 million claims in 1993 (BNA, 1993; Cleary et al., 1995; Guo et al., 1995, 1999; Kahlil, 1993; Murphy, 1996; NIOSH, 1996). Back surgeries continue in excess of 250,000 per year and are the third most common surgery in America (Cleary et al., 1995). Primary and secondary cost estimates to the nation's economy due to LBP range from \$50 to \$100 billion annually (Bureau of National Affairs, 1993; Guo et al., 1995, 1999; Kahlil et al., 1993; Marras, 2000). The average back claim was recently reported to have exceeded \$40,000 in the state of Ohio (Marras, 2000). In addition, low back injury can devastate the quality of life of its sufferers and adversely affect their lives in many ways. LBP victims who are away from work longer than six months have a 50% chance of returning to work, while those out for 12 months or more have less than a 10% to 25% chance of returning to their pre-injury work (Cleary et al., 1995; Deyo, 1987; Hagen and Thune, 1998; Kelsey and White, 1980).

The construction industry is the sixth largest employer nationwide employing more than 7 million men and 687,000 women, representing 6% of the nation's labor force (BLS, 1998a, b, c, d; Kisner and Fosbroke, 1994; NIOSH, 1997b; Robinson and Burnett, 1994). This industry accounts for 25% - 50% of all fatal falls, 15% - 17% of all reported workplace injuries, and 10% of all disabling injuries (Toscano et al., 1996; NIOSH, 1997b). Zwerling et al. (1996) found injury rates 4.6 times higher for construction workers compared to all other professions in their study of 7,798 injury cases in Iowa. Furthermore, 25% of back pain sufferers had lost in excess of 30 days from work due to back pain. Holmstrom (1992a, b) found that among the 1,773 construction workers studied, an annual prevalence rate of LBP was 54%. Lipscomb et al. (1997) found back strain injury rates 5.7 per 100 FTEs when assessing 10,935 construction workers in Washington State. Guo et al. (1995, 1999) evaluated data from over 30,000 respondents and found that construction laborers and carpenters had the highest prevalence of back pain within the construction industry. Among construction workers, back pain is at epidemic proportions (CPWR, 1997) in part due to ergonomic hazards (Bhattacharya et al., 1997; Buchholz et al., 1996; Latza et al., 2000a; Li, 2000; Schneider et al., 1998; Schneider and Susi, 1994; Stubs, 1981; Xu et al., 1996).

STUDY DESIGN AND METHODS

This investigation was a nested cross-sectional study of 94 residential framing carpenters within a larger longitudinal cohort study looking at the effectiveness of the HomeSafe Pilot Program, a safety and health program designed by OSHA Region VIII and the Home Builders Association of Metropolitan Denver to reduce injuries and fatalities in residential construction (Gilkey et al., 1998). Approximately 5,500 framing carpenters were identified within the larger residential construction population of approximately 50,000 working in the program area, which was restricted to five counties in the Denver metropolitan area. A randomly selected sample of 94 framing carpenters was identified through participating general contractors within the HomeSafe Pilot Program. The study also incorporated a laboratory component for ergonomic analysis using computer-based software. Data were collected using a 91-question self-report survey focused at identifying prevalence and risk factors for LBP as well as obtaining video samples of select job-tasks. Subjects were asked to rate perceived strain to the low back while performing the 44 major job-tasks required to build a wood-framed house using a modified Borg scale 1 - 5 where 1 = non strain and 5 = very high strain. Using the subjective strain scores a subset of 10 job-tasks were identified and analyzed using The Ovako Working Posture Analysis System

(OWAS) and ErgoMaster 2-D software to evaluate risk of injury and compression and shear forces to the lumbar spine during routine carpentry work. The computer-based evaluations were carried out in the Ergonomics Laboratory at Colorado State University. The protocol was approved by Colorado State University's Human Research Committee (campus IRB).

DATA ANALYSIS

Questionnaire data were entered into SPSS[®] for storage, management, and limited analysis. SAS[®] software was principally used for statistical analysis. Descriptive statistics, frequencies, univariate analysis, and correlations were derived for the analysis using appropriate methods (Neter et al., 1993; SAS, 1999; SPSS, 1999). Survey data were found to be normally distributed using the one-sample Kolomorov-Smirnov test (SPSS, 1999). Descriptive statistics included the generation of mean scores for each of the variables measured including prevalence proportions for LBP. GLM-MANOVA and one-way ANOVA were used to evaluate variability between quantitative ergonomic job-task factors with mean values computed for each of 25 job-task elements for each of the 10 job-tasks (SAS, 1999). This statistical test was used to assess the differences and similarities between and within each of the ergonomic parameters between all ten job-tasks evaluated and identify the significance of any differences or similarities.

RESULTS

Ergonomic Elements of Posture and Strain

Subjective mean scores were derived for all 44 major job-tasks see Table 1. The range varied significantly between job-tasks from 1.051 – 3.082 (1=nonstrain to 5=very high strain).

Table 1 Mean Strain Scores for 44 Major Carpentry Tasks

Carpentry Task	N	Mean	Std. Dev.
Create cut list	93	1.051	0.854
Set up cut station	93	1.357	0.997
Cut roof vents	94	1.374	1.036
Measure layout	94	1.404	0.989
Install beams using crane	93	1.418	1.025
Plate beams place by crane	94	1.465	1.043
Install roof anchors	94	1.490	0.987
Snap lines	94	1.525	0.993
Roll out / set up tools	94	1.557	0.100
Roll up / put tools away	94	1.612	0.870
Install truss clips	94	1.626	0.932
Build basement floor	91	1.667	1.659
Lay out plates	92	1.691	0.993
Square wall	93	1.704	0.997
Nail metal connections	94	1.725	0.882
Install sill plates	94	1.788	1.062
Build exterior deck	94	1.821	1.530
Break materials	94	1.879	1.127

Boom trusses	94	1.889	1.058
Brace trusses	94	1.909	1.001
Sheet gable ends	92	1.928	1.148
Cut tails	93	1.949	1.319
Cut floor joists	93	1.969	1.069
Rack trusses	92	2.010	1.319
Install fascia rafters	93	2.031	1.599
Build and install partitions	92	2.071	1.133
Clean up scrap material	94	2.091	1.144
Cut material	93	2.173	1.036
Sheet exterior wall down	93	2.183	1.039
Sort precut floor trusses	94	2.192	1.307
Frame walkouts	94	2.212	1.145
Sort wall material	93	2.255	1.087
Build and install stairs	94	2.296	1.430
Install floor joists	92	2.412	1.256
Sort floor materials	94	2.444	1.180
Sheet first row on roof	94	2.541	1.278
Finish sheeting roof	94	2.551	1.219
Sheet exterior wall upright	93	2.556	1.250
Sort trusses	93	2.633	1.161
Set pre-built stairs	94	2.636	1.396
Plate beams place by hand	93	2.776	1.721
Sheet floor w/ 3/4" OSB	94	2.788	1.223
Stand walls	93	2.969	1.312
Install beams by hand	93	3.082	1.360
Strain sum score	94	91	33

*Job-tasks arranged in the order of mean strain scores

Ten job-tasks were selected for ergonomic evaluation to measure biomechanical and risk categories using computer-based software to develop job-task profiles based on objective elements measured. Each of the job-tasks was observed and recorded by video and was subsequently viewed and assessed using computer software. Five easier tasks with lower subjective mean strain scores < 2.0 and 5 harder tasks > 2.0 with higher subjective mean low-back strain scores were evaluated for comparison:

<u>Easy Tasks:</u>	<u>Mean Strain Score</u>
1. Creating a cut list	1.051
2. Set up cut station	1.357
3. Measure layout	1.404
4. Roll out	1.557
5. Lay out plates	1.691

Hard Tasks:

6. Sorting wall material	2.255
7. Installing floor joists	2.412
8. Sorting trusses	2.633
9. Sheeting floors	2.788
10. Standing walls	2.969

Each of the 10 tasks was evaluated for spinal loading and posture demands using ErgoMaster[®] and OWAS[®] software. OWAS[®] action categories were derived based upon work postures and loads managed for each job-task (Table 2). This is an overall ‘risk’ or ‘action category’ defined by previous authors (Kant et al., 1984; Koru et al., 1977; Kivi and Matilla, 1991; Matilla et al., 1992; Matilla et al., 1993).

Table 2 Comparing OWAS Action Categories Among Tasks

Carpentry Task	Percent of Time in Category			
	Category 1	Category 2	Category 3	Category 4
Creating a cut list	67	30	3	0
Set up cut station	3	97	0	0
Measure layout	32	65	3	0
Roll out / tool set up	77	17	7	0
Lay out plates	33	67	0	0
Sort wall materials	57	40	3	0
Installing floor joists	29	60	11	0
Sorting trusses	80	15	5	0
Sheeting floors	33	67	0	0
Standing walls	17	70	13	0

*Category 1 = Normal postures, no action required.

*Category 2 = The posture is slightly harmful, actions to change postures should be taken in the near future.

*Category 3 = The posture is distinctly harmful, actions to change postures should be taken ASAP.

*Category 4 = The posture is extremely harmful, actions to correct postures should be taken immediately.

Each task was evaluated for total spinal compression, total spinal shear, bending moment, joint reactive forces, erector spinae forces and compression due to load, upper body weight, and erector spinae muscles. Total shear was calculated as well as shear due to load, upper body weight, and erector spinae muscles. Tasks were also evaluated for differences in posture patterns by percent of total task-time including: back straight, bent, twisted, or bent and twisted, arms below shoulders, one or both arms above shoulder height, general body posture of sitting, standing, or walking, and load ranges < 10 kg, 10 – 20 kg, and > 20 kg. The NIOSH Action Limit (AL) of 3,425 N and Maximum Permissible Lift (MPL) of 6,361 N were used as reference doses for comparison values relative to task compression demands. Significant differences were seen between job-task ergonomic measures as well as within job-task variability, see Table 3.

Ergonomic Task Demand Parameter of Measure	Between Task Variability P-Value	Within Subject Variability P-Value
Total spinal compression	<0.0001*	0.041*
Total spinal shear	<0.0001*	0.009*
Total bending moment	<0.0001*	0.023*
Total joint reactive forces	<0.0001*	0.036*
Erector spinae forces	<0.0001*	0.029*
Spinal compression due to load	<0.0001*	0.842
Spinal compression due to upper body weight	<0.0001*	0.007*
Spinal compression due to erector spinae	<0.0001*	0.039*
Spinal shear due to load	<0.0001*	0.808
Spinal shear due to upper body weight	<0.0001*	<0.001*
Spinal shear due to erector spinae	<0.0001*	0.029*
Horizontal distance from spine to load	<0.0001*	0.718
Percent time back straight during task	<0.0001*	<0.001*
Percent time back bent during task	<0.0001*	<0.001*
Percent time arms below shoulders	<0.0001*	<0.001*
Percent time load was < 10 kg.	<0.0001*	0.999
Percent time load was between 10 - 20 kg.	<0.0001*	0.308
Percent time load was > 20 kg.	<0.0001*	0.166
Percent time in Action Category 1	<0.0001*	<0.001*
Percent time in Action Category 2	<0.0001*	<0.001*
Percent time in Action Category 3	<0.0001*	<0.001*

When comparing differences in ergonomic measures between easy vs hard job-tasks, less variability was seen, see Table 4.

Ergonomic Task Demand Parameter of Measure	Easy Tasks Mean N	Hard Tasks Mean N	Difference P-Value
Total spinal compression	3,681	4,436	0.226
Total spinal shear	1,045	1,019	0.879
Total bending moment	179	194	0.653
Total joint reactive forces	4,582	5,311	0.376
Erector spinae forces	3,595	3,897	0.649
Spinal compression due to load	12	218	<0.001*
Spinal compression due to body weight	132	358	0.002*
Spinal compression due to erector spinae	3,437	3,736	0.666
Spinal shear due to load	54	209	0.059
Spinal shear due to upper body weight	459	308	0.009*
Spinal shear due to erector spinae	499	541	0.648

OWAS Parameter of Measure	Easy Tasks Mean % Time	Hard Tasks Mean % Time	Difference P-Value
Horizontal distance from spine to load	45	42	0.620
Percent time back straight during task	55	56	0.878
Percent time back bent during task	43	36	0.214
Percent time back bent and twisted	0.3	7	0.032*
Percent time arms below shoulders	89	82	0.008*
Percent time one arm above shoulder	0.5	7	0.007*
Percent time load was < 10 kg.	87	57	<0.001*
Percent time load was between 10 - 20 kg.	6	6	1.000
Percent time load was > 20 kg.	6	36	<0.001*
Percent time in Action Category 1	47	48	0.884
Percent time in Action Category 2	46	48	0.648
Percent time in Action Category 3	6	3	0.161

* Significant $p < 0.05$

When comparing peak compression values for job-tasks to the NIOSH AL and MPL, estimated forces exceeded the AL threshold in seven of 10 job-tasks, see Table 5.

Carpentry Task	Compression N	% Exceeded AL	% Exceeded MPL
Measure layout	2884 N	Not Exceeded	Not Exceeded
Creating a cut list	2964.7 N	Not Exceeded	Not Exceeded
Roll out / tool set up	2964.7 N	Not Exceeded	Not Exceeded
Sorting wall material	3497.4 N	.02 Percent	Not Exceeded
Set up cut station	3574.8 N	.04 Percent	Not Exceeded
Lay out plates	3742.1 N	.08 Percent	Not Exceeded
Sheeting floors	3855.3 N	11 Percent	Not Exceeded
Sorting trusses	4129.2 N	17 Percent	Not Exceeded
Installing floor joists	4352.4 N	21 Percent	Not Exceeded
Standing walls	8606.7 N	60 Percent	26 Percent
NIOSH Action Limit (AL) 3,425 N Maximum Permissible Lift (MPL) 6,361 N			

Low Back Pain and Injury

Point prevalence – 14%: Fourteen percent of respondents reported that they had suffered a recent episode of LBP within the past two weeks of sufficient intensity to seek treatment or alter some aspect of normal living. Fifteen of the 44 job-tasks were also significantly correlated ($p < 0.05$) to the point prevalence of LBP such as creating a cut list, measure layout, layout plates, rollout / tool set up, and sorting trusses.

Period prevalence – 38%: Thirty-eight percent of respondents reported that they had suffered an episode of LBP within the past 12 months sufficient to seek treatment or alter some aspect of normal living. Nineteen of the 44 job-tasks were significantly correlated

($p < 0.05$) to the 12-month prevalence of LBP such as installing floor joists, sheeting floors, laying out plates, and squaring walls.

Lifetime prevalence – 54%: Fifty-four percent of respondents reported that they had suffered an episode of LBP or injury in their lifetime that had caused them to seek medical care or altered some aspect of normal living. Nineteen of the 44 job-tasks were also significantly correlated ($p < 0.05$) to lifetime LBP such as installing floor joists, sheeting floors, squaring walls, setting pre-built stairs, and standing walls.

DISCUSSION AND LIMITATIONS

It is believed that job-task specific risk factor identification provides a superior basis for designing appropriate interventions. Understanding those partial contributions to the overall work stress can provide information for developing effective controls. Prior studies have focused on the presence of ergonomic risk factors such as heavy loads, high trunk stresses, and awkward postures, or epidemiological approaches to identify problematic job-tasks. Ten job-tasks were sampled using video recording and then analyzed using OWAS[®] for elements of postural variation and load demand. Significant differences ($p < 0.01$) were seen between the 10 job-task samples for all applicable OWAS[®] elements measured. This software system classifies a relative ranking for ergonomic intervention if needed. Action Categories (AC) classify the relative risk and urgency for intervention to prevent musculoskeletal disorders due to exposure, especially to LBP. No job-tasks were classified into AC 4, requiring immediate intervention. Looking at those job-tasks rated in AC 3 (8/10), most had exposure from three to six percent of the time. The job-task “standing walls” was assigned 15% exposure time in AC 3; this was by far the highest exposure of all 10 tasks. A study by Kivi and Mattila (1991) evaluated 12 jobs and 39 essential tasks in commercial construction but did not include carpenters in their sample. They did, however, identify timbermen and construction workers at less than 10% time in OWAS AC 3; the 4 trades exceeding 10% were cement, repair, concrete workers, and bricklayers. These trades may compare well to carpenters in that they also do not appear to rank high in AC 3, recognized as distinctly harmful. Carpenters perform many tasks bent forward but have much greater mobility and postural change in the course of their workday than do concrete and cement workers. Much of their work is performed at ground level and requires prolonged forward bending and heavy lifting. Work done in the kneeling position that requires excessive and prolonged forward reaching might reveal higher AC ratings.

The 2-D ErgoMaster[®] software used in the study quantifies and separates contributing elements of spinal compression due to body weight, load, and joint reactive forces. The values felt most meaningful were total compression and shear values. The present study findings ranged from 2,884 N to 8,606 N, much higher than seen by other investigators. Prior research led NIOSH to establish the action limit (AL) at 3,425 N to protect workers from low back injury (Waters et al., 1993, 1999). Mirka et al. (2000) did not find values close to those seen in this study when looking at framing carpenters. His team integrated compression values over the entire work shift and did not present peak loading per job-task as done in this study. In this study 7 of 10 evaluated tasks breached the action limit, whereas the standing-walls job-task exceeds the MPL by 26%. Standing walls can be a very stressful job-task depending on the size and weight of the wall.

The present study has certain limitations in its design and conclusions. The design was a nested cross-sectional study within a larger cohort of volunteer residential construction workers in the Denver Metro area of Colorado participating in the HomeSafe Pilot Program. By virtue of their voluntary participation, the subjects were not truly randomly selected and may not represent the average framing carpenter either in Colorado or in the nation (Bigelow et al., 1998a, b).

The use of a cross-sectional design is inherently limiting (Heacock, Koehoorn and Tan, 1996). The findings represent a slice in time and cannot establish causation. The order of risk factors, endpoints, and other potential confounders and their actual interactions cannot be determined with this type of study (Sorock and Courtney, 1996). The sampled job-tasks may not represent the most common methods of work. The job-task variability may not have been captured due to small sample size, and the non-random sample may not represent the average worker (Sorock and Courtney, 1996).

Construction is difficult and physically demanding work and is clearly affected by survivor bias (Burdorf et al., 1997; Sorock and Courtney, 1996). Men and women who cannot manage the stresses and strains inherent in this work leave the industry. Those framers evaluated may represent a group of workers not representative of the average population. Mean anthropometric measures for stature/height and weight suggest that the average residential framer is slightly larger and heavier than the average American citizen or military personnel (Kroemer et al, 1997). This subset of people may have additional features or characteristics not measured that further influence findings in ways not recognized.

The use of a self-report survey instrument is inherently influenced by the multitude of factors that can potentially affect personal opinions (Davis and Heaney, 2000; Viikari-Juntura et al., 1996). Although the ergonomic assessment tools in the present study have been validated and appeared appropriate, their exact use in this study may not have represented their optimum measurement ability. Tools may not have been used in a manner required to obtain accurate data in results. There may exist misclassification of information on the subject due to inaccurate or incomplete reporting.

The workers may have been affected by the presence of the investigator onsite collecting video recordings of their work, a “Hawthorne effect” (Rossi et al., 1979). Workers may in fact be exposed to greater stresses through common work practice not seen or sampled during filming. Job-task sampling time was limited in many cases due to the fragmented nature of construction work, erratic building schedules, lack of materials supply, weather, and lack of cooperation by workers or management, etc. Many phases of building facilitate parallel job-tasks making it very difficult to separate specific job-tasks from the overall work activity. Materials or equipment availability, tool operations, job-task skills, authority, interest, or management factors may result in job-task changes moment by moment. Framing carpenters follow a building plan but may have many divergent paths to achieve the overall goal of building a house with little regard for investigational activities on site. Carpenters performing job-tasks are not necessarily doing so in a linear systematic fashion but rather tend to maneuver between job-tasks. Sampling some job-tasks was quite challenging for this reason and may not accurately represent the intended job-task.

In some cases, the major job-task of interest was a multi-step process and was not fully assessed. Decisions were made by the investigator about the representative sampling necessary to capture the job-task demands through whole-task or sub-task sampling. These decisions may not have been adequate to describe all the actual elements of posture and loading associated with each job-task evaluated. Inadequate exposure assessment has been identified as a significant limiting factor in studies looking at ergonomic risk factors for LBP and other musculoskeletal disorders (Burdorf et al., 1997; Heacock et al., 1997; Sorock and Courtney, 1996).

The nature of 2-D sampling is inherently limited in its ability to assess real-life activities and motions. Only those images at or near perpendicular to the subject can be used for assessment and may not represent the actual forces being generated. This type of assessment makes no effort to describe torsional forces, which may also pose significant risk. The investigator was limited by hazards on the jobsite as well as the need to be inconspicuous and non-disrupting to the usual work process. The use of ErgoMaster[®] is fairly friendly but does require height and weight of subject and weight of load values. Carpenters consenting to be filmed were asked for this personal information. The carpenters may not have provided accurate information. The tools and materials were weighted with a force gauge provided by the Industrial Hygiene Laboratory from the Department of Environmental Health at Colorado State University. Errors in weighing may have affected the accuracy of this information and thus the results. Software use requires placement of the cursor on specific body parts to determine moment arms and vectors in the calculation of compression and shear forces. It is possible that human error in the evaluation process affected the accuracy of the estimates made.

The OWAS[®] software does classify twisting and bending postures but is limited to 30 second observation intervals for predominant posture and load classifications. OWAS[®] is a validated assessment tool for ergonomic risk but the sensitivity of the tool is still limited to 30 second captures. The nature of construction work is dynamic and changing. Postures, loads, and activities may change dramatically from moment to moment. The sensitivity of OWAS[®] may not have captured this dynamic work as it is actually performed.

For the multiple parameters of measurement a much larger sample size would be more robust for both sampling subjective strain ratings and ergonomic elements. The sample size is adequate for making external inferences about 12-month prevalence of LBP in residential carpenters but it lacks power for several other endpoints. Statistical power has been identified as a limiting factor by other investigators (Bouter et al., 1998; Burdorf et al., 1997; Heacock et al., 1996).

Regardless of the quality of tools used for exposure assessment in this study, the multi-dimensional nature of factors attributable to LBP cannot all be measured (Burdorf et al., 1997). Not fully understanding all exposure elements and their relationships limits the quality of the data and the inferences drawn. Burdorf et al. (1997) identify postural loads, mechanical loads, psychophysical, physiological, psychological, organizational, and individual factors as areas relating to LBP causation. These areas were not fully investigated.

The definition of LBP was vague. The verbiage represents standard medical terminology used in performing medical evaluations of injured and/or disabled workers with LBP (Gilkey and Williams, 1998). There was no attempt to delineate types of pain or a diagnosis. The inexact

nature of symptomatic complaints such as LBP has been recognized as a source of potential bias by many investigators (Bouter et al., 1998; Miettinen and Caro, 1989).

LBP is ubiquitous among humankind. Although it doesn't occur purely on a random basis and risk factors have been identified (Sorock and Courtney, 1996) it is not well understood in total. Carpenters appear to be a group of workers exposed to greater levels of risk relating to LBP; however, no clear job-task associations can be made. This study does not possess the scope and depth to thoroughly compare job-tasks of residential framing carpentry to that of the general population. The real causes of their back pain will remain a mystery for the present.

Future research can focus on the link between subjective and objective measures. Additional work needs to be completed to evaluate the explanation of strain ratings using objective measures.

FINAL CONCLUSIONS

The forces and risks experienced daily in residential framing are significant and need to be addressed. LBP remains a problem in all areas of construction, both residential and commercial. This investigation has pioneered ergonomic research in residential framing carpentry. The benefits of such research can be achieved through the development of control strategies to reduce workloads from their present levels thereby reducing risk of LBP in workers. The present study establishes new ground for understanding framing carpentry, asking questions, and suggesting improved methodologies for additional research.

Future evaluation will explore and compare differences and similarities between the two ethnicities. It is hoped that more can be learned about multifactorial nature of LBP and its influences on framing work in residential carpentry. There remains an interest in developing integrated models to predict LBP among carpenters using ergonomic and psychosocial factors as well as control strategies to reduce risk in injury.

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