DISSERTATION

OCCUPATIONAL LOW BACK PAIN IN RESIDENTIAL CARPENTERS:
ERGONOMIC ELEMENTS OF POSTURE AND STRAIN

Submitted by

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ASBSTRACT OF DISSERTATION

OCCUPATIONAL LOW BACK PAIN IN RESIDENTIAL CARPENTERS:

ERGONOMIC ELEMENTS OF POSTURE AND STRAIN

Occupational low back pain (LBP) continues to be industry's number one health and safety challenge. Despite the advances in health care diagnosis and treatment, LBP is at epidemic proportions among many industries including construction. Identifying and understanding the risk factors for occupational LBP is critical to the development of effective prevention controls and management.

Residential homebuilders make up nearly half of all construction workers in the US. Few studies have been carried out in the home building industry to investigate risk factors for LBP. This study was initiated for the purpose of investigating ergonomic elements of strain, posture, and spinal loading in residential construction as well as personal and workplace factors and their relation to occupational LBP. Subjects were framing carpenters within the HomeSafe Pilot Program.

Ninety-four framing carpenters were evaluated for subjective low back strain related to 44 major job-tasks in addition to personal and workplace risk factors. The point, 12-month, and lifetime prevalence of LBP was determined. Ten job-tasks were sampled and evaluated using computer-based ergonomic assessment tools to characterize ergonomic elements of posture, spinal loading, and risk categories.

Findings from this study suggest that carpenters do have higher prevalence rates for LBP compared to the general population. It was also found that many personal and workplace factors are related to perceived low back strain ratings of specific job-tasks. Ergonomic profiles were developed on 10 representative job-tasks confirming that postures and spinal loads do vary among job-tasks in residential carpentry. Integrated logistic regression models were developed that identified both job-tasks and personal factors that were related to increased risk of LBP.

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DEDICATION

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CHAPTER 1

Introduction

This project investigated the ergonomic risk factors for occupational low back pain (LBP) in residential carpenters. The primary focus was measuring subjective low back strain at the job-task level and elucidating the elements of working postures and spinal loading to better understand risk factors associated with LBP. In addition, personal and workplace factors were evaluated to determine their relationships to the perception of stress and strain related to performing specific job-tasks and to LBP. The point, 12-month, and lifetime prevalence of LBP was determined in the study subjects. Chapter 1 provides a brief background of the subject, problem statement, hypothesis, and description of the research aims for the study. Chapter 2 provides a review of the literature for each of the relevant topic areas: occupational low back pain, the construction industry, residential construction, and the health and safety program called HomeSafe, carpenters, risk factors, and risk perception. Chapter 3 describes in detail the study design, research methods, and statistical procedures used to carry out the investigation and analysis. Chapter 4 presents the results from the data analysis. Chapter 5 includes a discussion of the findings and conclusions including statements concerning the study aims, limitations, and future research needs and interests.

Background

Occupational LBP remains the most costly industrial health problem in America. Despite the plethora of research on LBP, precise causes continue to elude health care providers, scientists, and safety professionals. It has been established that ergonomic, personal, and workplace factors have a bearing on the incidence and prevalence of LBP in every industry studied. Construction requires heavy physical work and carpenters are plagued with a higher prevalence of LBP than the general population. Residential construction employs nearly 50% of the 7 million workers presently employed in construction nationwide. Research is needed to better understand the perceptions, risks, and hazards in residential construction that are linked to LBP.

Problem Statement

Occupational LBP is occurring at epidemic proportions among America's construction workers. It can have devastating affects on workers' compensation and health care costs, disrupt normal business operations, and result in chronic disability for those afflicted. Ergonomic risk factors have been associated with onset and re-occurrence of LBP in construction work but they are not well understood in relation to specific job-tasks in residential carpentry. There is minimal understanding about the link between personal characteristics, perceptual influences, and ergonomic elements and LBP in framing carpenters.

Research Aims

The aims of this study provide a framework for investigation to evaluate risk factors for LBP in residential carpenters; they define research goals, activities, and components of the study. Addressing these aims provides a basis for discussing relationships between personal, workplace, mechanical, and psychosocial risk factors to LBP. The specific aims are to:

1. Measure and analyze those job-tasks related to LBP in residential framing carpenters and evaluate personal and workplace characteristics that may have relationships.
2. Measure and analyze subjective strain / effort related to framing job-tasks and evaluate personal and workplace characteristics that may relate to the perception of strain / effort.
3. Measure and analyze body postures related to job-tasks using the Ovako Working Posture Analysis System (OWAS).
4. Measure and analyze lumbar spine compression with ErgoMaster 2-D software.
5. Measure prevalence of LBP in residential carpenters.
6. Measure risk perception relating to framing carpentry and analyze the relationship to major carpentry job-tasks.

Hypothesis

Framing carpentry workers are at increased risk of LBP due to specific job-tasks.

CHAPTER 2

Literature Review

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). Guo et al. (1995, 1999) estimated that over 22.4 million back pain cases were reported in 1988 with 65% being occupationally related. Occupational LBP is a devastating and paramount concern to business and industry, the economy, and the nation's health care system (Cassidy and Wedge, 1988; Cleary et al., 1995; Cote et al., 1998; Kelsey and Gordon, 1987; NIOSH, 1996). 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). Kahlil et al. (1993) reported that the average surgical case cost exceeds $40,000. 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, 2001). The average back claim was recently reported to have exceeded $40,000 in the state of Ohio (Marras, 2000). The most startling fact is that between 7.4% and 15% of the cases consume 90% of the dollars spent on LBP. 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

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, 1997a; 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). The non-fatal incidence rate (IR) (number of non-fatal injuries per 100 full-time employees [FTEs]) and severity rate (SR) (number of lost workdays per 100 FTEs) reported by the Bureau of Labor and Statistics (1998e) for 1997 in the construction industry, combining all trades, were 10.0 and 4.7 per 100 FTEs, respectively; these levels are significantly higher than the national corresponding averages of 3.3 per 100

FTEs and 2.1 per 100 FTEs. 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).

Residential Construction and HomeSafe

Residential construction workers represent nearly half of the construction labor force and are among the highest at risk for injury, illness, and death (Guo et al., 1995). In 1997, there were 678,300 injuries reported in residential construction alone (BLS, 1998b). Dement and Lipscomb (1998) evaluated 30,000 workers' compensation claims within residential construction over an eight-year period in North Carolina and found that overall injury rates for all trades were 16.4 (IR) per 100 FTEs and 10.78 (SR) per 100 FTEs. Back injuries were the most frequently injured body part at 25%, and strain was the most common (21%) reported cause. Looking closely at lifting and movement injuries, investigators found that 59% affected the back and 73% were strain related. Lipscomb et al. (1997) investigated 10,935 construction workers in Washington State and found a back strain rate of 5.4/100 workers with an odds ratio (OR) of 1.5 for back injury among residential builders.

Because of the paucity of research on injury in residential construction, OSHA Region VIII and the Home Builders Association of Metropolitan Denver (HBA) worked together to identify those hazardous exposures and activities most common to residential construction workers. Their intent was to identify those specific and unique hazards that were known to cause injury or death within the homebuilding industry. After reviewing all available death and injury reports from 1995, they identified 10 areas: scaffolding, ladders, electrical power and power cords, access and housekeeping, open holes and unprotected sides and edges, falls, power tools, and motorized equipment (Gilkey et al., 1998). The HomeSafe Pilot Program was launched in January 1997 as a strategic partnership between OSHA Region VIII and the HBA. Their diligence formed the basis for developing the core content of HomeSafe. HomeSafe is a specifically designed safety and health program meant to address those real risks and hazards unique to residential construction. Transportation and drug abuse were also significant concerns but could not be integrated into HomeSafe. The evaluation of the HomeSafe Pilot Program was a longitudinal study funded by NIOSH and conducted at Colorado State University from 1997 through 2001 (Bigelow et al., 1998a, b). The successes of HomeSafe have led to over 60 strategic partnerships nationwide between industry and OSHA.

Carpenters

Carpenters comprise the largest trade in the construction industry with nearly one million workers who are among the highest at risk for injury, illness, and death (BLS, 1998a, b, c; CPWR, 1997; Guo et al., 1995, 1999; NIOSH, 1997b). The non-fatal incident and severity rates (IR & SR) reported by the Bureau of Labor and Statistics (1998b) for carpenters were among the highest at 12.2 IR per 100 FTEs and 5.9 SR per 100 FTEs, respectively. Dement and Lipscomb (1998) also found an IR of 22.9 and SR of 15.3 per 100 FTEs among carpenters. It has been well established that framing carpenters are exposed to significant postural strain and excessive physical effort due to job-task demands and therefore suffer unnecessary low back pain (Cook et al., 1996; Helander, 1981; Holmstrom et al., 1992a, b). Carpenters are also confronted with open holes and unprotected sides exposing them to potential fall hazards, a leading cause of death in construction. The major sources of injury in carpentry involved: parts and materials, floor and ground surfaces, and worker motion or position; these accounted for nearly 60% of all sources of non-fatal injury. The major events that caused non-fatal injury were reported to be: contact by, struck by, overexertion, and fall to a lower level. The leading types of non-fatal injuries and illnesses experienced by carpenters are: sprains and strains, bruises and contusions, cuts and lacerations, soreness and pain, fractures, multiple injuries, back pain, carpal tunnel syndrome, heat burns, tendonitis, and chemical burns. Sprains and strains comprise nearly half of all non-fatal injuries at 43.6%. The most common body parts injured in decreasing order are trunk, back, upper extremities, and lower extremities (BLS, 1998d). Cook et al. (1996) found 71.6% of 438 carpenters surveyed reported low back complaints within the past 12 months with 10.3% missing work due to symptoms and 33.7% consulting medical care.

The nature of residential carpentry work includes a variety of job-task demands such as cutting, handling, fitting, installing, and assembling wood materials into products such as single-family homes, duplexes, apartments and other wood frame structures (BLS, 1998a, c; Cook et al., 1996; Helander, 1981). Framing carpenters build the skeleton structure of a building by erecting walls, partitions, window wells, floors, stairways, ceiling and roof joists, and preparing the structure for other trades to follow in the sequence of home building. As a consequence of the diversity of work demands and environment, they are exposed to a variety of potential hazards including excessive physical demands and awkward postures. Cook et al. (1996) investigated the degree of problem or difficulty associated with specific carpentry work tasks as reported by workers. Three hundred thirty-three carpenters responded to the survey and reported the major problematic tasks involved: holding the same position for an extended time, awkward bending/twisting of the back, being in awkward or cramped positions, reaching overhead or away from the body, and carrying or lifting heavy materials.

Carpenters are skilled workers whose task is to build structures made of wood. A carpenter's work is primarily dynamic muscular work with varying postures and loads within the context of a changing environment resulting in exposure to a wide array of potential work practice and workplace hazards. Framing carpenters, who predominately build and erect framing for residential dwellings, face numerous risks and hazards beyond those encountered by other carpenters.

Risk Perception

Perception is "the process through which we select, organize, and interpret information gathered by our senses in order to understand the world around us" (Greenberg and Baron, 1997 p.72). Risk perception is the process of recognizing, evaluating, and judging the risk inherent to activities and environments so that we can engage the world around us. Carpenters, like all construction workers, are faced with the challenge of identifying, assessing, and interacting with known hazards on a daily basis. Workers respond to hazards they perceive; risk perception and understanding of a situation determines how workers behave or what actions and risks they are likely to take (Geller, 1996; Geller et al., 1996; Hollnagel, 1997; Slovic et al., 1980).

Research on safety motivation shows that hazard recognition is an essential element of human behavior. "Inexperienced construction workers generally underestimate the hazard and need training in hazard recognition. The studies in risk perception also indicate that construction workers typically underestimate the hazards inherent in their own work" (Helander, 1991, p. 221). "Behavior is determined by perceived rather than actual risk" (Geller, 1996, p.60). "As each day goes by without receiving an injury, or even a near hit, we become more accepting of the common belief, 'It's not going to happen to me' " (Geller, 1996, p. 59). Construction workers take risks every day; each of the risks taken must be appreciated in the context of their "beliefs, expectations, needs, loves, hopes, and fears which justify it or which, at least, make it explicable in human terms" (Sagoff, 1985, p.29). To take action, human perception and judgment must be exercised.

Judgments are a reflection of both past and present experience and influenced by many variables. Hoyos and Ruppert (1995) outlined the 'mental load' a worker must exercise to control one hazard: "5 perceptual acts, 2 judgment acts, 3 acts of planning and taking precautions, 2-3 psychomotor acts, and 2-3 acts of cooperating and communicating" (p. 114). Judgments about risks are not always accurate. Misjudging risks is common and can lead to injury or death; "decisions about risk-taking are made every day by workers. By playing the odds and shooting for the short-term gains, risky work practices are often accepted and not perceived to be as dangerous as they actually are" (Geller, 1996, p. 62).

Carpenters continue to experience unacceptable levels of injury and death on the job. Rey and Bousquet (1995) ranked the building and construction industry as highest for rate of injury. High rates of injuries suggest inappropriate risk perception by workers. Health behavior models suggest that all behaviors begin with perceptions and judgments before actions are taken (Dejoy, 1996; Melamed et al., 1996; Rundmo, 1995). Helander (1991) concludes that, "It is important to investigate the motivational issues in safety training to understand what aspects should be emphasized to change the behaviors of construction workers" (p. 221). More research is needed on job-specific injury risks in the construction industry (Hunting et al., 1994). "Accidents may be an important consequence of risk perception or, more precisely, an inaccurate perception of the risk" (Rundmo, 1995, p. 87). A task-based approach to evaluating the activities of framing carpenters establishes the framework for understanding their jobs. The risk perception, task, exposure, and behavior link have not been fully explained. Risk perception is a link to understanding human behavior and injury potential.

Ergonomic Risk Factors of Occupational Low Back Pain

NIOSH (1997a) published the most comprehensive review to date of over 600 studies selected from over 2000 published epidemiologic and scientific investigations that evaluated potential causes of musculoskeletal disorders (MSDs) including occupational LBP. Their findings strongly suggest that lifting, forceful movement, awkward postures, whole-body vibration, and psychological factors are associated with occupational LBP in the working population. Kumar (2001) discussed theoretical underpinnings of musculoskeletal injury including multiple ergonomic risk factors mediated by mechanical degradation of collagen structures. Ergonomic risk factors such as overexertion and sudden loading are impacted by biomechanics, psychological, morphological, and genetic factors. Solomanow et al. (1999) suggested that creep-induced viscoelastic changes due to cyclic loading result in destabilization of the spine and thus render it vulnerable to injury. Additional investigators also confirm adverse responses to cyclic loading in the spine (Adams and Dolan, 1995; Gedalia et al., 1999; McGill, 1997).

Marras (2000) modeled the onset of LBP due to ergonomic risk factors generated from internal and external forces including compression, shear, and torsion. The theory alleges that biomechanical forces cause micro fractures of the disc endplate leading to scarring, reduced nutrients, degeneration, and decreased tolerance and work capacity. It has been commonly accepted that a load of 3,400 Newtons (N) of force can cause endplate micro fracture and loading of 6,400 N will adversely affect at least 50% of the working population (NIOSH, 1981).

LBP has also been associated with additional work, personal, psychosocial, and social risk factors including: age, sex, stature, strength, mobility, previous history of LBP, co-morbidity, depression, job dissatisfaction, monotony, heavy physical work, education, whole body vibration, marital status, exercise, non-work recreation, and smoking. Investigators have identified one or more preceding risk factors for LBP (Adams et al., 1999; Andersson, 1981, 1997; Barnekow-Bergkvist et al., 1998; Battie et al., 1989a, b; Battie et al., 1990; Biering-Sorrensen, 1984; Bigos et al., 1986a, b; Bigos et al., 1991; Bovenzi and Zadini, 1992; Burdorf and Sorock, 1997; Burton et al., 1989; Ciriello and Snook, 1983; Cleary et al., 1995; Clemmer et al., 1991; Dempsey et al., 1997; Deyo and Bass, 1989; de Zwart et al., 1997; Fergason and Marras, 1997; Frymoyer et al., 1980; Goldberg et al., 2000; Heliovaara, 1987; Hoogendoorn et al., 1999; Koster et al., 1999; Kumagai et al., 1995; Kumar et al., 1999a; Latza et al., 2000b; Leboeuf-Yde et al., 1998; Leboeuf-Yde, 2000; Linton, 2000; Marras et al., 1993 a, b; Marras et al., 1999a, b; Marras, 2000; Oleske et al., 2000; Riihimaki et al., 1994; Skovron et al., 1994; Silverstein et al., 1996; Svensson et al., 1983; Svensson and Andersson, 1989; Thorbjornsson et al., 2000; Wilder, 1993; Xiang et al., 1999)

Ergonomic Methods of Low Back Risk Evaluation

Numerous techniques have been used to assess ergonomic hazards in construction. Common methods include: observations; still images; video recordings of work postures and activities, and the use of computer software, electrical and motion sensors, goniometry, and checklists. Ergonomic evaluation has focused on body postures, movements, load and distance measurements, and estimation of forces including compression, shear, torsion, and push and pull. Numerous investigators have identified one or more of the preceding methods for ergonomic assessment (Bhattacharya et al., 1997; Buchholz et al., 1996; Chaffin, 1969; Fathallah et al., 1998; Grieco et al., 1997; Hoozemans et al., 2001; Juul-Kristensen et al., 2001; Kee and Karwowski, 2001; Lavender et al., 1999; Lechner, 1996; Marras and Sommerich, 1993; Marras et al., 1995; Marras et al., 1999; Marras, 2000; Punnett et al., 1991; Schneider and Susi, 1994; Schneider et al., 1998; Schoaf et al., 1997; Schultz et al., 1982; Straker et al., 1997).

Spinal Compression and 2-D Evaluation

Lumbar spine compression has been considered an important parameter of measurement when considering risk of injury to the lumbar spine (Andrews and Wells, 1996; Halpren, 1992; Lavender et al. 1999; Marras et al., 1999a, b;

Marras, 2000; Mirka et al., 2001; Neumann et al., 1999; Schultz et al., 1982; Stubs, 1981). Waters et al. (1993) investigated the basis for selecting criteria to develop the Revised NIOSH Lifting Equation. These criteria included the research done on biomechanical modeling including the 2-D model for estimation of spinal loading (Water et al., 1993). They felt that the dynamic components of job-tasks such as lifting can be especially important in understanding the potential for injury. Investigators also concluded that compressive forces might be more accurately predicted using computer-based modeling such as the 2-D software available from multiple sources including ErgoMaster©.

Schultz and Andersson (1981) concluded that loads on the lumbar spine were related to back injury, potential aggravation to unstable spines, and increased chance of lost workdays. Straker et al. (1997) investigated compression and shear forces on the lumbar spine using the 2-D model to assess risk of injury. Compression and shear force were evaluated in combination with other ergonomic variables to predict relative risk of low back injury. Norman et al. (1998) investigated peak versus cumulative exposure loads to low back pain sufferers in a case-control study using the 2-D model. They found that workers in the top 25% loading category were at six times the risk for reporting low back pain. Neumann et al. (1999) investigated four spinal peak measurement methods against measured lumbar spine compression, moment, and shear forces. They set out to compare different methods used in ergonomic analysis such as video analysis, checklist, questionnaire, and work sampling. They concluded that the video analysis was the "gold standard". This type of work sampling facilitated accurate force determination and thus prediction of relative risk.

ErgoMaster© is a commercially available software program containing multiple computer-based tools to measure ergonomic risk factors including the lift analysis 2-D model. This tool was used to estimate lumbar spine compression and shear forces related to job-tasks by analyzing body position and load demands.

Work Postures and OWAS

The Ovako Working Posture Analysis System© (OWAS) was developed and introduced by Finnish researchers in 1977 as an analytical method for ergonomic analysis of work postures (Karhu et al., 1977, 1981). Work postures are classified as one of four Action Categories: 1 = normal postures which do not need special attention, 2 = postures that pose slight harm and must be considered during the next regular check of working methods, 3 = postures that pose distinct harm and need consideration in the near future, and 4 = postures that pose severe harm and need immediate consideration. Findings represent relative risk of injury related to poor ergonomic design and demand of the job-tasks (Karhu et al., 1977). OWAS has been shown to be an effective method for analyzing and evaluating work postures in many different types of industries (Kivi and Mattila, 1991; Li, 2000; Li and Buckle, 1999; Kant et al., 1984; Long, 1992; Matilla et al., 1992; Matilla et al., 1993; Vikki et al., 1993). Past studies report better than 90% reliability with OWAS between evaluations (Kiva and Matilla, 1991; Matilla et al., 1993; Tampere University, 1992). Kivi and

Matilla (1991) used OWAS to investigate various postural demands in multiple construction trades. They concluded that OWAS was an effective method, well suited for analyzing work postures in construction. Mattila et al. (1993) again used OWAS to analyze postural demands in construction looking at posture related to hammering tasks as well as perceived strain. These investigators found that a positive relationship existed between posture demands, the OWAS category, and perceived strain scores. They concluded that it is possible to identify critical postural strain using OWAS. Li and Buckle (1999) reviewed posture-based techniques used in ergonomic assessments to identify utility of the method. They concluded that OWAS is appropriate for whole-body posture analysis.

Perceived Strain

Previous investigators have used subjective scales to measure worker strain or effort required to perform various jobs (Borg, 1990; Boussenna et al., 1982; Burdorf and Laan, 1991; Ciriello et al., 1993; Davis et al., 2000; Genaidy et al., 1990; Herrin et al., 1986; Moore and Garg, 1995; Troup et al., 1987). These studies have shown that the subjective scales for perceived effort/strain are both high in reliability and validity. Borg pioneered the rating of perceived exertion (RPE) demands with the 6 – 20 scale in his original work in 1962 where 6 was no exertion and 20 was maximal exertion. Later he modified RPE to the category ratio (CR–10) scale where 0 was nothing at all and 10 was extremely strong (Borg, 1990). Borg (1990) indicates that his scaling techniques are especially appropriate in heavy aerobic work as seen in carpentry. Ulin et al. (1993) used the Borg CR-10 to assess the perceived exertion related to screwing job-tasks. Genaidy et al. (1990) compared perceived exertion ratings of workers performing both static and dynamic work to measured physiological responses such as heart rate, blood pressure, and endurance time. They found that the RPE was useful in measuring static components of the task. Kumar et al. (1999b) evaluated the sensitivity of psychophysical techniques, including the Borg scale, to assess physical stress related to manual material-handling work tasks. These investigators found that the Borg RPE was sensitive for certain task parameters of physical stress. The focus of this study was posture demands in relation to hammering tasks in construction. Moore and Garg (1995) introduced a scale patterned after the Borg scale using a 1 – 5 range where, 1 = light exertion and 5 = near maximal exertion. Matilla et al. (1993) used a 1 – 6 scale where, 1 = no strain to 6 = intolerable strain. This method was used in conjunction with OWAS to analyze the relationship between postural stress and perceived physical effort. Their findings confirmed that a relationship existed between perceived effort/strain and postural strain identified with OWAS measurements. These strain measurement techniques are ideally suited for this investigation of ergonomic risk factors in residential construction.

CHAPTER 3

Materials and Methods

Data for this study were collected in two phases. The initial phase included a 91-question survey developed and administered to 335 framing carpenters (Appendix A). The second phase was analyzing a video-sampling taken of framers performing select tasks.

The survey was designed to assess the amount of 'self-reported' back strain experienced during the major job-tasks performed by residential framing carpenters, as well to as gather personal and workplace information on other potential risk factors for low back pain.

To identify those major job-tasks performed by residential framing carpenters, individual general contractors, framing companies, building experts, OSHA, and HBA representatives were contacted by phone and mail. Lists of building phases and tasks were requested from each source. Information was received, reviewed, and assessed for similarities and differences and a comprehensive list of 44 major job-tasks was produced.

Next, a series of focus groups were scheduled with framers in the field to refine the list to accurately reflect those major job-tasks performed when building a wood-frame home. The survey was fully developed and piloted through another series of focus groups with additional modifications made as necessary. The final survey was then sent to 15 of those original expert sources for review and comment. The last step was to have the survey translated into Spanish and back-translated into English.

Copies of the survey were produced in both English and Spanish. Access to job-sites was obtained for a random sample from the list of general contractor members of the Home Builders Association (HBA) of Metropolitan Denver. General contractors were able to identify home building projects in various framing stages. General contractors obtained authorization and cooperation from the framing contractors, and site visits were scheduled.

Attempts were always made to ensure that bilingual individuals were available to assist with Spanish-speaking-only workers. A bilingual student in the Department of Environmental Health at Colorado State University assisted whenever possible for consistency and accuracy of communication with Hispanic workers.

Upon arriving at the jobsite, the foreman or crew leader was approached and authorization was obtained to survey his workers. There were no females encountered in this phase of data collection. The crew members stopped work and assembled on the worksite at the location designated by the foreman. An introduction and explanation was offered to the group by the Colorado State University investigator in the appropriate language of the crew. Crews were consistently either Spanish or English speaking but rarely mixed. Surveys were circulated and questions addressed (Appendix A). Respondents were encouraged to complete the survey using their own personal opinions and not the opinions of others. Respondents completed surveys in a timely fashion ranging from 10 - 60 minutes. Surveys were collected, returned to CSU, scored, and entered into the computer for analysis. Scoring included assigning numerical values to responses. Many responses were ordinal beginning with zero for none-effected replies increasing by one representing an increasing level of effect by the variable in question. Examples of ordinal responses included income level, amount of exercise, time spent in side jobs, or alcohol intake per week. Other responses were scored either zero or one where one was the event of interest and zero was the non-event such as in the presence of LBP or not. Numerical responses were recorded for a limited number of responses such as height or weight of the respondent.

The second phase of data collection was achieved through field video sampling of actual carpenters performing work tasks. Using mean score results from the previous survey, 10 tasks were identified: five difficult tasks representing higher strain levels, and five easier tasks representing low or no strain. Job-tasks were also considered based on their likelihood of being sampled. In some cases, tasks rated either high strain or low strain may have been very short cycled, infrequent in occurrence, and difficult to capture. Therefore, tasks likely to be viewed by the researcher and representative of the type needed were selected for final sampling. Subjects were "typical" framing carpenters and in many cases the same people who had completed the strain survey some months earlier. It was believed that those sampled by video represent the larger survey sample of 94 well.

Task sampling was orchestrated through the general contractors who best know their construction projects and building phases and the likelihood of capturing those identified tasks on video. The general contractors were randomly selected though the HBA and contacted for access. They were presented the list of desired tasks for review and recommendation. The general contractors made referrals to specific site operations and contact persons. The investigator contacted the designated construction site and scheduled a visit with the site superintendent.

Upon arriving at the jobsite, the first order of business was to check in with the site superintendent. The investigator was then directed to a specific work crew on the site location. Again, meeting the foreman or crew leader was essential for securing their cooperation and authorization to video film any members of the work crew. Typically the foreman selected one or two potential candidates for video sampling. The investigator introduced himself to all members of the crew and explained the nature, purpose, and procedures related to filming select workers. Volunteers were given informed consent forms and explained all procedures related to video sampling. The workers were given two 12" (25.4cm) aluminum rulers to fasten on either side of their work belt. Workers were instructed to perform their normal work. The investigator set up a Sony Super-8 video recorder on a tripod in the approximate area of specified workers to sample specific tasks. Electrical power was usually available onsite. If power was not available, batteries were used to power the video recorder. The NIOSH video sampling protocols were adhered to as much as possible (Appendix B).

Nineteen video sessions were conducted between March and July 2001. The typical video session samples ranged from two to four hours at any site location. On rare occasion, sessions were as short as 20 minutes or as long as 6 hours.

Laboratory analysis of video samples was carried out in the Ergonomics Laboratory in the Department of Environmental Health at Colorado State University using computer-based software. The raw video was reviewed and manually edited to separate task categories. At least three samples of each task were obtained using different workers and jobsites to reflect variability among subjects performing tasks.

The Ovako Working Posture Analysis System© (OWAS) was used to evaluate work postures. This ergonomic evaluation tool provides for systematic recording of work postures based on observer analysis and recordings while viewing actual work or videotape of work. The investigator chose to evaluate all tasks using videotape observation. A television screen and video player were placed next to the computer for ease of viewing and recording. The tapes and tasks were systematically viewed and recorded using the software tools. Analysis protocols were followed as outlined in the OWAS© operator's handbook.

A case file was created for each task evaluated. OWAS© provides screen interfaces for whole-task and sub-task analysis. Each task was characterized as whole-task and evaluated as such. Observations are made and recorded every 30 seconds. OWAS's observation screen is equipped with posture categories for back, arms, and legs as well as load range definition. Back posture observations included: 1) straight, 2) bent, 3) twisted, and 4) bent and twisted. Arm posture observations included: 1) both below shoulder, 2) one above shoulder, and 3) both above shoulder. Leg posture observations included: 1) sitting, 2) standing on two legs, 3) standing on one leg, 4) standing on two bent knees, 5) kneeling, and 6) walking. Load ranges included: 1) less than 10 kg, 2) greater than 10 kg but less than 20 kg, and 3) greater than 20 kg. Sequential observations were recorded to characterize postural changes during the task. For extremely short cycled tasks, observations were recorded through several repetitions of the task to capture the variability of work posture between cycles and individuals. Data were generated for all 10 job-tasks.

ErgoMaster© software was used to assess loading of the spine related to task demands. Use of this software was in accordance with the operator's manual and assistance from the distributor. Task videos were viewed to identify postures for peak loading during job-tasks. The computer program Dazzle, was used to capture still images from real-time video in groups of 5 – 15 frames for analysis. The image collection was evaluated by the study investigator for maximum postural deviation and spinal loading. Images were then imported into ErgoMaster© for detailed analysis. Once in ErgoMaster©, a file was created to evaluate each image and task. Locating and marking body landmarks identifies moment arms and fulcrum lengths. Key landmarks included: lateral ankle (maleolus), knee (mid-joint line), hip (trochanter), shoulder (acromion), elbow (lateral epicondyle), hand (second knuckle), and ear (meatus). The key landmarks are necessary to estimate length of body parts or fulcrums to calculate forces acting on joints. Forces provided are weight of load and body weight.

Each vector change creates a load moment or stress. The software was able to calculate compression and shear force acting on the L5-S1 level. For each analysis subject height, weight, and weight of load were entered into the file. The software then generated values for compression and shear due to posture, anthropometrics, and load factors. Data were generated for all 10 tasks and 30 workers sampled.

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 method (Neter et al., 1993; SAS, 1999; SPSS, 1999). Survey data were 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, this was performed for all variables in the data. Frequency tables were generated for all variables in the strain survey to assess the distribution of scores within the range of responses measured. Univariate analysis was accomplished to assess significance against the population mean of zero and provide mean scores for all variables. A correlation matrix was generated assessing correlation values between all data variables. This was used to assess relationships between variables and for additional analysis as in logistic regression. LBP endpoints and risk perception were correlated to job-tasks and personal and workplace characteristics to assess relationships between these variables.

The General Linear Model, Multiple Analysis of Variance (GLM-MANOVA) was used to evaluate variability in strain responses for each of the 44 job-tasks using 32 of 51 personal and job related factors as dependent variables (SAS, 1999). This statistical manipulation was used to assess the relationship of each of the personal and workplace factors to the mean strain scores for each of the job-tasks and identify variables that significantly influenced those scores.

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.

SAS© stepwise logistic regression was used to identify predictors of occupational low back pain (LBP); specifically, data on the prevalence of LBP were evaluated against the 44 tasks and 32 personal factors for predictability. Prevalence odds ratios prevalence (ORs) and confidence intervals (CIs) were obtained for each predictive model (SAS, 1999).

CHAPTER 4

Results

The entire subject sample surveyed, n = 335, was comprised of men ranging in age from 18 to 65 years. The sample comprised 68% Hispanic, 30% white non-Hispanic, and 2% other ethnicities. Differences in strain assessment scores were clearly different between Hispanic and non-Hispanic workers. Analysis of variance (ANOVA) was used to evaluate the significance of apparent differences between Hispanic and non-Hispanic groups (SPSS, 1999). Statistically significant differences were found in 42 of 44 task scores and 37 of 51 personal risk factors ($p < 0.05$, Tables 1a, 1b). It was decided to stratify the data by ethnicity and conduct a separate analysis on the non-Hispanic data and evaluate the Hispanic data separately. The non-Hispanic data were deemed to most appropriately meet the requirements of this investigation. It is possible that the Hispanic data may have bias due to language barriers, legal status, and machismo cultural influences of the Hispanic male carpenter. The resulting data set represented n = 94 non-Hispanic framing carpenters derived by collapsing all other ethnicities except Hispanic into one set.

Subject Demographics

The non-Hispanic (n = 94) data descriptive information is presented in Tables 2, 3, and 4. All respondents were male, aged 18–65 yrs. (with 50% being 35 yrs. or less) who spoke English as a primary language. The subjects tended to be larger in stature and heavier than men of the general population. Mean stature was 179.07 cm (70.5") and body weight was 83.18 kg (183 lb) compared to 175.6 cm (69") and 78 kg (172 lb), respectively, for the average U.S. male (Kroemer et al., 1997). Quetelets (body weight/stature^2) were computed and arranged in tertiles (three equal ranges) consistent with presentations by other authors (Table 56b). Fifty percent of carpenters were classified in the midrange 2.39 – 3.78, while 17.4% fell below and 32.6% were classified above. One half were married and reported at least a high school education with 36% reporting some college and 12% reporting college graduation. Thirty-three percent reported personal incomes exceeding $50,000/yr., 26% reported incomes between $35,001 and $50,000/yr., 26% reported income levels between $20,001 and $35,000/yr., 11% reported incomes between $10,001 and $20,001/yr., and only 3% reported incomes below $10,000/yr. Thirty-five percent had never smoked tobacco, and 20% were former smokers while 45% were smoking presently. Twenty-six percent reported consuming more that 10 alcoholic drinks or beers per week; 29% consumed 5 – 10 drinks per week, while 19% consumed less that five drinks or beers per week with 26% reporting no regular alcohol consumption at all. Seventy-two percent reported some regular exercise activity in addition to their work. The majority, 78%, reported no serious health problems while 6% reported having some type of arthritis and 2% reported having heart disease. Only 14% of respondents reported their health status as excellent. The majority, 76%, reported their health to be good or very good and 10% assessed their overall health as fair or poor. The majority, 71%, reported they were self-employed sub-contractors while 44% reported they were employees of the framing company. Experience in residential framing construction ranged from one to 45 years. Twenty-eight percent reported less than five years experience. Nearly 40% reported more than 10 years experience in the field. The average workweek was 45 hours, but 40% reported 50 or more hours per week. Ninety-nine percent reported being exposed to temperature extremes and 89% reported being exposed to loud noises. Fifty-four percent reported being physically exhausted frequently or more often at the finish of a day's work while 46% reported very little or no physical exhaustion related to their work. Thirty-eight percent reported no side jobs in addition to their regular carpentry work while nearly 20% reported an additional 9 – 16 hours per month involved in outside work and 5% of respondents reported more than 21 hours per month involvement in other work activities. Forty-one percent reported no coverage by workers' compensation insurance for work related injuries or illnesses. The remaining fifty-nine percent reported coverage through the general contractor (CG), sub-contractor, or self-purchased (Table 2).

Psychosocial Factors

Seventy-six percent reported being mostly or very satisfied with their work. Less than six percent reported very little or no job-satisfaction with their work. Only 9% reported being bored with their work "most of the time" or "all the time". The majority (91%), reported being bored only "sometimes", "very little", or "not at all". Seventy-one percent reported that co-workers "mostly care" or are "very concerned" about each other's safety and well-being. Twenty-four percent ranked co-workers' caring as "some", while only five percent rated the level at "very little" or "not at all". A similar distribution was seen in evaluating employer caring. Eighty-one percent indicated that the boss "mostly cares" or is "very concerned" about the employees' safety and well-being while 19% ranked the level of caring as "very little" or "not at all". Slightly over half, 53% assessed risk related to residential carpentry at a moderate level. Twenty-eight percent ranked the risk levels high or severe while only 19 % ranked it at slight or none. Mental exhaustion was reported by 42% of the respondents as "frequently", "almost always", or "always". Fifty-eight percent reported sometimes or never feeling mentally exhausted. Forty-two percent reported working under significant time pressure demands and ranked the level of time pressure at "most of the time" or "all of the time" while 58% rated the time pressure at "sometimes", "very little", or "not at all" (Table 2).

Low Back Pain and Injury

Point prevalence: 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 (Table 3). The point prevalence of LBP was significantly correlated ($p < 0.05$) with a select number of personal, workplace, and job-task factors including: back strain rating in carpentry, job satisfaction, level of co-workers caring, mental and physical exhaustion, amount of time spent in side jobs, health problems, and rating of LBP problem in carpentry (Table 91). 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 (Table 94).

Period prevalence: 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 (Table 3). The 12-month prevalence of LBP was significantly correlated with certain personal and workplace factors including: hours of safety training, level of back strain in carpentry, physical exhaustion, level of boring work, working under time pressure, job-task related LBP, self employed status, and level of LBP problem in carpentry (Table 92). 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 (Table 95).

Lifetime prevalence: Fifty-five 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 (Table 3). The lifetime prevalence of LBP was significantly correlated with certain personal and workplace factors including: level back strain in carpentry, job-task related LBP, excessive noise exposure, and body height (Table 93). 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 (Table 96).

Thirty-two percent of respondents reported suffering some form of continuous LBP. Fifty-nine percent reported that they felt their LBP was related to work activities and 92% reported that specific job-tasks were associated with LBP. Thirty-five percent had lost days away from work due to LBP in the past 12 months. Of those reporting lost workdays, 32% reported losing 1-5 days in the past year due to LBP. An additional 15% had lost more than 20 days away from work while the remaining 53% had lost between 6 and 20 days during the past year. Thirty-one percent felt their LBP was from repeated activity while 23% reported a single event was more likely the cause. Seventy-four percent rated back strain in framing carpentry as "moderate" or "high" while 15% rated it "very high" and 9% rated it "low". Thirty percent of respondents reported self-treating their LBP while 28% sought chiropractic care and 18% sought medical care; however, 18% also sought more than one provider or modality for treatment of their LBP. In an overall assessment of LBP, respondents were asked to rate the problem LBP poses to framing carpenters: 82% rated the problem as a "moderate" or "severe" problem, only 3% rated it as no problem (Table 3).

Safety and Health Training

Respondents reported a range of 0 to 100 hours of safety training in the previous year with a mean of 13 hours. Eighty percent reported receiving some form of safety training. Fifty-four percent reported less than 6 hours training while 18% reported more than 20 hours. Nearly 20% reported receiving no training in the previous 12 months while 7% received 50 hours or more. Thirty-nine percent received safety training from a combination of sources including GC, foreman, safety consultant, OSHA, or HBA representatives. Foremen provided 16% of safety training followed by GCs and safety consultants at 15%

and 14% respectively. Seventy-six percent reported receiving training in risk and hazard identification and 69% reported receiving training in low back injury prevention (Table 4).

Perceived Job-Task Strain Analysis

The physical demands of carpentry are significant (Cook et al., 1996; Mirka et al., 2000). This study aimed to measure aspects of carpentry work from both subjective and objective perspectives. Assessment of materials indicates that significant loads must be managed to frame houses. Review and calculation from "housing pack" inventory sheets indicates that approximately 13,181 kg (29,000 lb) of wood-based building materials are used to construct a 186 m^2 (2,000 sq. ft.) home. Larger homes contain more materials, which increases the material-handling demands on carpenters. Homes of 223 m^2 (2,400 sq. ft.) and 279 m^2 (3,000 sq. ft.) use approximately 16,363 kg (36,000 lb) and 18,363 kg (41,000 lb) of building materials respectively.

These materials are principally lumber of standard sizes and dry weights per linear foot as follows: 5.08 cm x 10.16 cm = 567.5 g (2" x 4" = 1.25 lb), 5.08 cm x 15.24 cm = 908 g (2" x 6" = 2 lb), 5.08 cm x 20.32 cm = 1.09 kg (2" x 8" = 2.4 lb), 5.08 cm x 25.40 cm = 1.36 kg (2" x 10" = 3 lb), and 5.08 cm x 30.48 cm = 1.78 kg (2" x 12" = 3.9 lb). Additional materials include rim board = 1.72 kg (3.8 lb), pre-manufactured floor joists 1.08 kg (2.38 lb), and micro-lamination board 1.6 kg (3.53 lb), oriented stringboard (OSB) 1.2 m x 2.44 m (4' x 8') sheets usually come in two basic thicknesses, 1.27 cm (½") and 1.905 cm (¾") weighing 20.9 kg (46 lb) and 31.8 kg (70 lb) per sheet respectively. Wet materials may be as much as 25% heavier than dry materials due to water content. In addition to materials that may contribute to lower back strain, frequently used tools may also add to low back stress; these include hammers 454 g. – 908 g. (1-2 lb), circular saws 6 kg – 7 kg (14 -16 lb), nailguns 4.5 kg (10 lb), drills 3 kg (6 lb), and various ladders ranging from 11 kg – 17 kg (23 lb to 37 lb). Less managed items but also stressful loads include compressors up to 32 kg (70 lb), box of nails 20 kg (45 lb), and tubs used to store tools up to 23 kg (50 lb). Low back job-task strain scores are summarized by the relative order in which the job-task occurs in framing and by rank (Tables 5a and b).

Breaking materials is the initial task performed when beginning work at any jobsite. The mean strain score for this task was 1.88 (SD 1.13) with 31% reporting moderate low back strain or above. Sorting floor materials involves lifting and carrying 32 kg sheets of OSB and had a mean strain score of 2.44 (SD 1.18) with 52% reporting moderate or above low back job-task strain demands. Measure layout involves little use of materials and was considered an easier task with a mean score of 1.40 (SD 0.99). Plating beams by hand was considered a difficult task with a mean score of 2.78 (SD 1.72). Fourteen percent of carpenters ranked the low back strain at moderate or above. Plating beams with a crane was ranked less strenuous with a mean score of 1.40 (SD 1.04). Forty-two percent ranked this at 1, no low back strain.

Installing sill plates involves capping the foundation wall with treated lumber in preparation for erecting a wall. This task had a mean score of 1.79 (SD 1.06). Framing walkouts had a mean score of 2.12 (SD 1.15) with 47%

ranking the low back strain at moderate or above. Cutting floor joists had a mean score of 1.97 (SD 1.07) with 26% ranking low back strain moderate or above. Sorting pre-cut trusses was rated with a mean score of 2.19 (SD 1.31) where 51% of respondents ranked the low back strain at moderate or above.

Installing floor joists had a mean score of 2.41 (SD 1.26) with 50% of respondents rating the back strain at moderate or higher. Sheeting floors was rated higher with a mean score of 2.79 (SD 1.22). Sixty-eight percent of respondents rated this task at moderate or higher low back strain. Snapping lines was rated less stressful to the low back with a means score of 1.53 (SD 0.99).

Installing beams by hand was ranked the highest low back stress of all tasks with a mean score of 3.08 (SD 1.36). Seventy-seven percent of respondents ranked this task as moderate or higher strain on the low back. Whereas, installing beams with a crane is substantially less stressful with a mean score of 1.42 (SD 1.03).

Sorting wall materials was ranked more demanding on the low back with a mean score of 2.26 (SD 1.09); 43% rated the low back strain at moderate or higher. Eighty-three percent of respondents ranked layout plates at low or no strain on the low back; the mean score was 1.69 (SD 0.99). Likewise, creating a cut list and setting up a cut station were ranked low with mean strain scores at 1.36 (SD 0.10) and 1.05 (SD.85) respectively. Cutting material was ranked stressful to the low back with a mean strain score at 2.17 (SD 1.04).

Squaring a wall involves using a nine-pound sledgehammer to square-up the shape of the wall to 90^0 before standing it upright. This task was ranked at 1.70 (SD 0.10) mean strain score. Sheeting walls down involved handling 21 kg (46 lb) sheets of OSB and requires less physical demands than sheeting in the upright position; the mean strain score was 2.18 (SD 1.04). Sheeting the walls in an upright position requires more low back stress with a higher mean strain score of 2.56 (SD 1.25).

Standing walls was rated the second most stressful job-task after placing beams by hand with a mean score of 2.97 (SD 1.31). Seventy-one percent of respondents rated standing walls at moderate or higher levels while 16% ranked it at 5, very high strain. Weights handled frequently ranged from 10 kg for an interior non-sheeted wall, to over 681 kg for a sheeted, two-story, exterior wall and required several men to accomplish the job-task.

Sorting the roofing trusses was also rated demanding with a mean score of 2.63 (SD 1.16). Fifty-seven percent of respondents ranked this job-task at moderate or higher. Sheeting gables was ranked with a 1.93 (SD 1.15) mean score. Only 27% ranked this task at a moderate or higher level of low back strain.

Racking trusses involves lifting, dragging, and bundling trusses in combination to lift them to the roof for installation. Respondent carpenters rated the low back strain with a mean score of 2.01 (SD1.32) and 36% ranked the low back strain at moderate or higher levels.

Cutting tails refers to sawing the roof rafter ends to desired length and shape. This task has awkward postural demands and was rated with a 1.95 (SD 1.32) mean strain score. Forty-seven percent of respondents ranked this low back demand at moderate or higher. Installing the roof anchor is a short cycled task occurring once or twice per unit. This task was rated less strenuous with a mean score of 1.49 (SD 0.99).

Booming trusses involves using a crane to lift trusses to workers perched on wall edges to prepare for erecting the roof frame structure. This job-task is generally considered demanding and dangerous among residential carpenters. The mean score for booming trusses was 1.89 (SD 1.06). Installing truss clips is a means of connecting trusses to the structure and was rated with a mean score of 1.63 (SD 0.93). Rolling and bracing trusses involves installing the roof trusses that have been positioned on the wall tops. Carpenters lift these framed structures to an upright position, fasten, and stabilize them to each other and the building structure. This is dangerous and involves standing on scaffolding outside the structure or between the trusses from within the structure. This was rated with a 1.91 (SD 1.00) mean strain score.

Sheeting the first row on the roof is also considered dangerous and difficult due to the lack of a stable work surface. Carpenters must accomplish this either from standing on scaffolding outside the structure or from between the trusses. The job-task requires placing and nailing 31.82 kg (70 lb) sheets of OSB into position. This job-task was rated with a mean score of 2.54 (SD 1.28). Fifty-five percent of carpenters rated the demands on the low back at moderate or higher. Finishing the roof sheeting is also dangerous and physically demanding due to the repeated handling of 1.2 m x 2.44 m (4' x 8') sheets of OSB on the rooftop and existing fall hazard. These 31.82 kg sheets may be lifted to the roof with a forklift but still require handling to position and fasten. A typical 186 m^2 (2000 sq. ft.) home roof requires approximately 1,000 kg (2,200 lb) of OSB. The mean strain score for finishing sheeting is 2.55 (SD 1.22).

Installing fascia boards was rated with a mean strain score of 2.03 (SD 1.60). Building and installing stairs is stressful to the low back, yet setting pre-built stairs rates even higher strain due to large awkward weights. These job-tasks were rated with mean strain scores of 2.30 (SD 1.43) and 2.64 (SD 1.40) respectively. Sixty-one percent of carpenters rated setting pre-built stairs at a moderate or higher strain to the low back.

Building and installing partitions was rated with a mean score of 2.07 (SD 1.13) with 36% of carpenters rating the low back strain at a moderate or higher level. Building basement floors is less common for carpenters in recent years due to increasing popularity of concrete materials for basement flooring. Forty percent of respondents reported they do not undertake this job-task. Of those carpenters performing this job-task, 29% rated the task at a moderate level while only 13% rated it higher.

Building exterior decking is also a specialty job-task with a mean score of 1.82 (SD 1.53). Thirty-four percent of carpenters surveyed reported they do not perform this job-task. As with building basement floors, 29% rated this job-task at moderate low back strain. Nailing metal connectors was rated with a mean score of 1.73 (SD 0.88). Ninety-one percent of carpenters rated low back strain at moderate or below, only 19% rated it at high or very high. Cutting roof vents was rated less stressful with a mean strain score of 1.37 (SD 1.04). Eighty-nine percent of respondents rated this job-task at a low or no strain level to the low back.

Cleaning up scrap material can be very demanding depending on the operation. The mean strain score was 2.09 (SD 1.14) with 44% rating the low back strain at moderate or higher. Two daily tasks related to arrival and departure are called "roll out" and "roll up". These are long cycled tasks and occur at the beginning and end of each workday. These typically require approximately 20 – 30 minutes and are orchestrated by the job foreman. Tools, supplies, and equipment are unpacked or packed into cars, trucks, or trailers. These two job-tasks are rated very similar in demand with mean strain scores of 1.56 (SD 0.10) and 1.612 (SD 0.87); in both cases, over 85% of carpenters rate these at low or no strain to the low back.

Lastly, an overall total mean score for the subject sample is 91 (SD 33.00). With a possible range from 44 to 220, the mean is slightly above the 50th percent mark suggesting an overall strain index of low to moderate stress to the low back.

Ergonomic Elements of Posture and Strain

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. The selection was based upon the subjective mean low-back-strain scores for the surveyed carpenters (Tables 4a and b). Five easier tasks with lower subjective mean strain scores and 5 harder tasks with higher subjective mean low-back strain scores were evaluated for comparison (Tables 6 – 15).

Easy Tasks:	Mean Strain Score	Table
1. Creating a cut list	1.051	6
2. Set up cut station	1.357	7
3. Measure layout	1.404	8
4. Roll out	1.557	9
5. Lay out plates	1.691	10
Hard Tasks:		
6. Sorting wall material	2.255	11
7. Installing floor joists	2.412	12
8. Sorting trusses	2.633	13
9. Sheeting floors	2.788	14
10. Standing walls	2.969	15

Each of the 10 tasks was evaluated for spinal loading and posture demands using ErgoMaster© and OWAS© software (Tables 6 – 43b). 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 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 (Tables 43a, b). 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 (Table 43a). OWAS action categories were derived based upon work postures and loads managed for each job-task (Table 43b). This is an overall 'risk' or 'action category' defined as follows (Kant et al., 1984; Koru et al., 1977; Kivi and Matilla, 1991; Matilla et al., 1992; Matilla et al., 1993):

OWAS Action Categories:

Category 1 = Normal postures, no action required.

Category 2 = Posture is slightly harmful; actions to change postures should be taken in the near future.

Category 3 = Posture is distinctly harmful; actions to change postures should be taken as soon as possible.

Category 4 = Posture is extremely harmful; actions to correct postures should be taken immediately.

"Creating a cut list" is a job-task that requires minimal physical effort based on subjective survey. The carpenter must assess the building plans, obtain measurements, and write down the necessary dimensions to cut material for a precise fit. Measurements are usually written on a scrap piece of wood and given to another carpenter to cut the material or accomplished by the same person. Ninety-seven percent of the time, both arms are below shoulder height. Ergonomic risk factors related to this task are minimal but include prolonged forward bending (Table 6). Total spinal compression was measured at 2,965 N with the major contributor from the joint reactive forces secondary to posture. Shear forces were secondary to upper body weight and forward bent postures. The average task-time in a forward bent posture was 33% of total. The major work posture was upright with both hands below shoulders. The OWAS© Action Category ratings indicated that 67% of the task posed no risk while 30% of the task-time did pose slight harm and 3% of the total time ranked as distinctly harmful (Table 43b). The NIOSH action limit (AL) of 3,425 N for lumbosacral loading was not breached with peak loading during the job-task observed (Table 43a). This job-task ranked third from the least demanding when looking at total compression and shear. The total sum of compression values was 14,325 N and ranked second least demanding task overall (Table 42). Evaluating ergonomic elements between the 10 tasks did reveal significant differences overall ($p < 0.01$) for all job-task elements measured (Tables 16 – 39).

"Set up cut station" is a task principally performed one of three ways. It was identified as a less strenuous job-task with a mean strain score of 1.36. Most carpenters use the dorsum of their foot as their cut station. Framing carpenters typically bend over with circular saw in hand and raise the material a few inches off the ground to perform a cut. Some carpenters use a wooden block as a substitute for their foot for risk reduction reasons. Few framing carpenters actually set up a cut station by placing two sawhorses approximately six feet apart and positioning a 1.22 m x 2.44 m (4' x 8') sheet of 1.27 cm (½") OSB or plywood on top. This serves as a working platform for cutting materials and other work manipulations. The use of a fixed cut station is more acceptable and practical for trim carpenters than framers. In rare instances, framing carpenters have a pre-manufactured aluminum table and frame with adjustable legs and a mounted miter saw. This device is awkward, heavy, and placed once daily for use; it serves as an excellent high-quality cut station. However, most carpenters prefer the convenience of using their foot. This high-risk behavior makes for rapid uninterrupted work. Using a fixed cut station requires that the carpenter stop his/her immediate work and walk to the station to perform the necessary cuts. On one occasion, I observed the use of a pre-manufactured cut station at a jobsite. This device was operated by a female crewmember. In this case, she did all the cuts for crewmembers onsite where materials could be handled by manual manipulations. When cutting larger materials or during stages of actual assembly, crewmembers resorted to their foot or blocks when needing to support the work piece for cutting. Ergonomic evaluation of this job-task identified the forward bent posture with loading as a risk factor (Table 7). Total spinal compression measured 3,575 N with the major contributor from joint reactive forces secondary to posture. This value slightly breached the NIOSH AL of 3,425 N by 150 N (Table 43a). Compression due to load was 48 N generated by a 7 kg – 9 kg circular saw. Lumbosacral shear force due to load was 105 N. The job-task required a forward bent posture 33% of the time with loading. The

OWAS Action Categories for postural assessment were as follows: 67% of task-time posed no risk, 30% was slightly harmful, and 3% was distinctly harmful (Table 43b). Overall, summing compression forces ranked this job-task sixth and the actual total compression value also ranked sixth (Table 42). The between task comparisons reveal significant differences ($p < 0.01$) between all job-task elements measured (Tables 16 – 39).

"Measure layout" is a task that requires little physical strength or endurance, but absolute accuracy is necessary. This is the process by which the wall placement is identified on a freshly installed floor. The clean, dry surface is measured and chalk lines are placed on the floor. This process involves careful evaluation of building plans, exact measurements, and acceptable chalking technique. The lead foreman and one other seasoned carpenter usually perform this job-task. Total spinal compression was measured at 2,884 N (Table 8). The major contributor was joint reactive force only. The shear forces were secondary to body weight and forward postures. The job-task does require significant and prolonged forward bending. OWAS© assessment revealed that 68% of the time the back is bent forward. Action categories were as follows: 32% of the time no risk was posed, 65% of the time posed slight harm and 3% of the time was distinctly harmful (Table 43b). The NIOSH AL was not breached (Table 43a). The combined compression summed was 13,973 N and ranked the lowest of the 10 job-tasks. The between task comparisons reveal significant differences ($p < 0.01$) between all job-task elements measured (Tables 16 – 39).

"Roll out", and/or tool setup, is the first job-task of the day. The entire work crew accomplishes this job-task; it is also considered less demanding with a mean strain score of 1.56. This process involves setting up the worksite for that day and includes unpacking the cars, trucks, or work trailer. Many crews maintain a work trailer that remains onsite for the duration of the project. Equipment, tools, and supplies not left onsite overnight must be packed up at the end of each workday and unpacked at the beginning of each new workday. Tools, equipment, or supplies may be stored in tubs weighing up to 23 kg (50 lb). The compressor is the largest and heaviest piece of equipment and may weigh up to 32 kg (70 lb). The process of rolling out takes approximately 20 – 30 minutes depending on the number of crewmembers helping. Total spinal compression measured 3,186 N with 285 N secondary to lifting equipment (Table 9). The shear force due to load was 76 N. The nature of this job-task facilitates an upright posture 73% of the time. The OWAS action categories were as follows: 76% of the time normal posture was recorded, posing no harm, 17% of the time postures posed slight harm, and 7% of the time a distinctly harmful posture was present (Table 43b) The NIOSH AL threshold was not breached (Table 43a). Total summed compression was 15,167 N. Based on total stress value, actual spinal compression, and subjective rating, all subjects ranked this job-task third least stressful to the low back (Table 42). The between task comparisons revealed significant differences ($p < 0.01$) between all job-task elements measured (Tables 16 – 39).

"Lay out plates" is the process in which carpenters pre-cut the top and bottom boards for each wall and place these where the wall is to be built. A different carpenter may accomplish the layout or the same person may perform both cutting and layout. This job-task involves careful evaluation of the building plans and exact measurements but is not significantly physically demanding with a mean strain score of 1.69. This job-task requires some materials handling, cutting lumber, and forward bending for placement of the cut plates. Ergonomic assessment revealed only mild loading with a total compression of 3,755 N (Table 10). However the compression due to load is minimal at 42 N. The shear forces due to load were measured at 95 N. Most materials used to make plates are either 5.08 cm x 10.16 cm (2" x 4") = 567.5 g or 5.08 cm x 15.24 cm (2" x 6") = 908 g per linear foot. The majority of studs used for plates are between 2.44 m (8 ft) to 4.88 (16 ft) in length. Therefore, weights range between 4.55 kg (10 lb) and 14.55 kg (32 lb). This job-task requires excessive forward bending measured at 67% of task-time. The OWAS© categories suggest greater concern with 67% of time posing slight harm to workers. The remaining 33% of task-time was considered normal postures posing no risk of harm (Table 43b). The NIOSH AL was breached slightly by 330 N, far below the MPL of 6,361 N (Table 43a). The summed compression values totaled 15,363 N and ranked fourth (Table 42). The between-task comparisons revealed significant differences ($p < 0.01$) between all job-task elements measured (Tables 16 – 39).

"Sorting wall materials" can be accomplished systematically or as needed. It was the first of the harder tasks to be sampled; the mean strain score was

2.26. Some carpenters break open the house pack and systematically sort the materials by size into smaller stacks of lumber while others break into the pack and sort as they need materials throughout the day and project. The majority of wall materials are either 5.08 cm x 10.16 cm (2" x 4") = 567.5 g or 5.08 cm x 15.24 cm (2" x 6") = 908 g per linear foot and 1.22 m x 2.44 (4' x 8') 1.27 cm (½") OSB with loads ranging from a few kilograms to 32 kg (70lb). Ergonomic evaluation reveals total spinal compression at 3,497 N (Table 11). Compression due to load was measured at 104 N and 115 N for shear. This job-task requires substantial forward bending. Forty-three percent of task-time was recorded in a forward bent posture. The OWAS action categories were as follows: 57% considered normal posture, 40% considered to pose slight harm, and 3% posing distinct harm (Table 43b). The NIOSH AL was breached by only 72 N (Table 43a). The total compression summed was 16,491 N and ranked fifth (Table 42). The between task comparisons reveal significant differences ($p < 0.01$) between all job-task elements measured (Tables 16 – 39).

"Installing floor joists" is a multi-step process not fully evaluated in this study; however; the mean strain score was 2.41. The investigator chose to evaluate the actual placement and nailing of the joist in place as a representative subpart of the whole task. The total spinal compression was measured at 4,352 N with compression due to load at 105 N (Table 11). The shear forces due to load were 114 N. This job-task requires substantial forward bending and twisting with loading. Carpenters walk on the foundation or wall plates bent forward, and reach out with a 10 lb nailgun to fasten joists into place. This is a short cycled task lasting only 10 – 20 seconds. The constrained work surface necessitates substantial twisting and reaching to apply the nailgun to the surface to be fastened. The bent and twisted posture was observed 30% of the task-time. Ergonomic assessment reveals total spinal compression of 4,352 N (Table 12). While compression due to load is only 24 N, the shear forces are four-fold greater at 114 N directly due to sustained forward bending with a load. The OWAS© categories were as follows: 28% no risk, 66% posing slight harm, and 6% posing distinct harm (Table 43b). The NIOSH AL was breached by 927 N; however, this is far below the MPL of 6,361 N (Table 43a). The total summed compression was 21,288 N and ranked ninth (Table 42). The between-task comparisons reveal significant differences ($p < 0.01$) between all job-task elements measured (Tables 16 – 39).

"Sorting trusses" involves lifting and carrying or dragging trusses to specific locations on the jobsite for booming to the roof; it is significantly stressful to the low back with a mean strain score of 2.63. Trusses come packed and bound with steel straps. They are broken out of the pack and sorted by size to locations needed for roof placement. This is usually a multi-person job-task with a minimum of two men sorting. Trusses range widely in size and weight depending on the span of the house. Truss weights ranged from 27.27 kg (60 lb) to over 181.82 kg (400 lb) and varied in size from 5.49 m (18 ft) to 13.73 m (45 ft) in length. The basic shape was triangular to support the pitch of the roof. The ergonomic evaluation revealed that the total spinal compression measured 4,129 N with compression due to load at 259 N (Table 13). The shear force due to load was 259 N. The majority, 93%, of this task is performed in an upright posture. Upper extremities are often raised above shoulder height. The OWAS action categories are as follows: 80% no risk, 15% posing slight harm, and 5% posing distinct harm (Table 43b). The NIOSH AL was breached by 704 N (Table 43a). This compression is far below the MPL of 6,361 N. No threshold has been established by NIOSH for shear force. The shear mechanism poses greater risk of injury than compression. The total summed compression was 18,542 N and ranked eighth (Table 42). The between task comparisons reveal significant differences ($p < 0.01$) between all job-task elements measured (Tables 16 – 39).

"Sheeting floors" typically has two major sub-tasks: 1) obtaining the sheet and placing it, and 2) nailing it into place. The video samples taken included both phases of materials management and nailing in place; it is significantly stressful to the low back with a mean strain score of 2.79. Sheeting floors is accomplished with the entire crew working together. The senior-most carpenter usually adjusts and fastens the 1.22 m x 2.44 m (4' x 8'), 31.82 kg (70 lb) sheet of OSB in place. The least-senior carpenters obtain the sheets of OSB from stacks on the jobsite. These are initially carried to the structure and handed to the next carpenter who moves them to the exact location for installation. The sheet is then dropped or laid into place and is ready for nailing. The lead man makes final adjustments before using a pneumatic nailgun to fasten the sheet to the substructure. This process cycles approximately one sheet per minute and moves very quickly. For example, in a 186 m^2 (2,000 sq. ft.) house there is over 1,000 kg (2,200 lb) of flooring handled in a fairly rapid time frame and can be completed in approximately one hour. Ergonomic evaluation reveals total compression of 3,846 N with compression due to load measured at 241 N (Table 14). The shear force due to load was 152 N. For the carpenter performing the fastening, the posture demands include 60% forward bending while using a 10 lb nailgun. The other carpenters tend to use good lifting techniques and remain upright as much as possible to manage the heavy loads. The OWAS© action categories were as follows: 33% normal posture and 67% posing slight harm (Table 43b). The NIOSH AL was breached by 421 N (Table 43a). Again, this is nowhere near the MPL of 6,361 N. The total summed compression was 17,441 N and ranked seventh (Table 42). The between task comparisons reveal significant differences ($p < 0.01$) between all job-task elements measured (Tables 16 – 39).

"Standing walls" can be an extremely physically demanding and dangerous job-task (Table 15). This involves raising framed walls from a horizontal position to their upright placement in the structure, it was rated the highest of the 10 tasks sampled in this study with mean strain score of 2.97. Walls vary dramatically in weight and size depending on their location and design criteria. Interior, non-weight bearing walls are much lighter, whereas exterior, two-story walls can be in excess of 681 kg (1,500 lb) and 4.88 m (16 ft) high. Standing walls is often a one-man job for the lightweight interior walls but a multi-person task for exterior walls. The typical approach on exterior walls is to line up men spaced evenly over the width of the wall who lift it simultaneously to its upright position. The job-task is an explosive, short cycled effort requiring usually less than 30 seconds. The total compression is substantially higher than any other task sampled at 8,606 N with the load contribution at 373 N. The joint reactive forces exceed 10,000 N. The total shear is 1,974 N with 480 N due to very high load. This task is 87% upright in posture, but that 13% bent posture is under maximum loading. The OWAS© categories were as follows: 17% no risk, 70% posing slight harm, and 13% posing a distinct harm. The OWAS© system of analysis did not offer a rating of category 4, extreme risk, despite the high physical stress (Table 43b). The NIOSH MPL was exceeded by 5,181 N posing substantial risk for lumbosacral injury (Table 43a). The total compression summed was 40,305 N and ranked10th. The between task comparisons reveal significant differences ($p < 0.01$) between all job-task elements measured (Tables 16 – 39).

Looking at the 10 tasks grouped as "five easy" vs. "five hard", significant differences were seen for spinal compression due to load, and for spinal compression and shear due to upper body weight ($p < 0.01$, Table 40). Spinal shear due to load was nearly significant ($p = 0.06$). Mean total spinal compression values of 3,681 N vs. 4,436 N were not significantly different, nor were total spinal shear values of 1,045 N vs. 1,019 N. Postural patterns were significantly different for percent of time that the back was bent and twisted, the percent of time that arms were above shoulders, and loading below 10 kg and above 20 kg ($p < 0.01$, Table 41). Horizontal distances from load were 45 cm vs. 42 cm and found not to be significantly different. General spinal postures were not significantly different for percent of time in the upright posture: 55% vs. 56%, or the forward bent position: 43% vs. 36%. No significant differences were seen in percent of time in OWAS© action categories 1 – 3. Category 1, normal posture, was identified 47% vs. 48% of job-task time, while Category 3, distinctly harmful, was identified 46% vs. 48% of job-task time. The distribution of task-time percent in OWAS© action categories 1 – 4 is presented in Table 43b.

Summing the job-task compressions to yield an overall stress index was arbitrary. The logic here was to develop a relative single value representing cumulative compressions from all contributions available. Total scores ranged from 14,325 N to 40,305 N (Table 42). Total stress scores do not correspond well to the subjective rating scale on the individual job-task basis for all 10 job-tasks, but do compare well for easy vs. hard groups. Summing posture scores did not yield much variability among the data and appears less meaningful unless weighted by action category.

Personal Influence on Strain Scores

Perceived low back strain scores were evaluated using GLM-MANOVA in an effort to identify relationships to strain scores and potential confounders. The 44 major tasks were evaluated for the influence of each of the personal variables (Tables 44 – 74), and compared to initial findings seen in Table 4. Many personal, perceptual, and organizational variables had significant relationships to many low back strain rating responses. Carpenters were asked how much back strain they felt existed in framing carpentry. Respondents ranked the level of overall back strain in framing carpentry on a scale of 1 – 5 where 1 was "no strain" and 5 was "very high strain". The level of responses increased the mean scores linearly by increasing with the level of back strain reported. Significant differences were noted in all 44 job-tasks ($p < 0.05$, Table 44). For example, the least stressful task sampled was "creating a cut list". The mean score was 1.05, yet if there is a very high rating for back strain in framing carpentry, the mean score increased to 1.60. The most difficult task sampled was "standing walls" with a mean score of 2.97; yet if the respondent rated back strain very high, the mean score increased to 3.70.

Framing carpenters were asked if back injuries were a problem within their trade. Their variation in responses indicated a significant relationship did exist between mean strain scores for 37 of 44 job-tasks ($p < 0.05$, Table 45) and the level of back problem reported. For example, the least stressful task sampled was "creating a cut list". The mean score was 1.05, yet if rating was "severe" for back injuries as a problem, the mean score increased to 1.30. Correspondingly, the most difficult task sampled was "standing walls" with a mean score of 2.97, yet if the respondent rated the back injury problem in framing carpentry as "severe", the mean score increased to 4.10. This is substantially higher than all mean scores found among all job-tasks.

If a carpenter reported his low back injury or problem was due to a "single incident" vs. "cumulative" in nature, the relationship between mean strain score rating of many job-tasks changed. In fact, in 34 of 44 job-tasks, there was statistically significant difference ($p < 0.05$) between rating scores based upon the type of injury or problem (Table 46). The "cumulative" causation response yielded higher mean score values across all 44 tasks. For example, the mean score was 1.05 for "creating a cut list"; yet if there was "cumulative" causation for the back injury or problem, the mean score increased to 1.40. Conversely, if the respondent reported a "single incident" causation, the mean score dropped to 0.88. Comparatively, "standing walls" had a mean score of 2.97; yet if the respondent reported "single incident" causation, the mean increased to 3.10 and for "cumulative" causation it climbed to 3.80.

If respondents suffered constant low back pain, the relationship between strain score ratings changed significantly ($p < 0.05$) for 29 of 44 job-tasks (Table 47). This was a dichotomous response, present vs. not present, and in nearly all of the 44 job-task ratings the affirmative response yielded higher low back strain scores. For example, "creating a cut list" had a mean score of 1.05, if there was "constant pain" the mean score remained the same. Comparatively, "standing walls" had a mean score of 2.97, yet if the respondent reported "constant pain", the mean increased to 3.80 ($p < 0.01$).

If carpenters had suffered a recent episode of LBP within the past two weeks, this also affected the low back strain scores (Table 48). In 23 of the 44 job-tasks, significant differences were seen between those levels of strain reported ($p < 0.05$); rating levels were higher if they had suffered a recent episode of LBP. In all 44 job-task strain ratings, the presence of a recent episode resulted in a higher low back strain score. For example, "creating a cut list" had a mean score of 1.05, yet if there was a recent episode of LBP the mean score increased to 1.50. Comparatively, "standing walls" had a mean score of 2.97, yet if the respondent reported a recent episode of LBP the mean increased to 3.70. A similar pattern was seen for those reporting an episode of LBP within the past 12 months (Table 49). The presence of an episode of LBP within the prior 12 months significantly ($p < 0.05$) affected 13 of the 44 job-task low back strain ratings but did show increases in 42 of 44 job-tasks. In both temporal categories, the presence of a LBP episode increased ratings of affected low back strain scores.

Respondents were asked to rate their health status on a progressive scale from poor to excellent. It was found that health status impacted their low back strain scores in 19 of 44 job-task ratings (Table 50). In most instances, there was an inverse linear relationship between low back strain scores and health status. If their health status was excellent, the low back strain ratings were lowest. If the health status was poor, the ratings were very high across nearly all 44 tasks. For example, "creating a cut list" had a mean score of 1.05, yet if there was an excellent health status reported, the mean score decreased to 0.84. However, if the health status was rated poor, the mean score increased to 2.00. Comparatively, "standing walls" had a mean score of 2.97; if the respondent reported an excellent health status, the mean remained at 2.90. Whereas, if the carpenter reported poor overall health the low back strain increased to 5.00 In fact, 38 of the 42 major job-tasks rated by those with poor health had a mean of 4.00 or 5.00 low back strain rating. Forty-three percent of all respondents rated their health at fair or poor levels.

Respondents were surveyed regarding their alcohol consumption. They were asked to rate the number of beers or drinks consumed in an average week as follows: categories 0 to 4 where 0 = no consumption, 1 = 1 – 2 beers or drinks per week, 2 = 3 – 5 beers or drinks per week, 3 = 6 – 10 beers per week, and 4 = more than 10 drinks per week. There was no statistically significant relationship seen in low back strain scores for any of the 44 job-tasks based on alcohol consumption (Table 51).

Carpenters were surveyed regarding their smoking status: never, former, or present. It was found that 44% were smokers at the time of the study, significantly higher than the national average of 25% (CDC, 1999). Despite prior research (Andersson, 1997; Thorbjornsson et al., 2000), only three low back strain scores had a statistically significant relationship based on smoking status (Table 52). Mean scores for "sorting materials", "plating beams by hand", and "cutting tails" were significantly increased ($p < 0.05$) if respondents were smokers. Interestingly, if respondents were former or present smokers they tended to rate the low back strain scale higher for most job-tasks than those who never smoked (Table 52).

Respondents were surveyed about their level of physical exhaustion after a day's work. Their ratings ranged from "never" to "always". This variable significantly affected 36 of the 44 mean strain scores ($p < 0.05$, Table 53). The level of physical exhaustion had a positive linear relationship to low back strain. For example, the least stressful task sampled was "creating a cut list". The mean score was 1.05, yet if there was an "always" rating for exhaustion after a day's work in framing carpentry the mean score climbed to 2.40. Correspondingly, the most difficult task sampled was "standing walls" with a mean score of 2.97, yet if the respondent rated exhaustion as occurring "always" the mean score climbed to 4.00. There clearly existed an upward trend in strain scores correlated to increasing levels of physical exhaustion.

Carpenters were surveyed about their work being mentally exhausting. They were asked to rate the frequency of mental exhaustion from "never" to "always". It was found that significant differences ($p < 0.05$) did exist between job-task strain and level of mental exhaustion for 30 of the 44 job-tasks (Table 54). When plotting these variables the relationship was inconsistent, neither consistently positive or negative. For some tasks, the strain scores remained the same or decreased for "sometimes" and "frequently" rated levels. For most job-tasks the highest level, "always," yielded the highest strain scores (Table 54). For example, "creating a cut list" had a mean score of 1.05, yet if there was mental exhaustion "sometimes", the mean score decreased to 0.94. Whereas, if the respondent reported "frequently", "almost always", or "always", the score climbed progressively to 1.10, 1.20, and 2.70, respectively ($p < 0.01$). Comparatively, "standing walls" had a mean score of 2.97. However, in this question, respondents who reported no mental exhaustion rated the low back strain at 4.00. The score decreased to 3.00 with mental exhaustion "sometimes" and then progressively climbed back to 4.00 with an "always" response. The plot is a u-shaped curve.

Carpenters were surveyed regarding their body weight and stature. Actual weights and heights were collected. Weights ranged from 45 kg (100 lb) to 150 kg (350 lb). Heights ranged from 152 cm (60") to 200 cm (79"). Outliers were dropped and ranges were created for analysis. The means, 82.73 kg (183 lb) and179 cm (70.5") represent the average carpenter in HomeSafe in the Denver metro area of Colorado. Body weight categories were divided by 13.63 kg (30 lb) increments beginning at 59 kg (130 lb) (Table 55). Body weight had no significant effect on low back strain rating scores. Body stature / heights were also organized by 15.24 cm (6") increments into three groups (Table 56). As in the case of body weight, there was no significant relationship between height and perception of low back strain. However, there was a pattern of increasing low back strain rating with increasing height for many job-tasks. Conversely, for some job-tasks no relationship was seen.

Risk perception was assessed by asking respondents, "how much risk do you feel is present in residential carpentry?" Responses were scaled 0 – 4 where: 0 = no risk, 1 = slight risk, 2 = moderate risk, 3 = high risk, and 4 = severe risk. Risk perception did not significantly alter mean strain scores for many tasks (Table 57). Statistically significant ($p < 0.05$) relationships were seen for three job-tasks: "plate beams with crane", "installing floor joists", and "sorting trusses". Mean strain scores trended upward with increasing risk perception for many job-tasks.

Job satisfaction levels were assessed using a 0 – 4 scale, where: 0 = not at all, 1 = very little, 2 = some satisfaction, 3 = mostly satisfied, 4 = very satisfied. Statistically significant ($p < 0.05$) relationships were seen in 16 of 44 job-tasks (Table 58). The pattern is clearly an inverse linear relationship between these variables. The lower the level of job satisfaction, the higher the low back strain scores. For example, “creating a cut list” had a mean score of 1.05, yet if there was no job satisfaction the mean score climbed to 2.00. However, if the level of satisfaction was very high the mean strain score dropped to 0.88. Comparatively, “standing walls” with a mean score of 2.97 increased to 4.60 when respondents reported no job satisfaction.

Carpenters were surveyed regarding their level of boredom and monotony on the job. Respondents ranked their level of boredom and monotony on a scale of 0 – 4 where: 0 = not at all, 1 = very little, 2 = sometimes, 3 = most of the time, and 4 = all the time. Boredom and monotony did significantly affect mean low back strain scores for 7 of 44 job-tasks (Table 59). There were no “all the time” ratings recorded. Scores did not suggest any consistent patterns between the levels of boredom and monotony and strain levels. However, it is noted that those with the greater amount of boredom and monotony rated low back strain scores higher for 43 of 44 job-tasks. For example, “creating a cut list” had a mean score of 1.05, yet if there was a “most of the time” rating for boredom and monotony the mean score climbed to 1.70. Comparatively, “standing walls” had a mean score of 2.97, yet if the respondent reported being bored “most of the time” the mean score climbed to 3.80.

Carpenters were surveyed about the pressure they felt to work faster. Working under time pressure was evaluated by using a 0 – 4 scale: 0 = not at all, 1 = very little time pressure, 2 = some time pressure, 3 = time pressure most of the time, and 4 = time pressure all of the time. Surprisingly, this factor did not significantly affect any mean low back strain scores of job-tasks (Table 60).

However, differences were seen between those who report "no time" pressure and to those who felt they worked under pressure "all the time". Those who felt pressure all the time had the highest mean low back strain scores for many job-tasks.

When surveyed whether carpenters felt their co-workers cared about their health and well-being, findings suggested that statistically significant ($p < 0.05$) relationships exist between low back strain scores and the level of co-working caring and concern for safety and well-being in 18 of 44 job-task ratings (Table 61). Carpenters were asked to rate the level of caring by co-workers on a scale from "not at all" to "very concerned". There exists an inverse linear relationship for nearly all job-task strain scores. If the respondent felt that co-workers were very concerned, the low back strain rating was lowest. Comparatively, if the rating for co-worker caring was "not at all", low back strain rating scores were highest in all but two job-tasks. For example, "creating a cut list" had a mean score of 1.05 yet, if there was a "not at all" level of co-worker caring, the mean score increased to 2.50. However, if the level of caring was "very concerned" the score dropped to 0.88. Comparatively, "standing walls" had a mean score of 2.97 that increased to 5.00 if the respondent reported a "not at all" level of co-worker caring. In this case, if the level of caring was reported as "very concerned" the score slightly increased to 3.10.

Carpenters were also surveyed about whether they believed that their boss cared about their health and well-being. Using the same scale described above, respondents ranked the level of management caring and concern for their health and well-being. Findings suggest that few low back strain scores had statistically significant ($p < 0.05$) relationships to the level of caring and concern by the boss (Table 62). Only 3 of 44 job-tasks had statistically significant differences: "sorting materials", "plating beams with a crane", and "installing beams with a crane". All three of these job-tasks had relationships that were statistically significant ($p < 0.02$). However, it is also clear that employees who felt that the boss cared "very much" about them had lower strain scores compared to those who ranked caring as "very little".

Respondents were surveyed about the amount of safety training they had obtained in the prior twelve months and the source(s) of that training. The average carpenter had received 13 hours of safety training. The actual hours were recorded and grouped into three categories: 0 – 5 hours, 6 – 20 hours, and more than 20 hours (Table 63). The number of hours did not have a significant relationship to the low back strain scores of 43 of 44 job-tasks. Carpenters received their training potentially from several sources: GC, foremen, S & H consultant, OSHA, HBA, or a combination of sources. Sources of safety training also had no significant relationship to the low back strain scores (Table 64). No particular pattern was evident to suggest even a mild relationship. Only one job-task, "framing walkouts", showed a significant ($p < 0.01$) relationship between sources of safety training to low back strain scores.

Subjects were asked their age, years in construction, and years in residential framing carpentry. Actual years were obtained and grouped into six categories (Tables 65, 66, and 67). None of these three variables had a statistically significant ($p < 0.05$) relationship to job-task strain scores. There tended to be a pattern of increasing low back strain scores with increasing age, but this however was sporadic (Table 65). For example, "standing walls" had a mean score of 2.97. The two youngest groups, 18 – 24 and 25 – 30, ranked this task at 2.70; however, the two older age groups, 41 – 45 and over 45, ranked the job-task strain level at 3.6 and 3.8 respectively. Similar patterns can be seen in Tables 66 and 67 with respect to the years within the industry and trade (Tables 66 and 67, respectively).

Data were obtained on the number of hours that carpenters worked per week. Respondents were found to work 45 hours per week on average, with many working 50 hours per week. Actual hours were recorded and then grouped into three categories (Table 68). The number of hours worked had little relationship to low back strain scores. Only two job-tasks of 44 had statistically significant ($p < 0.05$) relationships to the number of hours worked per week, and neither shows a consistently positive or negative relationship between variables. Those who worked between 20 – 39 hours per week tended to have higher low back strain scores than those who worked more than 45 hours per week.

Many carpenters work after hours performing construction services on "side jobs". Carpenters were surveyed for hours per month spent doing additional after-hours carpentry work. Respondents were asked to rank their commitment to outside work on a scale of 0 – 4 where: 0 = none at all, 1 = < 8, 2 = 9 – 16, 3 = 17 – 20, and 4 = > 21 hours per month. Additional work hours did not reveal significant relationships between any of the 44 job-task low back strain scores (Table 69). No pattern was apparent between different levels of side-jobs and strain scores; however, in many cases there were higher scores for those working more than 21 hours per month in addition to their normal work.

Carpenters were surveyed about their personal income levels. Respondents were asked to identify their annual income with one of the following categories: < \$10,000; \$ 10,001 - \$20,000; \$20,001 - \$35,000; \$35,001, - \$50,000; and > \$50,000 (Table 70). The lowest income earners tended to rank their low back strain scores higher than other income brackets; however, only one statistically significant ($p < 0.05$) relationship was seen among the 44 job-tasks and income level.

Respondents were asked about their level of education. They were asked to identify the proper category that matched their formal schooling (Table 71). Education did not have a significant relationship to low back strain scores for any of the 44 job-tasks. There was no consistent pattern seen between these two variables; there is a slight tendency for those with lowest education levels to rate their job-task strain highest.

Carpenters often work as subcontractors to general contractors or other subcontractors. Respondents were asked about their employment status as employees and as subcontractors (Tables 72 and 73). While 70% reported they were subcontractors, only 43% reported they were employees of the framing company. Employment status did not have a significant relationship to low back strain scores with any definite pattern. For many job-tasks, employees of the framing company rated low back strain scores slightly higher than non-employees.

Workers' compensation benefits have been thought to be an influence in the reporting of work-related injuries. In the survey, carpenters were asked if they were "covered" vs. "not-covered" by workers' compensation insurance (Table 74). While the presence of benefits did seem to indicate a relationship existed between these variables, none were statistically significant.

Logistic Regression Evaluations

The study data were evaluated to identify risk factors for occupational LBP in carpenters with three endpoints of concern: lifetime LBP, 12 month period LBP, and recent episode LBP. The initial screening process eliminated those variables with p-values greater than 0.10. The remaining low back strain, personal, and workplace variables were entered via a stepwise logistic regression analysis to identify significant explanatory variables for each endpoint (Tables 75 - 80).

Lifetime LBP:

Two models were created, one based on considering only the subjective strain scores of the 44 major job-task variables, and the other based on considering 32 of the 51 personal and work-related potential risk factors. Assessing job-task variables to the 0.10 significance level yielded a model containing 11 job-tasks (Table 75). Nine of the 11 were significant to the 0.05 level. This model identified job-tasks both that increased risk and that were protective. Job-tasks with statistically significant increased odds ratio estimates included: squaring walls, sorting trusses, bracing trusses, setting pre-built stairs, and building wood floors in basements. Significant protective effects were noted with the job-tasks: plating beams by hand, framing walkouts, installing wood beams with a crane, building partitions, and cleaning up scrap. All job-task variables were highly correlated .37 - .63 ($p < .01$). Setting pre-built stairs produced the most significant increased risk, OR = 9.21 (CI 2.53 – 33.50) (Table 75). No statistically significant interactions were identified.

When evaluating personal and workplace risk factor variables, the model yielded seven significant variables at the 0.10 significance level (Table 76). Six of the seven variables produced increased risk estimates for LBP. The greatest risk estimate was seen for whether the boss was caring or concerned about the employee's health and well-being, OR 2.33 (CI 1.093 – 4.96). The only protective effect seen was related to the number of hours worked in the week, OR 0.90 (CI 0.02 – 0.98). No statistically significant interactions were found.

<u>Twelve Month Period LBP</u>:

The 12-month period prevalence of LBP was also evaluated as an endpoint using logistic regression to identify risk factors for occupational LBP. The evaluation yielded a model with only three job-task variables significant at the 0.10 level (Table 77). Two job-tasks, installing floor joists and cleaning up scrap, resulted in increased risk, while roll-up was protective. All job-tasks were highly correlated .39 - .54 ($p < 0.01$). No significant interactions were found. Personal and workplace factors found to be statistically significant included excessive physical exhaustion, working under time pressure, and height/stature (Table 78). Stature had the most significant OR 5.82 (CI 2.01 – 16.84).

Recent Episode of LBP:

Only one job-task variable entered the logistic regression model for the occurrence of recent LBP at the 0.10 level (Table 79). Building stairs was associated with increased risk of LBP, OR 2.52 (CI 1.41 – 4.49). Eight personal and workplace factors entered the model at the 0.10 significance level (Table 80). Two very large OR estimates, one significant and one not statistically significant, 48.61 (CI 0.94 - > 999.99) and 148.33 (CI 1.53 - >999.99), were associated with "risk identification training" and "self employed status". No significant interactions were seen.

Adjusted Logistic Regression Models:

The logistic regression models were then adjusted for level of physical and mental exhaustion, health status, level of co-workers' caring, and job satisfaction. Lifetime LBP model changed by dropping two significant job-tasks: cut materials and building partitions (Table 81). The remaining job-tasks retained significance below the 0.10 level. The model for LBP during the12-month period lost a single job-task, roll up, but retained two significant job-tasks (Table 82). The point prevalence model did not change but remained at the 0.02 significance level.

Integrated Logistic Regression Models:

Variables from job-task and personal logistic regression models were evaluated together. In the lifetime model, several variables dropped from the 0.10 significance level: hours worked per week, workers' compensation insurance, level of education, strain sum, squaring walls, and cutting materials (Table 84). The model was then adjusted for potential confounders (Table 85). Additional variables dropped from the model: working under time pressure, stature, and building partitions. Interestingly, one variable, worker's compensation insurance coverage, returned to the model at the < 0.05 significance level. The remaining variables in the models represent an integrated and adjusted set of indicators for lifetime occupational LBP at the 0.01 level.

The prevalence of 12-month period LBP was also evaluated via logistic regression including all significant job-tasks and personal variables combined (Table 86) and then a single task, physical exhaustion, dropped from the model. The model was then adjusted for confounders (level of physical and mental exhaustion, health status, level of co-workers' caring, and job satisfaction), and two additional variables dropped from the model, clean up scrap and roll-up (Table 87). The remaining variables represent a set of integrated and adjusted indicators of 12-month period occupational LBP at the 0.01 significance level.

Finally, the job-task and personal variables found to be significant were evaluated together via logistic regression. The point prevalence LBP models were combined and treated (Table 88). Five variables dropped from the model: age, hours worked per week, side jobs, risk identification training, smoking status, strain sum, and building stairs. The model was then adjusted for confounders, and only one variable, self-employed status, remained in the final model at the 0.10 significance level (Table 89).

Final Integrated Logistic Regression Models:

The final integrated models were then identified at the 0.05 significance level (Table 90). Lifetime LBP indicators were: boss caring and concern, workers' compensation insurance coverage, sorting trusses, bracing trusses, and building wood basement floors. Three job-tasks exerted a protective effect: plate beams by hand, install wood beams with a crane, and cleaning up scrap. All six job-tasks were significantly correlated (.23 - .56, $p < 0.01$). The personal variables of boss's caring and concern and W.C. insurance coverage were not significantly correlated (.10, $p = 0.35$) to each other. The boss's caring and concern was significantly negatively correlated with two job-tasks: installing beams with a crane (-.29, $p < 0.01$) and sorting pre-cut trusses (-.23, $p = 0.030$).

The final 12-month period LBP model included working under time pressure, stature, and installing floor joists (Table 90). All variables were indicators of increased risk of LBP. Variables were not well correlated (-.13 - .18, $p \geq 0.09$). The point prevalence LBP model contained only two variables: self-employed status, and quetelet (Table 90). The carpenter's self-employment status was a very strong indicator of a recent episode of LBP, OR = 277 (CI 2.44 - > 999.99). Conversely, quetelet exerted a protective effect, OR = .010 (0.03 – 0.68).

CHAPTER 5

Discussion and Conclusions

The scope and depth of the available data are such that they cannot be exhaustively evaluated in this dissertation. An emphasis was placed on the measurement of subjective low back strain on job-task basis and elucidating the ergonomic elements of posture and strain. The decision to investigate ergonomic risk factors in construction at the job-task level came from a growing realization among ergonomists that this type of data was more meaningful than general mechanical risk factor analysis related to the overall work process (NIOSH, 1994). 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. This section will discuss study findings, comparisons, and advances to relevant research in the literature.

Research Aim 1: Measure and analyze those job-tasks related to LBP in residential framing carpenters and evaluate personal and workplace characteristics that may have relationships.

This aim was a major goal of the present study. This was accomplished through a multi-step process outlined in the methods section. However, due to the multiple steps prescribed by the research protocol and statistical tools used, the ergonomic characterization for all relevant job-tasks identified using logistic regression were not accomplished. Tables 75, 77, and 79 contain key findings suggesting that certain job-tasks pose increased risk of LBP while other job-tasks offer protective effects. Looking purely at perceived low back strain as a risk factor, high risk job-tasks were identified as significant ($p < 0.10$) level using SAS© logistic regression. Eleven job-tasks were associated with lifetime LBP; six posed increased risk while five exerted protective effects. Of those job-tasks posing increased risk, only sorting trusses was sampled and evaluated for ergonomic elements of posture and strain. Those job-tasks posing increased risk of LBP included: cutting materials, squaring walls, sorting trusses, bracing trusses, setting pre-built stairs, and building wood basement floors (Table 75).

Characterization of all tasks except sorting trusses is based solely on observation, expert description, construction manuals, and worker low back strain scores (OSHA, 1998; Simpson, 1991). Job-task strain scores associated with increased risk of LBP ranged from 1.67 for building wood basement floors to 2.64 for setting pre-built stairs. Of the high risk job-tasks identified, five of six had mean scores above 1.70. However, 32 of the 44 job-tasks rated were also above the 1.70 level. Summing mean scores results in an average mean of 2.12 for that group of tasks posing increased risk. However, averaging the five strain scores for those job-tasks having a protective effect, their mean is 2.11, essentially the same. This is somewhat consistent with the comparisons seen in Tables 40 and 41. In 15 of 23 ergonomic elements measured, no significant differences were seen. When looking at the final model at the 0.05 significance level, a total of six job-tasks remained in the model, three posing increased risk, and three with protective effects. When summing the mean scores, the average is higher or essentially the same for those exerting protective effects 2.10 vs. 2.07 for those posing increased risk; this is puzzling. In contrast, when summing those mean scores for actual job-tasks sampled and comparing averages between easier vs. harder job-task groups, there is considerable difference 1.41 vs. 2.61. The variability between the mean strain scores of those in the models is not nearly as great as those seen in sampled job-tasks. These findings may suggest that a relationship exists between those eight ergonomic elements that were significantly different (seen in Tables 40 and 41) and the subjective mean strain job-task ratings. Those job-tasks in the final model, when adjusted and integrated with personal and workplace factors, altered the OR estimates. If compared to the five easier job-tasks actually sampled, five of six had higher strain scores; however, if compared to the five harder job-tasks, only sorting trusses and setting pre-built stairs ranked within the range seen for those job-tasks. Sorting trusses was evaluated and found to contain certain ergonomic risk factors.

Sorting trusses was associated with lifetime LBP with an OR 4.36 (CI 1.22 – 15.61) based on strain score alone. It ranked third highest in subjective strain to the low back (mean score 2.63) of the 10 job-tasks sampled, and it was characterized as a harder job-task. Correspondingly, it also ranked third most stressful when looking at the total compression scores presented in Table 42. This job-task also ranked fifth most stressful on the low back out of the 44 major job-tasks ranked by workers (Table 4b). Sorting trusses is clearly a stressful work activity. The ergonomic elements are listed in Table 13. Elements of posture and strain were evaluated statistically and found to be different ($p < 0.01$) among all 10 job-tasks sampled. Individual ergonomic elements were evaluated among the 10 job-tasks sampled and presented in Tables 17 through 39. Meaningful evaluations were believed to include significant differences ($p < 0.05$) for total compression, total shear, and OWAS Action Categories; these were thought to best represent ergonomic risk of LBP. Equal comparisons cannot be made to job-tasks not sampled and evaluated. When the job-task logistic regression model included adjustment for personal and workplace variables and was finally integrated, the OR for sorting trusses increased substantially from 4.36 (CI 1.22 – 15.61) to 38.50 (CI 2.26 – 586.93). It is apparent that personal and workplace factors have a significant influence on perception of strain and effort to the low back. The low back strain scores are not complete characterizations of risk. The combination of job-task variables, personal, and workplace factors is most likely a better estimation of risk. A significant number of job-tasks are highly correlated to different LBP endpoints (Tables 94 – 96).

Of the limited research available in this area, only one other investigator has evaluated ergonomic risk factors for LBP in residential construction in a remotely similar manner as seen in this study. This aspect alone makes the present research unique and informative. 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. This study has successfully characterized multiple parameters of 10 job-tasks not seen previously in residential construction literature as well as perceived levels of low back strain for a larger set of job-tasks performed by nearly every homebuilding framing carpenter in America.

Stubs (1981) used radio pressure pills to measure intra-abdominal pressures of construction workers performing specific tasks in the telecommunication construction industry. This work was an early, successful attempt to quantify differences between job-tasks. These researchers found peak intra-abdominal pressures highest during materials handling job-tasks; they did not characterize additional ergonomic parameters. In this study we also found that greater lumbar compression occurred in job-tasks requiring heavy materials handling; this is consistent with findings by Stubs in 1981.

Using field observation methods, Bernold and Guler (1983) identified strenuous work, heavy materials handling, pushing, pulling, twisting, and frequent lifting over 11.35 kg (25 lb) as risk factors. This was an expert judgment without quantification of actual ergonomic stresses. Workers were not surveyed as to their perceived effort. The present study found loads above 20 kg handled 36% of the time for those harder job-tasks whereas only 6% of the time similar loads were managed performing easier job-tasks. Some of the job-tasks such as placing beams by hand, sheeting floors and roofs, and standing walls require loads far in excess of 20 kg to be managed. The nature of construction work requires nearly all trades be engaged in heavy physical demands on a perpetual basis. The preponderance of expert opinion is that these activities pose a potential ergonomic hazard to those who perform them (Bernold and Guler, 1983; Cook et al., 1996; Hildebrandt, 1995; Koningsveld, 1997; Riihimaki et al., 1994; Xu et al., 1996).

Using a more systematic approach, Schneider and Susi (1994) developed an ergonomics checklist for construction and identified job-task risk factors such as awkward posture, high force, heavy weight, high repetition, hand tool stress, prolonged static postures, and exposure to vibration. No quantification of demands is required to use this checklist. These factors were judged to be risky based on expert observation and opinion only. Workers were not surveyed regarding their perception of strain and effort. This ergonomic assessment tool was not designed for specific use in residential construction and was piloted in commercial construction only. Checklists have been used in ergonomics for many years in other industries. Susi and Schneider applied similar principles to the development of their unique construction ergonomics checklist. In contrast, the present study did not characterize the risks simply as present vs. not present from an expert standpoint, but went beyond this level of investigation to quantify potential risks.

Another investigator, Bhattacharya et al. (1997), also developed an ergonomics checklist approach to assessing ergonomic risk factors in construction. This tool was not specified for either commercial or residential building. These investigators looked at risk factors for musculoskeletal injury in general, including the back. They principally assessed postures, but also looked at weights handled and repetitions. Their pilot study evaluated drywall job-tasks and they concluded that differing ergonomic risks were present among different job-tasks. This approach was also based upon the opinion of the evaluator and did not sample the workers' subjective strain, nor were job-tasks quantified using a posture-based tool such as OWAS© as seen in the present study.

In a comprehensive study, Cook et al. (1996) surveyed 438 carpenters regarding the degree of difficulty when performing work activities. Their intent was to develop an injury profile of various trades within construction. Their total sample size for all trades was 2,518, based on returned surveys. These researchers did not make a distinction between commercial and residential divisions within the industry. Their survey respondents were construction union members in Iowa. It is likely that their subjects are largely commercial carpenters, whereas homebuilders are more often non-union workers. These researchers chose to characterize carpentry work into phases: milling, fashioning, joining, assembly, erecting, fastening, or dismantling of materials. They also characterized 15 different work activities such as: performing the same task over and over, fast work for short periods, handle and grasp small objects, awkward cramped positions, etc. This approach was a broader task analysis characterizing the job at a higher level than at the job-tasks level (Kirwin and Ainsworth, 1992; Shepard, 2001). Respondents were asked to rate the degree of difficulty on a scale of 0 – 10. This approach is very similar to this study and that of Mattila et al. (1993) and Moore and Garg (1995). The six activities rated highest were: working in the same position for long periods, awkward and cramped positions, bending and twisting the back awkwardly, reaching overhead or away from the body, working when hurt or injured, and carrying or lifting heavy materials. These postures were also seen in job-tasks sampled in this study. All of these six activities were rated between four and six. In other words, they exhibited a 40% to 60% difficulty in performing. When comparing these to the present study a broader range is seen, 28% to 71% difficulty on the low back. It appears these two study findings are consistent.

Using epidemiological methods, Latza et al. (2000b) identified job-task risk factors for LBP in a cohort of 285 construction workers in Hamburg, Germany. The study team was able to design a longitudinal study and conduct a pre-post survey and medical examinations over a three-year period. The study looked at various trades including carpentry. The overall 12-month prevalence for LBP and/or sciatica was 37.4%, consistent with our findings of 38%. The researchers found increased risk of LBP with some carpentry job-tasks such as sawing wood: 12-month OR 5.2 (CI 0.9 – 6.2) and erecting roof structures OR 6.0 (CI 0.8 – 44.7). A higher 12-month period PR of 33.10 was identified in this study and was related to the two job-tasks: installing floor joists and rollup. Latza and his team offered no ergonomic assessment of job-tasks but simply identified the prevalence rates associated with specific job-tasks. This study looked at personal and workplace factors and their influence on job-tasks in addition to the multiple parameters of ergonomic stress. It is clear that these variables must be considered in combination when estimating risk of LBP in the workplace.

In a comprehensive ergonomic assessment, Mirka et al. (2000) used 3-D modeling, tri-axial goniometry, and the 1994 NIOSH lifting equation to quantify job-task demands and LBP risk factors in framing carpenters working in residential construction. This study is the closest seen in the literature to the present study. These researchers sampled approximately 350 hours of framing carpentry work using goniometry and video recording. The researchers did not characterize ergonomic hazards by job-task but rather by ranges of spinal loading and risk by percent of time spent per job title. They characterized spinal compressions of 660 N increments into 10 categorical ranges. The logic here was to start with 10% of the MPL and work upward. Carpenters were exposed to between 1,980 N – 2,640 N for over 50% of the time while performing their usual work. The load range 2,640 N – 3,300 N was less than five percent of the work time and in the remaining work time, spinal loading was below 1,980 N. In contrast, this study total compression levels were measured at peak and much higher. These researchers did not find exposure above 3,300 N. The NIOSH AL is 3,425 N and seven of the 10 job-tasks evaluated in this study were above the AL. This clearly demonstrates that spinal compression integrated over time is lower than peak loading during specific job-tasks as seen in the present study. These investigators did not make a distinction between contributors or components of spinal compression as was done in the present study.

In contrast, the 2-D ErgoMaster© software used in the present 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 Mirka's group. However, the present study looked at peak loading to characterize risk, whereas the Mirka group looked at total workday spinal loading (integrated), which encompassed many job-tasks. If one considers cumulative loading a greater risk, then Mirka's team has best characterized the relative risk; however, if one considers peak loading the best indicator of ergonomic risk, then the present study has achieved that goal.

It is apparent that job-tasks should not be evaluated devoid of personal and workplace factors. The relationships of personal and workplace may be important in determining risk of LBP in residential construction as seen in many other industries (Bigos et al., 1991; Deyo and Bass, 1989; Heliovaara, 1987; Svensson and Andersson, 1983; Xaing et al., 1999). Latza et al. (2000a, b) looked at individual and psychosocial factors such as age, body weight, job control, and satisfaction. However, they did not find any significant effect due to these variables. In contrast, this study identified several factors related to not only the subjective strain rating but also the estimation of risk related to job-tasks in the logistic regression models. A number of personal and workplace factors are correlated with different LBP endpoints (Tables 91 – 93). These findings are consistent with many previous investigators (Adams et al., 1999; Burdorf and Sorock, 1997; Lagerstrom et al., 1995; Latza et al., 2000a, b; Riihimaki et al., 1994). The job-task of sorting trusses was impacted when adjusted for significant personal and workplace factors and when combined into an integrated model. The effect of personal and workplace factors increased the 12-month period OR estimates from 4.36 to 38.50 in the final model (Tables 75 and 90).

The characterization of job-tasks is meaningful. To whatever level or parameter the job-task and inherent demands can be evaluated and elucidated, light may be shed on the mysteries of work-related stress. The traditional ergonomic approach has been to look for exposure to excessive force, high repetitions, awkward postures, cold, vibration, and contact stress as the major musculoskeletal risk factors of interest. Greater effort has been made in recent years to accurately measure those factors and others to better describe their parameters and dose-response effects. This study has successfully characterized a limited number of framing job-tasks.

Research Aim 2: Measure and analyze subjective strain / effort related to framing job-tasks and evaluate personal and workplace characteristics that may relate to the perception of strain / effort.

This research aim was also accomplished through a multi-step process discussed in the methods section. Briefly, the first step was to determine what major job-tasks framing carpenters performed on a day-to-day basis followed by the development of a low back strain survey. The survey was administered and data recorded (Tables 4a, b). The strain survey used in this study was a modified Borg scale consistent with previous investigators.

Borg (1990) defines psychophysics to include that information we perceive about the world around us through our sensory system. He introduced the Rating Perceived Exertion (RPE) 20-point scale in 1962. Since that time the Borg scale and framework for RPE have become a standard tool used among ergonomists, therapists, physiologists, and many other health and science experts to assess work performance including low back stress (Boussenna et al., 1982; Burdorf and Laan, 1991; Ciriello et al., 1993; Davis et al., 2000; Genaidy et al., 1990; Herrin et al., 1986; Moore and Garg, 1995; Troup et al., 1987; Wilson and Corlett, 1995). He modified the scale in 1990 to 10 points. Mattila et al., (1993) used a six-point scale: 1) no strain, 2) low strain, 3) moderate strain, 4) high strain, 5) very high strain, and 6) intolerable strain. Moore and Garg (1995) modified the scale to five-points: 1) light exertion, 2) somewhat hard, 3) hard, 4) very hard, and 5) near maximal. Using the Mattila et al. (1993) scale and framework the present five-point scale was developed by dropping the sixth level. Zero was recorded if the job-task was not performed. No comparable data is available where similar job-tasks were rated.

In this study, all 44 job-tasks were rated by framing carpenters (Tables 4a, b); mean strain scores ranged from 1.05 to 3.08 with the midpoint being 2.07. Those job-tasks designated as easier were well below the midpoint level and those designated as harder were well above this level. However, in this study the ergonomic elements of posture and strain measured for the 10 job-tasks could not be correlated to 44 low back strain scores as a limitation of the study design. A complete set of ergonomic measurements would be necessary for all 44 job-tasks to facilitate linkage to physiological and biomechanical elements. However, prior studies have found a positive correlation between physiological parameters such as heart and respiration and perceived strain (Wilson and Corlett, 1995). Borg's RPE was meant to assess overall general exertional strain, whereas the 2D ErgoMaster© was designed to assess specific low back stress. Nonetheless, it is believed that a subjective characterization is valid and useful in understanding what job-tasks are felt to be most stressful.

The question remains, where does the stress come from? The job-task of plating beams by hand, with a perceived mean low back strain score of 2.78 (ranked very high), was determined to have a protective effect, OR 0.30 (CI 0.15 - .78); perceived exertion alone does not explain risk of low back injury. Unfortunately this job-task was not sampled for ergonomic elements of posture and loading. Having observed this job-task performed on jobsites, it appears more hazardous from a safety standpoint than physically stressful. Stress is internal and external, mechanical, physiological, and psychological. Further research is needed to understand the full spectrum of perceived and real stressors, both internal and external related to job-tasks. Construction framing carpentry includes a complex set of variables as do job-tasks in many industries; fertile ground exists for further research to fully understand risk factors for LBP.

The low back strain scores were statistically evaluated using the GLM-MANOVA procedure to assess the relationships of personal and workplace factors to scores. Eleven personal and workplace factors were found to significantly ($p < 0.05$) affect subjective strain scores in at least 25% (11/44) of job-tasks rated. The variability in strain ratings was presented in Tables 4a, 4b, and 44 through 71. When adjusting the job-task models for physical and mental exhaustion, health status, level of co-worker caring, and job satisfaction influenced the significance of some variables. In the lifetime model, Table 81, cutting materials and building partitions dropped from the model. In the 12-

month period model, Table 82, one job-task, roll up, dropped from the model and the point prevalence model, Table 83, remained unaffected. When combining variables, Tables 84, 86, 88 into an integrated model, job-task variables were impacted, as were personal variables. In looking at lifetime LBP, treating the initial job-tasks, Table 81 with personal and workplace factors, the POR estimates for LBP decreased. However, when integrating these same variables into one larger model with personal and workplace variables, Table 84, the OR estimates increased substantially. There clearly exists a relationship between the respondent's perception of job-task low back strain and other factors. Future research is needed to explore the nature of such personal and workplace variables and their effect, interactions, and significance when estimating risk of LBP.

Research Aim 3: Characterize and measure body postures related to job-tasks using the Ovako Working Posture Analysis System© (OWAS©) software.

This study aim was accomplished as outlined in the methods section. Ten job-tasks were sampled using video recording and then analyzed using OWAS© for elements of postural variation and load demand. Ergonomic elements of posture are presented in Tables 6 – 15. Significant differences ($p < 0.01$) were seen between the 10 job-task samples for all applicable OWAS© elements measured (Table 16). Values for each of the 11 OWAS© elements of posture are presented in Tables 29 – 39 for each of the10 job-tasks evaluated. 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.

The 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.

In another study using OWAS, Li (2000) also evaluated commercial construction workers in Taiwan. He characterized OWAS findings as percent of time in harmful postures including ACs 2 - 4. He found the following: form work 32.4%, iron work 35.9%, cement work 36.1%, and scaffold work 43.3%. When looking at equal comparisons for carpentry, the present study found 51.2% of time is spent in harmful postures. This may offer a more sensitive risk assessment of low back strain. The AC 2 is alleged to pose "slight harm" and often not considered as significant by investigators, whereas AC 3 and 4 are clearly higher risk categories. If one considers that recovery from slight harm is more readily achieved than from higher risk categories, then AC 2 is of less concern. Approximately one-half of the carpenter's time is spent in slightly harmful postures. The bulk of the remaining time is categorized as normal postures and thus facilitates recovery. This may be a fallacy. In fact, the cumulative effects of exposure may pose greater risk than realized. Future research in this area might include sampling of the entire workday as accomplished by Mirka and his team. A longitudinal cohort study would facilitate such an evaluation with LBP outcomes to assess relative risks due to cumulative and peak effects.

Mirka et al. (2000) investigated job-task postures using tri-axial goniometers. This technology is expensive and intrusive. Carpenters being assessed must wear this device around their waist fastened to their lumbar spine. This device tracks and records change in posture as well as speed and direction of movement. A goal of their study was to further characterize motions in terms of velocity and direction. The findings from this study were aimed at developing control technologies for reduction of spinal loading and postural strain related to carpentry work. In comparison, the OWAS is a simple data recording of standard posture classifications and does not record the kinematic details seen with lumbar goniometry.

Comparisons of the postures for the five-easier to those for the five-harder job-tasks can be seen in Table 41. Based on one-way analysis of variance (ANOVA), significant differences ($p < 0.01$) were seen for only two elements of ergonomic posture evaluation (SPSS, 1999). In the easier tasks, loads were below 10 kg for 87% of the time; for harder tasks and loads were above 20 kg for 36% of the time. No significant differences were seen relating to forward bent postures for any individual AC; all groups were approximately equally stressful. However, looking at the combined harmful postures in action categories 2 through 4, the easier tasks result in 45.4% time exposure compared to 57% time exposure for the harder tasks. The evaluation of strain scores to posture measures did not reveal significant correlations. Generally speaking, exposures to harmful postures were slightly greater among harder tasks than easier tasks.

Research Aim 4: Measure lumbar spine compression with 2-D ErgoMaster© software.

This aim was accomplished as outlined in the methods section. The 10 job-tasks identified using low back strain scores were sampled by video recording and then analyzed in the laboratory using the ErgoMaster© software. Multiple lumbar spine compressions and shear forces were calculated at peak loading for each of the job-tasks sampled (Tables 6 – 15). Significant differences ($p < 0.01$) were seen between the 10 job-tasks (Table 17, 20-24). The simple estimation of lumbar spine compression was accomplished for those job-tasks chosen, however it's the risk associated with identified loads that is of greatest concern.

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). Marras et al. (1999) evaluated validity, accuracy, and reliability of the 1993 NIOSH lifting equation. His team used a database of over 21 million work hours, injury data, and 353 jobs in 48 manufacturing plants. He found that the sensitivity of this ergonomic tool to detect high-risk jobs was 73%. The model did not perform as well for medium and low risk manual material handling jobs. However, it must be noted that the NIOSH lifting equation is not based solely on lumbar compression, but also integrates psychophysical and physiological parameters in estimating risk of low back injury. Their findings suggest that the higher risk job-tasks do include higher levels of spinal compression. It is now commonly accepted that most workers lifting in optimal conditions below the AL are not likely to suffer LBP due to lifting. Compression loads exceeding the AL are believed to pose increasing risk of LBP due to lifting. The maximum permissible limit of 6,600 N has been strongly associated with increased risk of LBP (Marras et al., 1999; Waters et al., 1999). The NIOSH lifting equation contains coefficients that are used to estimate risk through physical parameters that affect loading of the lumbar spine. These limits were directed at the assessment and prevention of materials handling low back disorders and are based upon a number of assumptions about the lift and environment including: loads are lifted in the sagittal plane, lift is smooth, no jerking or falling, not repetitive, width of material not exceeding 75 cm (~30"), lifting posture is unrestricted, two-hand lift, good footing, good coupling, and comfortable temperatures are all present.

In residential construction, these assumptions are usually violated by most job-task demands that require materials handling. For example, sheeting requires 32 kg sheets of OSB to be managed rapidly approximately 1/minute by multiple carpenters in adverse temperatures, without good footing or coupling in adverse environmental conditions. It is the nature of construction sites and job-tasks to be in a constant state of change, and workers are pressured to work quickly (Bernold and Guler, 1992; Helander, 1981, 1991; Koningsveld, 1997). If loading of the spine occurs under optimum conditions and yet poses increased risk, then how much more risk is associated with handling materials in construction work given the less than optimal conditions? That answer will require additional research. This study successfully estimated spinal loading in 10 job-tasks using a very small sample size. It is unfortunate that the design of this study did not call for statistical evaluation using logistic regression models prior to sampling and measurement. Future research designs should accomplish analyzing subjective strain data initially to identify significant job-tasks in the logistic regression models before sampling for ergonomic elements of posture and strain. While estimates made using the ErgoMaster© software are helpful, greater value for comparing subjective to measured levels could have been accomplished with more sampling.

Carpenters seen in this study performed all 44 job-tasks throughout the course of building a wood-frame house. The usual 186 m^2 (2,000 sq ft) requires approximately 5 – 10 days to erect the structure from the foundation to the roof depending upon crew size, and then the cycle is repeated with the next structure.

It is reasonable to conclude that residential carpenters are exposed to significant ergonomic risks for LBP due to materials handling and forward bent postures and associated higher levels of lumbar spine compression. Therefore, it is also reasonable to conclude that carpenters are likely to have higher levels of LBP than the non-construction population. This contention is well supported by Bernold and Guler (1993) who found residential builders at highest risk for LBP compared to all other areas of construction in Canada. Future studies should include longitudinal designs allowing for pre- vs. post-comparisons with periodic sampling and medical record outcomes evaluation. This type of data would have greater value in examining causation of LBP due to loading.

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% (Table 43a). Standing walls can be a very stressful job-task depending on the size and weight of the wall. Anecdotally, numerous workers reported that they had been hurt or seen others hurt performing this job-task. Once again, there remains a question as to the risk of cumulative loading vs. peak loading.

Research Aim 5: Measure prevalence of LBP in residential carpentry.

There exists a paucity of literature specific to LBP in residential carpentry. Our findings indicate a point prevalence of 14% with a prevalence rate (PR) of 12.29/100 fulltime equivalent (FTE) workers. The 12-month period prevalence for LBP was 38% with a PR 33.10/100 FTE. The lifetime prevalence of LBP was 54% with a PR of 51.06/100 FTE. The findings in this study appear to be less than what other researchers have found previously.

Holmstrom et al., (1992a, b) evaluated 1,773 construction workers from a randomly selected sample of 2,500 for LBP for risk factors and prevalence among a Swedish construction union membership. The data did not discriminate between residential and commercial workers. These researchers found a 12-month period prevalence of 54% and that 25% had suffered LBP for more than 30 days duration. They also reported that 13% had lost more than seven days of gainful employment due to LBP. That study found higher prevalence than the present study. Interestingly, the present study found that 35% of respondents had lost work due to LBP in the past 12 months and that 15% had suffered LBP more than 20 days. The Holmstrom data were collected by a survey mailed to respondents who were organized by union membership in a socialized culture that advocates universal health care. It is likely that findings are accurate and representative of Swedish construction workers. In contrast, this study collected surveys from non-union, willing participants, on-site, without prior notice, and among residential carpenters only in a highly competitive culture without universal health care. The disparity of 16% may be due to sample cooperation, worker variability, and reporting differences between studies and cultures. In the Swedish study, LBP is defined as pain or ache in low back or gluteal region being present for 1-7 days with any degree of functional impairment. Additional defining information or examples are not known. In the present study, carpenters were asked if they had suffered an episode of LBP in the past 12 months that caused them to seek medical care or alter activities of daily living. No additional definitions or information were offered. Many carpenters approached by the investigator to complete the survey declined to participate and may have biased our findings. The sample size differs dramatically between the two studies. The present study has substantially fewer respondents and lacks power seen in the Swedish investigation. Many researchers have looked at 12-month period prevalence on very large scales (Andersson, 1997; Cassidy et al., 1998; Guo et al., 1995, 1999; Linton et al., 1998; Thorbjornsson et al., 2000). The 12-month period prevalence among the general US population was 17% (Andersson, 1997; Guo et al., 1995; 1999). For population proportions equal to 17% and 38%, Fleiss (1981) recommends 79 subjects be sampled to have 0.80 power in comparing proportions at the .05 significance level. It is reasonable to conclude that 12-month prevalence rates seen in this study are higher than in the general population and that this may be extrapolated to the outside population of residential carpenters.

Another comparison can be made between the present study and the findings of Dement and Lipscomb (1999) who investigated workers' compensation records from a cohort of residential construction workers in North Carolina. They describe rates per 100 FTE but do not specify IR or PR. Given that they assessed 31,113 claims from only 7,400 workers over a seven-year time frame, it appears that each worker suffered approximately 4.2 reportable injuries. It is reasonable to conclude that the rates are likely to be seven-year

PRs and not IRs. While these rates may be similar, they are not equivalent. They reported a claims rate (CR) for carpenters at 22.9 compared to a lifetime PR of 51.01 seen in this study. The average framer had been in residential construction 10.9 years. When looking at the cause of injury, these investigators found straining of muscles was the most frequent mechanism, lifting was the most common job-task (73.3%), and the back was the most frequent area (25%). These types of injuries are directly related to ergonomic factors of posture, loading, and strain. The Dement and Lipscomb study used information found in workers' compensation records compared to our self-report. Although these sources are different, they do yield comparable information. It is reasonable to conclude that both studies support the evidence that LBP PRs are higher in residential carpenters.

In the big picture, Guo et al. (1995, 1999) found an occupational LBP 12-month period prevalence of 17.8% in a sample of 1,550 male respondents employed in construction. Their sample combined both commercial and residential specialties with a total population of approximately 6.5 million workers nationwide. Estimates made from their data suggested that over one million construction workers were stricken with occupational LBP that year. Based on the data captured in this study, estimates can be made that over 1.2 million cases of LBP occurred in residential construction alone with a total population of 3.2 million workers nationwide. All other studies looking at LBP in construction have found higher PRs than did Guo et al. It is again reasonable to assume that the present study had conservative findings. In the big picture, Guo et al. (1995,

1999) estimated that over 22 million cases of LBP occurred in 1988 nationwide and 65% were work related.

Research Aim 6: Measure risk perception relating to framing carpentry and analyze the relationship to major carpentry job-tasks.

The findings in this study suggest that personal and workplace factors do have a significant influence on the prevalence of LBP among residential construction carpenters (Tables 76, 78, 80, and 84 – 93). The final integrated models in Table 90 include: "boss caring and concern", "worker's compensation insurance coverage", "working under time pressure", and "self employed status" significantly ($p < 0.05$) affected the OR estimates for LBP. These are in combination with physically demanding job-tasks for the lifetime and 12-month period prevalence models. The point prevalence model is entirely comprised of personal and workplace factors. The combined effects of psychological and high physical stress factors are strongly linked to LBP (Vingard et al., 2000).

Riihimaki et al. (1994) found no association of supervisor and co-worker relations to LBP in construction workers but did find positive predictive results with office workers. Leino and Hanninen (1995) found no association of supervisor and worker relationships to LBP. Bigos et al. (1991) found significant risk of LBP associated with lack of job satisfaction; they found no association of the relationships between supervisors and workers to LBP. The effects of employee supervisor caring did influence low back strain scores on a limited basis in this study. Although most job-tasks were not rated significantly different due to the ranked level of caring, there tended to be higher strain scores from those who perceived the least amount of caring. This may be an indicator of poor job satisfaction, which is strongly linked to increased risk of LBP (Andersson, 1997). This is an area that would benefit from further evaluation and investigation in residential carpentry. Additional data analysis is planned to explore potential relationships with Hispanic workers.

Many individuals have made strong assertions about the relationship of insurance benefits to injury and illness reporting, particularly employers and insurance representatives. They often contend that only insured employees have injuries as though they were contrived for the purpose of filing claims and collecting lost wages for time away from work. It is logical that insurance benefit coverage may influence the reporting of any work related injury including LBP to an employer. It would follow suit that employees with coverage would report an incidence of LBP and seek necessary care, whereas the uninsured worker may suffer silently and/or seek care without the employer knowing. The data in this study show that of the 35 framers reporting LBP in the past 12-months, 14 (40%) were not covered by workers' compensation insurance while 21 (60%) were insured. It is difficult to measure the differences in LBP prevalence between insured and uninsured individuals due to lack of standardized reporting for uninsured workers. The reporting mechanisms used in this country rely on work-relatedness to qualify for reporting. In residential construction there exists a high percentage of subcontractors who do not receive workers' compensation benefits from the general contractor or other sources. The data from this study indicate that 70% of the respondents were self-employed sub-contractors and

41% had no benefit coverage. Not finding comparable data in the literature, it is not known if this is commonplace in residential construction at large. It is clear that this is a reporting phenomenon and not a biological or plausible cause of LBP. This could be an interesting and revealing area for additional research.

Working under time constraints has been linked to LBP in other studies but not found to be significant in the studies reviewed (Burdorf and Sorock, 1997; Koster et al., 1999; Latza et al., 2000b; Thorbjornsson et al., 2000). The present study indicates increased risk of LBP, OR of 2.300 (CI 1.149 – 4.768) for 12-month period prevalence. This POR estimate is greater than previously seen but may reflect the higher degree of risk taking and hazard exposure in residential construction compared to other types of work. Although the presence of time pressure had no significant affect on low back job-task strain scores, those workers who ranked the time pressure highest also tended to rank their perception of job-task strain on the low back highest. This area needs additional work to investigate the relationships and mechanisms by which increased work pace, work behaviors, and risks converge to result in LBP and injury.

The data on body stature/height as a risk factor for LBP has mixed results (Andersson, 1981; Barnekow-Bergkvist et al., 1998; Biering-Sorensen, 1984; Bigos et al., 1986a, b; Dempsey et al., 1997; Heliovaara et al., 1991; Krause et al., 1998). While most investigators found slight increases in risk estimates with increasing stature/height, most reported no significant relationships. However, in this study, height was found to increase risk of LBP substantially, OR 4.60 (CI 1.411 – 12.157). Heliovaara (1987) also found increased risk OR 2.3 (CI 1.4 –

3.7) for men over 180 cm (70.87") tall and LBP. Barnekow-Bergkvist et al. (1998) found a protective affect between height and LBP in men and a significant risk among women OR 2.55 (CI 1.08 – 6.02). This study was assessing physical and psychological factors in persons with LBP and comparing differences in adolescents to adults. Men had reduced risk OR 0.55 (0.26 – 1.15). This group represented a randomly selected cross-section of the normal population in Sweden. The study population in this investigation is considerably different in many characteristics and may not be comparable to carpenters in this study. The data in this study revealed no significant affect or pattern in the low back strain scores and stature/height, yet increased risk of LBP was found. This is an interesting area to evaluate further and look at interactions of variables to further explore potential relationships of the unique anthropometry of framing carpenters and LBP.

The body mass index, or quetelet, is a measure of weight/height^2 found to be useful in evaluation of human health as well as risk assessment for LBP (Adams et al., 1999; Cleary et al., 1995; Deyo and Bass, 1989; Heliovaara, 1987; Lagerstrom et al., 1995; Leboeuf-Yde, 2000; Oleske et al., 2000; Zwerling et al., 1993). While the mathematics are consistent, the units of measure were not the same across the literature. In this study, units of measure were not converted to metric before calculating quetelet; weight (lb)/ht^2 (inches) was used (Kleinbaum et al., 1998). Quetelets ranged from 2.78 to 5.16 with a mean of 3.66. This personal factor exerted a protective effect, OR 0.100 (CI 0.029 – 0.682). While no definite relationship was apparent, the mid range group (2.39 – 3.78) tended to rank low back strain scores higher. In contrast, Heliovaara (1987) ranked quetelet values from Low (< 21.9) to High (> 30.0). He and others have reported increased risk of LBP for those above 24.0. Oleske et al. (2000) found negative correlation of quetelet to LBP using five different standard health survey tools. This is consistent with the present study. Neither study was conducted in residential carpentry and may not represent framing carpentry well. Further study is needed to better understand relationships and mechanisms of LBP in carpenters and their anthropometric features.

Construction is clearly a high-risk industry (Guidotti, 1995). Workers' risk perception about LBP and the trade at large were areas of investigation in this study design. The emphasis has been placed on the ergonomic elements of posture, loading, and subjective job-task low back strain for this dissertation. The data clearly show a significant relationship between all 44 job-task ratings and the overall risk perception about carpentry ($p < 0.01$, Table 98). It would be anticipated that this positive relationship exists due to their direct linkage. Some personal and workplace factors are also linked to risk perception (Table 97). The literature was deficient in comparable studies demonstrating linkages to mental exhaustion, time pressure, and alcohol consumption in residential carpenters; however, it would seem logical that these factors would impair risk perception and increase risk taking. Another study looking at adolescent behaviors of fast driving and unprotected sex found that alcohol often impaired risk perception and judgment resulting in increased risk taking (Gerrard et al., 1996). Additional exploration is planned in the future with additional support from NIOSH/CDC.

Those key areas relating to risk perception and LBP and risk perception in general are presented in Tables 44, 45, 57, 97 and 98.

It is firmly established in the literature that the perception and recognition of hazards on the job affect work behaviors and the propensity for injury (Cooper et al., 1993; Duquette et al., 1997; Guidotti, 1995; Helander, 1991; Howarth, 1987; Landeweerd et al., 1990; Leather, 1987; Peterson and Wilson, 1996;). Carpenters must take risks to achieve the goal of building a house. However, they take increasing risks as they become conditioned to behaviors that don't result in injury. In construction, there exists a tendency for the acceptable risk level or "target level risk" to change over time with experience, thus progressively increasing actual risk exposure (Landeweerd et al., 1990). The changes in risk perception are due to increasing levels of risk acceptance that are met without injury or negative feedback. Carpenters work under pressure and essentially at piece rates as sub-contractors. The general contractor pays them when their phase of home building is complete. If they complete the project ahead of schedule they may be entitled to a bonus; however, if they are delinquent, they may face penalties and fines. The piece rate, bonus, and penalty system associated with construction are disincentives to safe work practices and thus extend the risk acceptance levels on a progressive basis (Leather, 1987). Helander (1991) suggests that younger workers lack the experience to recognize hazards and risk inherent to construction work.

This study found that carpenters do recognize back strain and injury as a significant threat as well as the overall risk inherent in residential construction.

The relationships between these variables and others are not well understood and need additional evaluation. The relationship between job-task low back strain and risk characterization is linear. This may represent different target levels of risk perception that correlate to each other due to commonly held perceptions (Tables 94 - 96, 98). The linkage between risk perception, injury, and LBP is not well understood and most likely involves complex relationships to other personal and workplace variables not identified in this study. Risk perception will be another area for further investigation with the added support from NIOSH in the coming year.

Limitations

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 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 focus groups used to develop the low back strain survey were entirely white Anglo framing carpenters and biased the content, delivery, and feedback. This may have had a significant impact on communication, understanding, and usability of the survey instrument and may also explain the divergent responses from Hispanic framers. Further analysis will explore the vast differences and similarities between ethnicities.

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-Juntaura et al., 1996). The data remain unclear on the relationship between biomechanical and psychosocial factors and LBP. Davis and Heaney (2000) found 30% of the studies they surveyed did identify links between these variables while 59% did not. They point out that there is no absolute "gold standard" in assessing these risk factors of interest relating to LBP but remind researchers that selection of assessment tools should be based upon the research questions being asked. Although the 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 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). They may not have performed their work in a usual manner resulting in a bias toward the null. 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 easy 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. There exists future opportunities to do this research with NIOSH funding.

Final Conclusions

The original protocol for investigation called for 335 surveys to be analyzed in this study. However, the data were adversely affected by the variability between ethnicities resulting in the non-white Hispanics being separated from the data set for this evaluation. Future evaluation will explore and compare differences and similarities between the two ethnicities. Although the research aims for this study were met sufficiently to formulate some opinions about the prevalence of LBP and ergonomic elements of posture, loading, and perceived strain among residential framing carpenters, the research has left many unanswered questions and much fertile ground for future study.

It is clearly apparent that the perceived strain related to performing certain job-tasks is affected by many variables including personal and workplace factors. The data developed from this investigation will remain the focus of additional work for some time to come. It is hoped that more can be learned about risk perception and its influences on framing work in residential carpentry.

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 seen 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.

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Table 1 A - Personal Risk Factors by Ethnicity

Personal and Workplace Factors	Non-Hispanic Mean	Non-Hispanic Std. Dev.	Hispanic Mean	Hispanic Std. Dev.	Difference
Yrs in construction	11.751	9.951	3.805	4.1780	< 0.01*
Yrs in framing	10.866	10.046	3.673	4.1600	< 0.01*
Hrs worked per week	44.375	9.276	44.141	7.935	0.32
Hrs of safety training	13.021	19.060	14.066	25.655	0.44
Trainer	4.470	2.431	3.222	2.311	< 0.01*
Risk rating	2.149	0.829	2.082	1.155	0.97
Back strain in carpentry	3.538	0.879	2.443	1.099	< 0.01*
Job satisfaction	2.915	0.924	3.136	0.922	0.02*
Coworkers caring	2.947	0.932	2.924	1.116	0.09
Boss caring	3.208	0.882	3.172	1.136	0.99
Mentally exhausted	1.653	1.019	1.291	0.936	< 0.01*
Excessively exhausted	1.771	1.051	1.193	0.814	< 0.01*
Boring work	1.368	0.923	0.809	0.900	< 0.01*
Time pressure	2.188	1.089	0.889	1.118	< 0.01*
Side jobs	1.093	1.134	0.794	1.293	0.12
W.C. insurance	1.779	1.658	1.750	1.302	0.04*
Risk and hazard id train	1.747	0.437	1.671	0.471	0.16
LBP prevention	1.699	0.461	1.639	0.481	0.53
Job-task related LBP	1.905	0.295	1.837	0.370	0.12
Temperature exposures	1.979	0.144	1.885	0.319	0.01*
Noise exposures	1.862	0.347	1.692	0.462	< 0.01*
Self employed	1.702	0.460	1.304	0.461	< 0.01*
Employee status	1.457	0.501	1.698	0.469	< 0.01*
Age	34.978	11.129	27.362	7.645	< 0.01*
Marital status	1.516	0.502	1.625	0.485	0.14
Height	70.495	3.488	67.104	3.707	< 0.01*
Weight	182.925	32.346	159.334	25.965	< 0.01*
Education level	3.945	1.369	1.883	1.304	< 0.01*
Income level	2.722	1.142	1.095	1.103	< 0.01*
Primary language	1.098	0.47	1.983	0.159	< 0.01*
Smoking status	2.079	0.895	1.708	0.808	0.001*

Alcohol consumption	1.989	1.565	0.856	0.958	< 0.01*
Exercise activity	1.247	1.069	0.662	0.763	< 0.01*
Health problems	1.090	2.249	0.317	1.167	< 0.01*
Health status	2.563	0.880	2.234	0.983	0.03*
Low back injury	1.521	0.502	1.203	0.403	< 0.01*
Type of LB injury	0.809	0.883	0.216	0.569	< 0.01*
Days suffered with LBP	1.271	1.726	0.444	0.912	< 0.01*
Continuous LBP	1.302	0.462	1.155	0.363	0.02*
Lost workdays due to LBP	1.333	0.474	1.116	0.321	< 0.01*
LBP that altered ADLs	1.354	0.481	1.099	0.300	< 0.01*
Recent episode of LBP	1.137	0.345	1.078	0.269	< 0.01*
LBP caused by work activities	1.283	0.881	0.605	0.753	< 0.01*
Type of provider sought	2.066	2.458	0.654	1.452	< 0.01*
LBP is a problem in carpentry	2.054	0.771	1.807	1.135	0.04*
Chiropractic treatment	0.253	0.437	0.032	0.179	< 0.01*
Medical treatment	0.172	0.379	0.070	0.256	< 0.01*

*N = 221 Hispanic
*N = 94 Non-Hispanic

Table 1 B - Task Strain Scores by Ethnicity

Framing Carpentry Job-Task	Non-Hispanic		Hispanic		
	Mean	Std. Dev.	Mean	Std. Dev.	Difference
Break materials	1.879	1.127	1.074	0.755	< 0.01*
Sort materials	2.444	1.180	1.199	0.765	< 0.01*
Measure layout	1.404	0.990	1.170	0.822	0.02*
Plate beams by hand	2.776	1.721	1.367	1.015	< 0.01*
Plate beams with crane	1.465	1.043	1.298	1.028	0.20
Install sill plates	1.788	1.062	1.109	0.683	< 0.01*
Frame walkouts	2.212	1.145	1.259	0.894	< 0.01*
Cut floor joists	1.969	1.069	1.263	0.889	< 0.01*
Sort pre-cut trusses	2.192	1.307	1.222	0.946	< 0.01*
Install floor joists	2.412	1.256	1.453	0.973	< 0.01*
Sheet floor w/ 3/4" OSB	2.788	1.223	1.277	0.860	< 0.01*
Snap lines on floor	1.525	0.993	1.034	0.700	< 0.01*
Install beams by hand	3.082	1.360	1.329	1.045	< 0.01*
Install beams with crane	1.418	1.025	1.118	0.855	< 0.01*
Sort wall material	2.255	1.087	1.358	0.758	< 0.01*
Layout plates	1.691	0.993	1.000	0.811	< 0.01*
Set up cut station	1.357	0.997	0.914	0.716	< 0.01*
Create a cut list	1.051	0.854	0.979	0.665	0.05*
Cut material	2.174	1.036	1.297	0.786	< 0.01*
Square wall	1.704	0.997	1.038	0.612	< 0.01*
Sheet wall on ground	2.184	1.039	1.203	0.881	< 0.01*
Sheet wall upright	2.557	1.250	1.201	0.921	< 0.01*
Stand walls	2.969	1.311	1.389	1.043	< 0.01*
Sort trusses	2.633	1.161	1.290	0.869	< 0.01*
Sheet gable ends	1.928	1.148	1.181	1.003	< 0.01*
Rack trusses	2.010	1.319	1.136	1.025	< 0.01*
Cut tails	1.949	1.319	1.257	0.977	< 0.01*
Install roof anchors	1.490	0.987	1.091	0.908	< 0.01*
Boom trusses	1.889	1.058	1.226	0.912	< 0.01*
Install truss clips	1.626	0.932	1.340	0.827	0.02*
Brace off trusses	1.909	1.000	1.177	0.781	< 0.01*

Sheet first row on roof	2.541	1.278	1.138	0.876	< 0.01*
Finish sheeting roof	2.551	1.219	1.134	0.943	< 0.01*
Install fascia rafters	2.031	1.599	1.207	1.093	< 0.01*
Roll out / set up tools	1.557	0.999	1.030	0.666	< 0.01*
Build and install stairs	2.296	1.430	1.146	0.883	< 0.01*
Set pre-built stairs	2.636	1.396	1.195	1.052	< 0.01*
Build and install partitions	2.071	1.133	1.158	0.925	< 0.01*
Build basement floors	1.667	1.659	1.009	0.954	< 0.01*
Build exterior decks	1.821	1.530	1.034	0.952	< 0.01*
Nail connections	1.725	0.883	1.110	0.914	< 0.01*
Cut roof vents	1.374	1.036	1.118	0.859	0.03*
Clean up scrap material	2.091	1.144	1.147	0.602	< 0.01*
Roll up / put tools away	1.612	0.870	1.080	0.606	< 0.01*
Strain sum score	91.000	33.000	54.000	19.000	< .001*

*N = 221 Hispanic

*N = 94 Non-Hispanic

Table 2 Descriptive Statistics for Residential Framing Carpenters

Worker Characteristics	N	Mean	Std. Dev.	Note	Findings
Gender	94	male	0	All	Carpenters surveyed were male
Age of worker	91	35	11	Varied	Ages ranged 18 - 65 yrs.
Ethnicity of respondent	94	Cauc.	0	All	Non-Hispanic
Primary language of respondent	90	English	0	All	Spoke English
Height of respondent	93	70.5"	3.5"	70.5"	Stature greater than average in US
Weight of respondent	92	183 lbs.	32	183 lbs.	Carpenters are heavier than average
Marital status	91	1.5	0.5	50%	Reported that half are married
Highest grade attained	89	3.9	1.4	51%	Reported high school graduates and above
Income level	88	2.7	1.1	60%	Reported earning $20K / yr. or greater
Smoking status	87	2.1	0.9	44%	Reported are current smokers
Alcohol consumption	87	2	1.6	42%	Reported 3 - 5 drinks week or greater
Exercise activity	88	1.2	1.1	59%	Reported light or moderate weekly exercise
Overall health status	93	2.6	0.9	53%	Reported "good" health or better
Health problems	87	1.1	2.2	78%	Reported no health problems
Employee of the framing Co.	91	0.4	0.5	43%	Reported as employees of framing company
Self-employed subcontractor	91	0.7	0.5	70%	Reported sub-contractor status
Years in residential construction	91	11.7	10	27%	Reported less than 5 yrs. experience
Years in residential framing	91	10.9	10	37%	Reported less than 5 yrs. in framing
Hours worked per week	92	44.4	9.3	78%	Reported working 40 - 50 hrs. per week
Risk in carpentry	92	2.1	0.8	76%	Reported risk as moderate or high
Cold and hot exposure	92	2	0.1	99%	Reported exposure to temperature extremes
Loud noise exposure	91	1.9	0.3	89%	Reported exposure to very loud noise
Satisfied with framing carpentry	92	2.9	0.9	76%	Reported mostly or very satisfied with job
Coworkers care	92	2.9	0.9	93%	Reported "some" or greater caring
Boss cares	93	3.2	0.9	95%	Reported "some" or greater caring
Mentally exhausting	93	1.6	1	24%	Reported frequent mental exhaustion
Excessively exhausted	93	1.8	1	31%	Reported frequent physical exhaustion
Boring work	93	1.4	0.9	41%	Reported "sometimes" being bored
Working with time pressure	93	2.2	1.1	41%	Reported most or all of the time
Hours working away from job	93	1.1	1.1	18%	Reported 9 -16 hours per month
Covered by W.C. insurance	92	1.8	1.7	59%	Reported being covered

Table 3 Descriptive Statistics for LBP in Residential Framing Carpentry

Low Back Pain and Injury	N	Mean	Std. Dev.	Note	Conclusion
Point prevalence (w/in 2 weeks)	92	0.1	0.3	14%	Reported they had suffered recent LBP
1-Year period prevalence	93	0.4	0.5	38%	Reported LBP within the last 12 months
Lifetime prevalence of LBP	93	0.5	0.5	54%	Reported work related LBP at some time
Continuous LBP	93	0.3	0.5	32%	Reported continuous LBP
Lost workdays due to LBP	93	0.4	0.5	35%	Reported lost work days due to LBP
Type of LB injury	91	0.8	0.9	31%	Reported LBP due to repeated activity
Days suffered with LBP	93	1.3	1.7	15%	> 20 days suffered in the past year
LBP caused by work activities	89	1.3	0.9	59%	Reported their LBP caused by work activity
Back strain in carpentry	91	3.5	0.9	74%	Reported strain as moderate or high
Type of provider sought	88	2.2	2.5	28%	Reported their LBP was self treated
Chiropractic treatment	94	0.7	0.4	28%	Sought chiropractic (DC) care
Physician treatment	94	0.2	0.4	18%	Sought medical (MD) care
LBP is a problem in carpentry	90	2.1	0.8	82%	LBP is a moderate or severe problem
Tasks associated with LBP	92	1.9	0.3	92%	Reported certain tasks associated with LBP

Table 4 Descriptive Statistics for S & H Training in Residential Carpentry

Safety and Health Training	N	Mean	Std. Dev.	Note	Conclusion
Hours of S & H training	90	13	19	54%	Reported < 5 hrs. in previous 12 months
S & H trainers	81	4.5	2.4	39%	Reported multiple sources of training
Risk and hazard identification	92	1.7	0.4	76%	Reported receiving training
Low back injury prevention	90	1.6	0.5	69%	Reported receiving training

Table 5a Mean Strain Scores for 44 Major Carpentry Tasks

Carpentry Task	N	Mean	Std. Dev.
Break materials	94	1.879	1.127
Sort floor materials	94	2.444	1.180
Measure layout	94	1.404	0.989
Plate beams place by hand	93	2.776	1.721
Plate beams place by crane	94	1.465	1.043
Install sill plates	94	1.788	1.062
Frame walkouts	94	2.212	1.145
Cut floor joists	93	1.969	1.069
Sort precut floor trusses	94	2.192	1.307
Install floor joists	92	2.412	1.256
Sheet floor w/ 3/4" OSB	94	2.788	1.223
Snap lines	94	1.525	0.993
Install beams by hand	93	3.082	1.360
Install beams using crane	93	1.418	1.025
Sort wall material	93	2.255	1.087
Lay out plates	92	1.691	0.993
Set up cut station	93	1.357	0.997
Create cut list	93	1.051	0.854
Cut material	93	2.173	1.036
Square wall	93	1.704	0.997
Sheet exterior wall down	93	2.183	1.039
Sheet exterior wall upright	93	2.556	1.250
Stand walls	93	2.969	1.312
Sort trusses	93	2.633	1.161
Sheet gable ends	92	1.928	1.148
Rack trusses	92	2.010	1.319
Cut tails	93	1.949	1.319
Install roof anchors	94	1.490	0.987
Boom trusses	94	1.889	1.058
Install truss clips	94	1.626	0.932
Brace trusses	94	1.909	1.001
Sheet first row on roof	94	2.541	1.278
Finish sheeting roof	94	2.551	1.219
Install fascia rafters	93	2.031	1.599
Roll out / Set up tools	94	1.557	0.100
Build and install stairs	94	2.296	1.430
Set pre-built stairs	94	2.636	1.396
Build and install partitions	92	2.071	1.133
Build basement floor	91	1.667	1.659
Build exterior deck	94	1.821	1.530
Nail metal connections	94	1.725	0.882
Cut roof vents	94	1.374	1.036
Clean up scrap material	94	2.091	1.144
Roll up / put tools away	94	1.612	0.870
Strain sum score	94	91	33

*Job-tasks arranged in the order of actual building by framing carpenters

Table 5b 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

Table 6 Creating a Cut List
Ergonomic Elements of Posture and Strain

Ergonomic Elements of Spinal Compression and Shear	**Mean Force in Newtons**	**Standard Deviation**
Total compression forces	2965	667.1
Total shear forces	852	256.2
Bending moment	136	41.8
Joint forces	3817	918.4
Erector spinae forces	2738	833.5
Compression due to load	0	0
Compression due to upper body weight	253	212.2
Compression due to erector spinae	2712	825.1
Shear due to load	0	0
Shear due to upper body weight	471	140.3
Shear due to erector spinae	381	115.8
Total Stress	**14325**	
Work Postures as Percentage of Job-Task Cycle		
Work Postures During Job-Task Cycle	**Percent Of Time**	**Standard Deviation**
Back straight during task	67	12.5
Back bent during task	33	12.5
Back twisted during task	0	0
Back bent and twisted during task	0	0
Both arms below shoulder height	97	4.7
Both arms above shoulder height	3	4.7
Standing	67	12.5
Standing with one knee bent	3	4.7
Kneeling	20	8.2
Walking	10	8.2
Load < 10 kg.	100	0
Action Category 1	67	12.5
Action Category 2	30	8.2
Action Category 3	3	4.7
Action Category 4	0	0
Category Frequency 1	7	1.2
Category Frequency 2	3	0.82
Category Frequency 3	0.32	0.47
Category Frequency 4	0	0
Total Stress	**510.32**	
Horizontal Distance to Load	**53 cm**	**9.4**

NIOSH Action Limit (AL) 3,425 N Maximum Permissible Lift (MPL) 6,361 N

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.

Table 7 Setup Cut Station
Ergonomic Elements of Posture and Strain

Ergonomic Elements of Spinal Compression and Shear	**Mean Force in Newtons**	**Standard Deviation**
Total compression forces	3575	226.2
Total shear forces	1006	21.7
Bending moment	167	8.4
Joint forces	4581	206.8
Erector spinae forces	3413	84.3
Compression due to load	48	50.7
Compression due to upper body weight	146	110.1
Compression due to erector spinae	3380	83.4
Shear due to load	105	26.5
Shear due to upper body weight	426	58.6
Shear due to erector spinae	475	11.4
Total Stress	**17322**	
Work Postures as Percentage of Job-Task Cycle		
	Percent	**Standard**
Work Postures During Job-Task Cycle	**Of Time**	**Deviation**
Back straight during task	67	12.5
Back bent during task	33	12.5
Both arms below shoulder height	97	4.7
Both arms above shoulder height	3	4.7
Standing	67	12.5
Standing with one knee bent	3	4.7
Kneeling	20	8.2
Walking	10	8.2
Load < 10 kg.	100	0
Action Category 1	67	12.5
Action Category 2	30	8.2
Action Category 3	3	4.7
Action Category 4	0	0
Category Frequency 1	7	1.3
Category Frequency 2	3	0.8
Category Frequency 3	0.32	0.5
Category Frequency 4	0	0
Total stress	**510.32**	
Horizontal distance to load	**45 cm**	**10**

NIOSH Action Limit (AL) 3,425 N Maximum Permissible Lift (MPL) 6,361 N

Category 1 = Normal postures, no action required.

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Table 8 Measure Layout
Ergonomic Elements of Posture and Strain

Ergonomic Elements of Spinal Compression and Shear	**Mean Force in Newtons**	**Standard Deviation**
Total compression forces	2884	90.4
Total shear forces	847	44.8
Bending moment	136	5.6
Joint forces	3731	72.5
Erector spinae forces	2718	111.5
Compression due to load	0	0
Compression due to upper body weight	192	169.5
Compression due to erector spinae	2691	110.2
Shear due to load	0	0
Shear due to upper body weight	396	141.3
Shear due to erector spinae	378	15.6
Total Stress	**13973**	
Work Postures as Percentage of Job-Task Cycle		
Work Postures During Job-Task Cycle	**Percent Of Time**	**Standard Deviation**
Back straight during task	33	12.9
Back bent during task	68	12.9
Both arms below shoulder height	100	0
Standing	46	13.8
Standing on one leg	3	4.7
Standing with one knee bent	3	4.3
Kneeling	22	10.7
Walking	26	4.2
Load < 10 kg.	100	0
Action Category 1	0.032	12.9
Action Category 2	65	12.3
Action Category 3	3	4.3
Action Category 4	0	0
Category Frequency 1	3	1.3
Category Frequency 2	7	1.3
Category Frequency 3	0.32	0.47
Category Frequency 4	0	0
Total Stress	**479.352**	
Horizontal distance to load	**29 cm**	**1.5**

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Table 9 Roll Out / Set Up Tools
Ergonomic Elements of Posture and Strain

Ergonomic Elements of Spinal Compression and Shear	**Mean Force in Newtons**	**Standard Deviation**
Total compression forces	3186	1167
Total shear forces	802	424.2
Bending moment	142	69.6
Joint forces	3989	1572
Erector spinae forces	2852	1392
Compression due to load	285	75.7
Compression due to upper body weight	285	247.7
Compression due to erector spinae	2824	1379
Shear due to load	76	73.5
Shear due to upper body weight	329	189.8
Shear due to erector spinae	397	194
Total Stress	**15167**	
Work Postures as Percentage of Job-Task Cycle		
Work Postures During Job	**Percent Of Time**	**Standard Deviation**
Back straight during task	73	20.7
Back bent during task	24	17.1
Back twisted during task	3	4.8
Both arms below shoulder height	100	0
Standing	43	4.8
Walking	67	17.1
Load < 10 kg.	80	8.2
Load > 20 kg.	20	8.2
Action Category 1	76	17.1
Action Category 2	17	12.5
Action Category 3	7	4.7
Action Category 4	0	0
Category Frequency 1	8	1.7
Category Frequency 2	2	1.2
Category Frequency 3	4	4.5
Category Frequency 4	0	0
Total stress	**524**	
Horizontal Distance to Load	**38 cm**	**17**

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Table 10 Lay Out Plates
Ergonomic Elements of Posture and Strain

Ergonomic Elements of Spinal Compression and Shear	**Mean Force in Newtons**	**Standard Deviation**
Total compression forces	3755	1011
Total shear forces	1002	220.1
Bending moment	179	47.8
Joint forces	3304	2327
Erector spinae forces	3598	962.3
Compression due to load	42	35.6
Compression due to upper body weight	149	110.5
Compression due to erector spinae	2334	1874
Shear due to load	95	26.2
Shear due to upper body weight	405	84.1
Shear due to erector spinae	500	133.9
Total Stress	**15363**	
Work Postures as Percentage of Job-Task Cycle		
Work Postures During Job-Task Cycle	**Percent Of Time**	**Standard Deviation**
Back straight during task	30	14.2
Back bent during task	67	9.5
Back twisted during task	3	4.7
Back bent and twisted during task	0	0
Both arms below shoulder height	100	0
Standing	57	9.5
Kneeling	30	14.18
Walking	14	12.6
Load < 10 kg.	93	4.8
Load > 10 kg.< 20 kg.	7	4.8
Load > 20 kg.	0	0
Action Category 1	33	9.5
Action Category 2	67	9.5
Action Category 3	0	0
Action Category 4	0	0
Category Frequency 1	3	0.95
Category Frequency 2	7	0.95
Category Frequency 3	0	0
Category Frequency 4	0	0
Total stress	**511**	
Horizontal Distance to Load	**57 cm**	**11**

NIOSH Action Limit (AL) 3,425 N Maximum Permissible Lift (MPL) 6,361 N

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Table 11 Sorting Wall Material
Ergonomic Elements of Posture and Strain

Ergonomic Elements of Spinal Compression and Shear	**Mean Force in Newtons**	**Standard Deviation**
Total compression forces	3497	1206
Total shear forces	894	421.7
Bending moment	158	71.6
Joint forces	4392	1613
Erector spinae forces	3161	1436
Compression due to load	104	90.7
Compression due to upper body weight	262	206.8
Compression due to erector spinae	3130	1422
Shear due to load	115	66.7
Shear due to upper body weight	339	179.3
Shear due to erector spinae	439	199.8
Total Stress	**16491**	
Work Postures as Percentage of Job-Task Cycle		
Work Postures During Job-Task Cycle	**Percent Of Time**	**Standard Deviation**
Back Straight during task	57	23.8
Back bent during task	43	23.8
Both arms below shoulder height	93	4.7
One arm above shoulder height	3	4.7
Both arms above shoulder height	3	4.8
Standing	67	9.5
Kneeling	7	9.5
Walking	27	9.5
Load < 10 kg.	50	8.2
Load > 10 kg.< 20 kg.	40	14.2
Load > 20 kg.	10	8.2
Action Category 1	57	23.8
Action Category 2	40	21.8
Action Category 3	3	4.7
Action Category 4	0	0
Category Frequency 1	6	2.4
Category Frequency 2	34	2.2
Category Frequency 3	0.32	0.47
Category Frequency 4	0	0
Total Stress	**540.32**	
Horizontal distance to load	**34 cm**	**19.1**

NIOSH Action Limit (AL) 3,425 N Maximum Permissible Lift (MPL) 6,361 N

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Table 12 Installing Floor Joists
Ergonomic Elements of Posture and Strain

Ergonomic Elements of Spinal Compression and Shear	**Mean Force in Newtons**	**Standard Deviation**
Total compression forces	4352	1164
Total shear forces	1250	310.668
Bending moment	213	56.863
Joint forces	5605	1471
Erector spinae forces	4266	1139
Compression due to load	24	28.636
Compression due to upper body weight	105	73.628
Compression due to erector spinae	4224	1128
Shear due to load	114	106.39
Shear due to upper body weight	542	82.358
Shear due to erector spinae	593	158.541
Total Stress	**21288**	
Work Postures as Percentage of Job-Task Cycle		
Work Postures During Job-Task Cycle	**Percent Of Time**	**Standard Deviation**
Back Straight during task	28	1.4
Back bent during task	41	20.3
Back bent and twisted during task	30	21.3
Both arms below shoulder height	100	0
Standing	94	4.2
Kneeling	6	4.3
Load < 10 kg.	79	18.7
Load > 10 kg.< 20 kg.	15	21.4
Load > 20 kg.	6	8.5
Action Category 1	28	1.4
Action Category 2	66	7.9
Action Category 3	6	8.5
Action Category 4	0	0
Category Frequency 1	3	0
Category Frequency 2	7	0.82
Category Frequency 3	0.66	0.95
Category Frequency 4	0	0
Total stress	**509.66**	
Horizontal distance to load	**52.3 cm**	**17**

NIOSH Action Limit (AL) 3,425 N Maximum Permissible Lift (MPL) 6,361 N

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Table 13 Sorting Trusses
Ergonomic Elements of Posture and Strain

Ergonomic Elements of Spinal Compression and Shear	Mean Force in Newtons	Standard Deviation
Total compression forces	4129	3130
Total shear forces	805	723.3
Bending moment	172	163.8
Joint forces	4935	3836
Erector spinae forces	3445	3273
Compression due to load	295	208.5
Compression due to upper body weight	422	144.5
Compression due to erector spinae	3411	3242
Shear due to load	259	511.7
Shear due to upper body weight	190	173.9
Shear due to erector spinae	479	455.6
Total Stress	**18542**	
Work Postures as Percentage of Job-Task Cycle		
	Percent	**Standard**
Work Postures During Job-Task Cycle	**Of Time**	**Deviation**
Back Straight during task	93	6.2
Back bent during task	7	6.2
Both arms below shoulder height	68	12.5
One arm above shoulder height	15	14.3
Both arms above shoulder height	17	9.5
Standing	32	8.5
Walking	68	8.5
Load < 10 kg.	23	6.27
Load > 20 kg.	77	6.2
Action Category 1	80	17.8
Action Category 2	15	10.8
Action Category 3	5	7.1
Action Category 4	0	0
Category Frequency 1	16	3.6
Category Frequency 2	3	2.2
Category Frequency 3	1	1.4
Category Frequency 4	0	0
Total Stress	**520**	
Horizontal distance to load	**34.9 cm**	**36.7**

NIOSH Action Limit (AL) 3,425 N Maximum Permissible Lift (MPL) 6,361 N

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Table 14 Sheeting Floors
Ergonomic Elements of Posture and Strain

Ergonomic Elements of Spinal Compression and Shear	Mean Force in Newtons	Standard Deviation
Total compression forces	3846	803.2
Total shear forces	844	361.3
Bending moment	160	48.8
Joint forces	4691	1134
Erector spinae forces	3211	974.6
Compression due to load	241	87.6
Compression due to upper body weight	425	186.4
Compression due to erector spinae	3180	964.9
Shear due to load	152	99.2
Shear due to upper body weight	245	138.3
Shear due to erector spinae	446	135.7
Total Stress	**17441**	
Work Postures as Percentage of Job-Task Cycle		
	Percent	**Standard**
Work Postures During Job-Task Cycle	**Of Time**	**Deviation**
Back Straight during task	33	9.5
Back bent during task	60	16.5
Back bent and twisted during task	7	9.5
Both arms below shoulder height	93	9.5
One arm above shoulder height	7	9.4
Standing	60	0
Kneeling	7	4.7
Walking	33	4.7
Load < 10 kg.	40	8.2
Load > 10 kg. <20 kg.	30	8.2
Load > 20 kg.	30	8.2
Action Category 1	33	9.5
Action Category 2	67	9.5
Action Category 3	0	0
Action Category 4	0	0
Category Frequency 1	3	0.95
Category Frequency 2	7	0.95
Category Frequency 3	0	0
Category Frequency 4	0	0
Total Stress	**510**	
Horizontal distance to load	**28 cm**	**7.4**

NIOSH Action Limit (AL) 3,425 N Maximum Permissible Lift (MPL) 6,361 N

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

Table 15 Standing Walls
Ergonomic Elements of Posture and Strain

Ergonomic Elements of Spinal Compression and Shear	**Mean Force in Newtons**	**Standard Deviation**
Total compression forces	8606	2576.27
Total shear forces	1974	719.69
Bending moment	407	137.09
Joint forces	10581	3202.62
Erector spinae forces	8164	2743.47
Compression due to load	273	244.54
Compression due to upper body weight	246	229.83
Compression due to erector spinae	8084	2716.82
Shear due to load	480	299.55
Shear due to upper body weight	356	173.07
Shear due to erector spinae	1134	379.09
Total Stress	**40305**	
Work Postures as Percentage of Job-Task Cycle		
	Percent	**Standard**
Work Postures During Job-Task Cycle	**Of Time**	**Deviation**
Back straight during task	87	4.7
Back bent during task	13	4.7
Both arms below shoulder height	17	4.7
One arm above shoulder height	13	4.7
Both arms above shoulder height	70	8.2
Standing	27	4.7
Walking	73	4.7
Load < 10 kg.	10	0
Load > 20 kg.	90	0
Action Category 1	17	4.7
Action Category 2	70	8.2
Action Category 3	13	4.7
Action Category 4	0	0
Category Frequency 1	5	0.5
Category Frequency 2	21	0.8
Category Frequency 3	4	0.5
Category Frequency 4	0	0
Total Stress	**530**	
Horizontal distance to load	**34 cm**	**19.10**

NIOSH Action Limit (AL) 3,425 N Maximum Permissible Lift (MPL) 6,361 N

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Table 16 Comparing Differences in Ergonomic Measures Due To Task Demands

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*

* Significant $p < 0.05$

Table 17 Comparing Differences in Total Spinal Compression Due to Task

Carpentry Task	Mean Values Newtons
Creating a cut list	2965 N
Set up cut station	3575 N
Measure layout	2884 N
Roll out / tool set up	2964 N
Lay out plates	3742 N
Sorting wall material	3497 N
Installing floor joists	4352 N
Sorting trusses	4129 N
Sheeting floors	3855 N
Standing walls	8606 N

Significant differences are noted between tasks p-value <0.001

NIOSH Action Limit (AL) 3,425 N Maximum Permissible Lift (MPL) 6,361 N

Table 18 Comparing Differences in Total Spinal Shear Due to Task

Carpentry Task	Mean Values Newtons
Creating a cut list	852 N
Set up cut station	1006 N
Measure layout	847 N
Roll out / tool set up	852 N
Lay out plates	1003 N
Sorting wall material	894 N
Installing floor joists	1250 N
Sorting trusses	805 N
Sheeting floors	848 N
Standing walls	1874 N

Significant differences are noted between tasks p-value <0.001

Table 19 Comparing Differences in Spinal Bending Moment Due to Task

Carpentry Task	Mean Values Newtons
Creating a cut list	136 N
Set up cut station	167 N
Measure layout	136 N
Roll out / tool set up	136 N
Lay out plates	178 N
Sorting wall material	158 N
Installing floor joists	212 N
Sorting trusses	172 N
Sheeting floors	161 N
Standing walls	408 N

Significant differences are noted between tasks p-value <0.001

Table 20 Comparing Differences in Spinal Joint Reactive Forces Due to Task

Carpentry Task	Mean Values Newtons
Creating a cut list	3817 N
Set up cut station	4581 N
Measure layout	3731 N
Roll out / tool set up	3817 N
Lay out plates	3244 N
Sorting wall material	4391 N
Installing floor joists	5605 N
Sorting trusses	4935 N
Sheeting floors	4704 N
Standing walls	10581 N

Significant differences are noted between tasks p-value <0.001

Table 21 Comparing Differences in Erector Spinae Muscle Forces Due to Task

Carpentry Task	Mean Values Newtons
Creating a cut list	2738 N
Set up cut station	3413 N
Measure layout	2718 N
Roll out / tool set up	2738 N
Lay out plates	3589 N
Sorting wall material	3161 N
Installing floor joists	4266 N
Sorting trusses	3445 N
Sheeting floors	3230 N
Standing walls	8164 N

Significant differences are noted between tasks p-value <0.001

Table 22 Comparing Differences in Spinal Compression Due to Weight of Load

Carpentry Task	Mean Values Newtons
Creating a cut list	0 N
Set up cut station	48 N
Measure layout	0 N
Roll out / tool set up	0 N
Lay out plates	41 N
Sorting wall material	103 N
Installing floor joists	25 N
Sorting trusses	295 N
Sheeting floors	235 N
Standing walls	274 N

Significant differences are noted between tasks p-value <0.001

Table 23 Comparing Differences in Spinal Compression Due to Upper Body Weight

Carpentry Task	Mean Values Newtons
Creating a cut list	253 N
Set up cut station	146 N
Measure layout	192 N
Roll out / tool set up	253 N
Lay out plates	145 N
Sorting wall material	262 N
Installing floor joists	105 N
Sorting trusses	422 N
Sheeting floors	421 N
Standing walls	247 N

Significant differences are noted between tasks p-value <0.001

Table 24 Comparing Differences in Spinal Compression Due to Erector Spinae

Carpentry Task	Mean Values Newtons
Creating a cut list	2712 N
Set up cut station	3380 N
Measure layout	2691 N
Roll out / tool set up	2712 N
Lay out plates	2286 N
Sorting wall material	3130 N
Installing floor joists	4224 N
Sorting trusses	3411 N
Sheeting floors	3199 N
Standing walls	8084 N

Significant differences are noted between tasks p-value <0.001

Table 25 Comparing Differences in Spinal Shear Due to Load

Carpentry Task	Mean Values Newtons
Creating a cut list	0 N
Set up cut station	105 N
Measure layout	0 N
Roll out / tool set up	0 N
Lay out plates	95 N
Sorting wall material	115 N
Installing floor joists	115 N
Sorting trusses	259 N
Sheeting floors	150 N
Standing walls	481 N

Significant differences are noted between tasks p-value <0.001

Table 26 Comparing Differences in Spinal Shear Due to Upper Body Weight

Carpentry Task	Mean Values Newtons
Creating a cut list	471 N
Set up cut station	426 N
Measure layout	396 N
Roll out / tool set up	471 N
Lay out plates	407 N
Sorting wall material	339 N
Installing floor joists	542 N
Sorting trusses	189 N
Sheeting floors	248 N
Standing walls	357 N

Significant differences are noted between tasks p-value <0.001

Table 27 Comparing Differences in Spinal Shear Due to Erector Spinae Muscles

Carpentry Task	Mean Values Newtons
Creating a cut list	381 N
Set up cut station	475 N
Measure layout	378 N
Roll out / tool set up	381 N
Lay out plates	499 N
Sorting wall material	439 N
Installing floor joists	593 N
Sorting trusses	479 N
Sheeting floors	449 N
Standing walls	1134 N

Significant differences are noted between tasks p-value <0.001

Table 28 Comparing Differences in Horizontal Distance from Spine to Load

Carpentry Task	Mean Values CM
Creating a cut list	52.6 cm
Set up cut station	44.8 cm
Measure layout	28.5 cm
Roll out / tool set up	52.6 cm
Lay out plates	56.4 cm
Sorting wall material	34.2 cm
Installing floor joists	52.3 cm
Sorting trusses	34.9 cm
Sheeting floors	29.1 cm
Standing walls	55.9 cm

Significant differences are noted between tasks p-value <0.001

Table 29 Comparing Differences in Percent of Time Back is Straight

Carpentry Task	Mean Values % Time
Creating a cut list	66
Setlup cut station	67
Measure layout	30
Rolllout / tool setlup	66
Laylout plates	30
Sorting wall material	57
Installing floor joists	28
Sorting trusses	93
Sheeting floors	33
Standing walls	87

Significant differences are noted between tasks p-value <0.001

Table 30 Comparing Differences in Percent of Time Back is Bent

Carpentry Task	Mean Values % Time
Creating a cut list	33
Set up cut station	33
Measure layout	33
Roll out / tool set up	33
Lay out plates	67
Sorting wall material	43
Installing floor joists	41
Sorting trusses	7
Sheeting floors	60
Standing walls	13

Significant differences are noted between tasks p-value <0.001

Table 31 Comparing Differences in Percent of Time Arms Placed Below Shoulders

Carpentry Task	Mean Values % Time
Creating a cut list	97
Set up cut station	97
Measure layout	100
Roll out / tool set up	97
Lay out plates	100
Sorting wall material	93
Installing floor joists	100
Sorting trusses	68
Sheeting floors	94
Standing walls	17

Significant differences are noted between tasks p-value <0.001

Table 32 Comparing Differences in Percent of Time One Arm Above Shoulder

Carpentry Task	Mean Values % Time
Creating a cut list	0
Set up cut station	0
Measure layout	0
Roll out / tool set up	0
Lay out plates	0
Sorting wall material	3
Installing floor joists	0
Sorting trusses	15
Sheeting floors	6
Standing walls	13

Significant differences are noted between tasks p-value <0.001

Table 33 Comparing Differences in Percent of Time Both Arms Above Shoulders

Carpentry Task	Mean Values % Time
Creating a cut list	3
Set up cut station	3
Measure layout	0
Roll out / tool set up	3
Lay out plates	0
Sorting wall material	3
Installing floor joists	0
Sorting trusses	17
Sheeting floors	0
Standing walls	70

Significant differences are noted between tasks p-value <0.001

Table 34 Comparing Differences in Percent of Time Load Remained < 10 Kg.

Carpentry Task	Mean Values % Time
Creating a cut list	100
Set up cut station	100
Measure layout	100
Roll out / tool set up	100
Lay out plates	93
Sorting wall material	50
Installing floor joists	78
Sorting trusses	23
Sheeting floors	71
Standing walls	10

Significant differences are noted between tasks p-value <0.001

Table 35 Comparing Differences in Percent of Time Load Between 10 Kg. - 20Kg.

Carpentry Task	Mean Values % Time
Creating a cut list	0
Set up cut station	0
Measure layout	0
Roll out / tool set up	0
Lay out plates	7
Sorting wall material	40
Installing floor joists	15
Sorting trusses	0
Sheeting floors	0
Standing walls	0

Significant differences are noted between tasks p-value <0.001

Table 36 Comparing Differences in Percent of Time Load Was > 20Kg.

Carpentry Task	Mean Values % Time
Creating a cut list	0
Set up cut station	0
Measure layout	0
Roll out / tool set up	0
Lay out plates	0
Sorting wall material	10
Installing floor joists	6
Sorting trusses	77
Sheeting floors	29
Standing walls	90

Significant differences are noted between tasks p-value <0.001

Table 37 Comparing Differences in Percent of Task in Action Category 1

Carpentry Task	Mean Values % Time
Creating a cutlist	67
Set up cut station	67
Measure layout	33
Roll out / tool set up	67
Lay out plates	33
Sorting wall material	57
Installing floor joists	28
Sorting trusses	80
Sheeting floors	33
Standing walls	17

Significant differences are noted between tasks p-value <0.001

Table 38 Comparing Differences in Percent of Task in Action Category 2

Carpentry Task	Mean Values % Time
Creating a cut list	30
Set up cut station	30
Measure layout	64
Roll out / tool set up	30
Lay out plates	67
Sorting wall material	40
Installing floor joists	66
Sorting trusses	15
Sheeting floors	67
Standing walls	70

Significant differences are noted between tasks p-value <0.001

Table 39 Comparing Differences in Percent of Task in Action Category 3

Carpentry Task	Mean Values % Time
Creating a cut list	3
Set up cut station	3
Measure layout	3
Roll out / tool set up	3
Lay out plates	0
Sorting wall material	3
Installing floor joists	6
Sorting trusses	5
Sheeting floors	0
Standing walls	13

Significant differences are noted between tasks p-value <0.001

Table 40 Comparing Ergonomic Stressors Between Easy vs Hard Tasks

Ergonomic Task Demand Parameter of Measure	Easy Tasks Mean N	Hard Tasks Mean N	Difference P-Value	R-Square
Total spinal compression	3,681	4,436	0.226	0.539
Total spinal shear	1,045	1,019	0.879	0.415
Total bending moment	179	194	0.653	0.491
Total joint reactive forces	4,582	5,311	0.376	0.511
Erector spinae forces	3,595	3,897	0.649	0.491
Spinal compression due to load	12	218	<0.001*	0.514
Spinal compression due to body weight	132	358	0.002*	0.263
Spinal compression due to erector spinae	3,437	3,736	0.666	0.483
Spinal shear due to load	54	209	0.059	0.340
Spinal shear due to upper body weight	459	308	0.009*	0.355
Spinal shear due to erector spinae	499	541	0.648	0.491

* Significant $p < 0.05$

Table 41 Comparing Ergonomic Stressors Between Easy vs Hard Tasks

Ergonomic Task Demand Parameter of Measure	Easy Tasks Mean % Time	Hard Tasks Mean % Time	Difference P-Value	R-Square
Horizontal distance from spine to load	45	42	0.620	0.294
Percent time back straight during task	55	56	0.878	0.771
Percent time back bent during task	43	36	0.214	0.656
Percent time back bent and twisted	0.3	7	0.032*	0.604
Percent time arms below shoulders	89	82	0.008*	0.945
Percent time one arm above shoulder	0.5	7	0.007*	0.485
Percent time load was < 10 kg.	87	57	<0.001*	0.950
Percent time load was between 10 - 20 kg.	6	6	1.000	0.690
Percent time load was > 20 kg.	6	36	<0.001*	0.977
Percent time in Action Category 1	47	48	0.884	0.712
Percent time in Action Category 2	46	48	0.648	0.759
Percent time in Action Category 3	6	3	0.161	0.335

* Significant p < 0.05

Table 42 Total Stress Task Comparisons

Comparing Subjective Strain to Objective Strain Totals			
Carpentry Task	**Strain Score**	**Newtons**	**Posture**
Creating a cut list	1.07	14,325	510.32
Set up cut station	1.38	17,322	510.32
Measure layout	1.46	13,973	512.32
Roll out / tool set up	1.60	15,167	527.00
Lay out plates	1.73	15,363	511.00
Sorting wall materials	2.31	16,491	540.32
Installing floor joist	2.49	21,288	509.66
Sorting trusses	2.74	18,542	520.00
Sheeting floors	2.88	17,441	480.00
Standing walls	3.09	40,305	530.00

Table 43a Percent Spinal Compression Exceeded NIOSH AL and MPL by Task

Carpentry Task	Compression	% 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

Table 43b Comparing OWAS Action Categories Among Tasks

Carpentry Task	Percent of Time in Category			
	Category 1	Catergory 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.

Table 44 Comparing Mean Task Strain Responses by Worker Back Strain Characterization

Carpentry Task	Level of Back Strain in Residential Carpentry					MANOVA
	No Strain	Low Strain	Moderate Strain	High Strain	Very High Strain	P-Value
Break materials	0	1.2	1.7	1.9	2.6	0.020*
Sort materials	0	1.6	1.9	2.9	3.5	< 0.001*
Measure layout	0	1.3	0.88	1.6	2.5	< 0.001*
Plate beams by hand	0	2.2	2.2	3.2	4.2	0.002*
Plate beams with crane	0	1.3	1	1.8	2	0.003*
Install sill plates	0	1.6	1.2	2	2.5	0.001*
Frame walkouts	0	1.3	2	2.5	3.1	< 0.001*
Cut floor joists	0	1.2	1.5	2.3	2.5	0.001*
Sort pre-cut trusses	0	1.7	1.5	2.4	3.3	< 0.001*
Install floor joists	0	1.7	1.6	3	3.3	< 0.001*
Sheet floor w/ 3/4" OSB	0	1.7	2.3	3.2	3.7	< 0.001*
Snap lines on floor	0	1.3	1.1	1.7	2.3	0.002*
Install beams by hand	0	2.1	2.5	3.5	4.3	< 0.001*
Install beams with crane	0	1.1	1	1.6	2.1	0.002*
Sort wall material	0	1.5	1.8	2.8	3	< 0.001*
Lay out plates	0	1.2	1.2	1.8	2.8	< 0.001*
Set up cut station	0	0.87	1.1	1.3	2.2	0.003*
Create a cut list	0	0.87	0.77	1.1	1.6	0.006*
Cut material	0	1.6	1.8	2.4	3.3	< 0.001*
Square wall	0	1.1	1.3	1.9	2.7	< 0.001*
Sheet wall on ground	0	1.6	1.8	2.5	3	< 0.001*
Sheet wall upright	0	1.8	2.1	2.9	3.3	0.004*
Stand walls	0	2.5	2.5	3.6	3.7	< 0.001*
Sort trusses	0	2.1	2	3.1	3.9	< 0.001*
Sheet gable ends	0	1.6	1.4	2.3	2.7	< 0.001*
Rack trusses	0	1.3	1.4	2.3	3.3	< 0.001*
Cut tails	0	1.1	1.2	2.4	3.1	< 0.001*
Install roof anchors	0	1.1	1.1	1.6	2	0.024*
Boom trusses	0	1.6	1.7	2	2.6	0.019*
Install truss clips	0	1.3	1.2	1.7	2.3	0.001*
Brace off trusses	0	1.3	1.5	2.2	2.8	< 0.001*
Sheet first row on roof	0	2	1.8	3.2	3.4	< 0.001*
Finish sheeting roof	0	1.8	1.8	3	3.6	< 0.001*
Install fascia rafters	0	1.6	1.2	2.6	3	0.001*

Roll out / tool set up	0	1.1	1.2	1.6	2.2	0.006*
Build and install stairs	0	1.3	1.7	2.6	3.6	< 0.001*
Set pre-built stairs	0	1.7	2	3.2	3.6	< 0.001*
Build and install partitions	0	1.7	1.7	2.4	2.7	0.004*
Build basement floors	0	0.75	0.85	2.2	3	< 0.001*
Build exterior decks	0	1.2	0.77	2.4	3.1	< 0.001*
Nail connections	0	1.5	1.3	2	2.3	< 0.001*
Cut roof vents	0	1.1	0.77	1.7	2.3	< 0.001*
Clean up scrap material	0	1.6	1.6	2.3	3	< 0.001*
Roll up / put tools away	0	1.2	1.3	1.7	2.3	0.002*

* Significant $p < 0.05$

Table 45 Comparing Mean Strain Responses by Perception of LBP Problem

Carpentry Task	Rank of LBP Problem in Carpentry				MANOVA
	None	Slight	Moderate	Severe	P-Value
Break materials	2	1.8	1.8	2.1	0.789
Sort materials	2.3	2	2.4	3.2	0.020*
Measure layout	1.3	1	1.3	2	0.008*
Plate beams by hand	2	2.6	2.8	3.5	0.198
Plate beams with crane	1.3	1.8	1.3	1.9	0.130*
Install sill plates	1.6	1.7	1.5	2.5	0.007*
Frame walkouts	2.6	1.9	2.1	3	0.003*
Cut floor joists	1.3	1.9	1.6	2.8	< 0.001*
Sort pre-cut trusses	1.6	1.5	1.9	3.1	< 0.001*
Install floor joists	2	1.8	2.1	3.4	< 0.001*
Sheet floor w/ 3/4" OSB	2.6	2.2	2.7	3.6	< 0.001*
Snap lines on floor	1	1.2	1.3	2.2	< 0.001*
Install beams by hand	3	2.7	3	3.9	0.008*
Install beams with crane	1.6	1.2	1.2	2	0.014*
Sort wall material	2	2.1	2.1	2.9	0.032*
Lay out plates	1	1.5	1.5	2.3	< 0.001*
Set up cut station	1	1.4	1.2	1.7	0.174
Create a cut list	0.66	1	1	1.3	0.338
Cut material	2	1.9	2.1	3	< 0.001*
Square wall	1.6	1.5	1.6	2.3	0.015*
Sheet wall on ground	2	2	2	3.1	< 0.001*
Sheet wall upright	3.3	2.3	2.3	3.3	0.018*
Stand walls	2.6	3.2	2.7	4.1	< 0.001*
Sort trusses	2.3	2.2	2.5	3.6	< 0.001*
Sheet gable ends	2	2	2.6	3	< 0.001*
Rack trusses	1.3	1	2	2.9	< 0.001*
Cut tails	1.3	2	1.6	3	< 0.001*
Install roof anchors	1	1.4	1.3	2.1	0.008*
Boom trusses	2	1.9	1.7	2.5	0.061
Install truss clips	1.3	1.3	1.5	2.2	0.004*
Brace off trusses	1.6	1.8	1.8	2.7	< 0.001*
Sheet first row on roof	2.6	2.2	2.3	3.6	< 0.001*
Finish sheeting roof	2.6	2	2.3	3.5	< 0.001*
Install fascia rafters	2.3	2	1.7	2.8	0.073
Roll out / tool set up	1.3	1.3	1.3	2.1	0.011*
Build and install stairs	1.6	1.9	2	3.5	< 0.001*
Set pre-built stairs	1.3	2.5	2.5	3.6	0.002*
Build and install partitions	2.3	2.1	1.9	2.7	0.037*
Build basement floors	2	0.63	1.5	2.8	< 0.001*
Build exterior decks	2.6	1.2	1.5	2.9	< 0.001*
Nail connections	2	1.7	1.6	2.3	0.013*
Cut roof vents	0.66	1	1.2	2	0.002*
Clean up scrap material	1.3	2	1.9	2.9	0.002*
Roll up /put tools away	1.3	1.5	1.4	2.1	0.020*

* Significant $p < 0.05$

Table 46 Comparing Mean Task Strain Responses by Type if Injury

Single Incident vs. Cumulative Trauma				MANOVA
Carpentry Task	**None**	**Single**	**Cumulative**	**P-Value**
Break materials	1.7	1.6	2.5	0.008*
Sort materials	2.3	2.2	3.4	< 0.001*
Measure layout	1.2	1.2	2	0.004*
Plate beams by hand	2.7	3	3.2	0.441
Plate beams with crane	1.4	1	2	0.004*
Install sill plates	1.7	1.4	2.3	0.009*
Frame walkouts	2.3	1.9	2.7	0.037*
Cut floor joists	1.8	1.7	2.4	0.038*
Sort pre-cut trusses	1.9	2	2.8	0.012*
Install floor joists	2.1	2.1	3.2	< 0.001*
Sheet floor w/ 3/4" OSB	2.6	2.7	3.5	0.002*
Snap lines on floor	1.4	1.3	2	0.013*
Install beams by hand	2.8	3.2	3.8	0.003*
Install beams with crane	1.4	0.94	2	0.001*
Sort wall material	1.9	2.4	3	< 0.001*
Lay out plates	1.8	1.5	2	0.184
Set up cut station	1.3	1.2	1.7	0.141
Create a cut list	1	0.88	1.4	0.047*
Cut material	2.1	2.1	2.8	0.004*
Square wall	1.5	1.3	2.3	0.001*
Sheet wall on ground	2.1	1.9	2.8	0.001*
Sheet wall upright	2.4	2.2	3.2	0.011*
Stand walls	2.8	3.1	3.8	0.007*
Sort trusses	2.4	2.7	3.4	0.002*
Sheet gable ends	2	1.6	2.5	0.028*
Rack trusses	2.7	2	2.7	0.026*
Cut tails	2	1.6	2.5	0.059
Install roof anchors	1.4	1.5	1.7	0.456
Boom trusses	1.9	1.7	2.2	0.277
Install truss clips	1.6	1.2	2	0.034*
Brace off trusses	1.9	1.7	2.4	0.022*
Sheet first row on roof	2.5	2.3	3.2	0.011*
Finish sheeting roof	2.4	2.3	3.3	< 0.001*
Install fascia rafters	1.9	1.7	2.8	0.018*
Roll out / tool set up	1.6	1.1	2	0.014*
Build and install stairs	2.1	2	3.1	0.004*
Set pre-built stairs	2.2	2.8	3.4	0.001*
Build and install partitions	2.2	1.7	2.4	0.063
Build basement floors	1.2	1.5	2.7	0.001*
Build exterior decks	1.6	1.3	2.7	0.002*
Nail connections	1.8	1.4	2.1	0.022*
Cut roof vents	1.3	1	2	0.002*
Clean up scrap material	2.1	1.9	2.5	0.209
Roll up / put tools away	1.6	1.4	2	0.071

* Significant $p < 0.05$

Table 47 Comparing Mean Task Strain Responses by Constant LBP Sufferers

Suffering Constant LBP Pain			MANOVA
Carpentry Task	**No**	**Yes**	**P-Value**
Break materials	1.8	2.1	0.355
Sort materials	2.4	3	0.011*
Measure layout	1.2	2	< 0.001*
Plate beams by hand	2.7	3.5	0.035*
Plate beams with crane	1.4	1.8	0.147
Install sill plates	1.6	2.2	0.013*
Frame walkouts	2.1	2.7	0.020*
Cut floor joists	1.8	2.3	0.050*
Sort pre-cut trusses	1.9	2.9	0.001*
Install floor joists	2.1	3.1	< 0.001*
Sheet floor w/ 3/4" OSB	2.6	3.4	0.002*
Snap lines on floor	1.4	2	0.006*
Install beams by hand	2.9	3.9	< 0.001*
Install beams with crane	1.4	1.7	0.137
Sort wall material	2.1	2.8	0.002*
Lay out plates	1.6	2.1	0.018*
Set up cut station	1.3	1.6	0.227
Create a cut list	1.1	1.1	0.698
Cut material	2.1	2.7	0.030*
Square wall	1.6	2.2	0.009*
Sheet wall on ground	2.1	2.6	0.028
Sheet wall upright	2.5	2.9	0.144
Stand walls	2.8	3.8	< 0.001*
Sort trusses	2.5	3.2	0.019*
Sheet gable ends	1.8	2.5	0.007*
Rack trusses	1.9	2.5	0.034*
Cut tails	1.7	2.7	0.003*
Install roof anchors	1.4	1.7	0.243
Boom trusses	1.9	2.1	0.455
Install truss clips	1.5	1.9	0.061
Brace off trusses	1.9	2.2	0.192
Sheet first row on roof	2.4	3.2	0.002*
Finish sheeting roof	2.4	3.1	0.019*
Install fascia rafters	2	2.4	0.214
Roll out / tool set up	1.8	1.4	0.090
Build and install stairs	2	3.2	< 0.001*
Set pre-built stairs	2.4	3.4	0.001*
Build and install partitions	2	2.5	0.031*
Build basement floors	1.4	2.4	0.019*
Build exterior decks	1.6	2.5	0.007*
Nail connections	1.6	2.2	< 0.001*
Cut roof vents	1.2	2	0.001*
Clean up scrap material	2	2.4	0.177
Roll up / put tools away	1.5	1.8	0.142

* Significant $p < 0.05$

Table 48 Comparing Mean Task Strain Responses by Recent LB Injury Vs. No LB Injury

Recent LBP and Injury w/in Last 2 Weeks			MANOVA
Carpentry Task	**No Injury**	**LB Injury**	**P-Value**
Break materials	1.8	2.1	0.413
Sort materials	2.5	3.2	0.037*
Measure layout	1.4	2	0.034*
Plate beams by hand	2.8	3.6	0.115
Plate beams with crane	1.4	2	0.127
Install sill plates	1.7	2.4	0.061
Frame walkouts	2.2	3	0.031*
Cut floor joists	1.9	2.6	0.029*
Sort pre-cut trusses	2	3.1	0.009*
Install floor joists	2.3	3.1	0.039*
Sheet floor w/ 3/4" OSB	2.8	3.5	0.051
Snap lines on floor	1.4	2.3	0.005*
Install beams by hand	3.1	3.9	0.039*
Install beams with crane	1.4	2	0.037*
Sort wall material	2.3	2.7	0.208
Lay out plates	1.6	2.3	0.029*
Set up cut station	1.3	1.8	0.107
Create a cut list	1	1.5	0.025*
Cut material	2.2	2.8	0.075
Square wall	1.7	2.4	0.022*
Sheet wall on ground	2.1	2.9	0.018*
Sheet wall upright	2.5	3.3	0.044*
Stand walls	3.1	3.7	0.108
Sort trusses	2.6	3.5	0.023*
Sheet gable ends	1.9	2.5	0.098
Rack trusses	2	2.5	0.227
Cut tails	1.9	2.7	0.062
Install roof anchors	1.5	1.7	0.457
Boom trusses	1.9	2.5	0.089
Install truss clips	1.5	2.2	0.017*
Brace off trusses	1.9	2.5	0.089
Sheet first row on roof	2.6	3.1	0.137
Finish sheeting roof	2.5	3.3	0.036*
Install fascia rafters	2	2.7	0.165
Roll out / tool set up	1.4	2.3	0.005*
Build and install stairs	2.2	3.6	0.001*
Set pre-built stairs	2.6	3.5	0.041*
Build and install partitions	2.1	2.6	0.120
Build basement floors	1.6	2.5	0.079
Build exterior decks	1.8	2.5	0.167
Nail connections	1.7	2.3	0.029*
Cut roof vents	1.3	2	0.021*
Clean up scrap material	2.1	2.7	0.072
Roll up / put tools away	1.5	2.1	0.019*

* Significant $p < 0.05$

Table 49 Comparing Mean Task Strain Responses by Period LB Injury

	W/in Last 12 Months		MANOVA
Carpentry Task	No Injury	LB Injury	P-Value
Break materials	1.8	2.1	0.253
Sort materials	2.1	3	0.004*
Measure layout	1.4	1.7	0.179
Plate beams by hand	2.8	3.2	0.287
Plate beams with crane	1.5	1.6	0.433
Install sill plates	1.7	2	0.154
Frame walkouts	2.2	2.5	0.323
Cut floor joists	1.9	2.2	0.225
Sort pre-cut trusses	1.9	2.7	0.011*
Install floor joists	2.1	3	0.001*
Sheet floor w/ 3/4" OSB	2.6	3.4	0.002*
Snap lines on floor	1.4	1.8	0.057
Install beams by hand	3	3.5	0.065
Install beams with crane	1.4	1.6	0.289
Sort wall material	2.1	2.6	0.039*
Lay out plates	1.6	2	0.039*
Set up cut station	1.2	1.6	0.075
Create a cut list	1	1.2	0.331
Cut material	2.1	2.7	0.005*
Square wall	1.6	2	0.069
Sheet wall on ground	2.1	2.6	0.015*
Sheet wall upright	2.5	2.9	0.088
Stand walls	3.1	3.3	0.416
Sort trusses	2.6	3	0.145
Sheet gable ends	1.9	2.2	0.360
Rack trusses	2	2.3	0.217
Cut tails	1.9	2.2	0.345
Install roof anchors	1.4	1.7	0.102
Boom trusses	2	2	0.791
Install truss clips	1.5	1.9	0.028*
Brace off trusses	1.8	2.3	0.032*
Sheet first row on roof	2.5	2.9	0.102
Finish sheeting roof	2.4	3	0.017*
Install fascia rafters	1.9	2.5	0.132
Roll out / tool set up	1.4	1.8	0.108
Build and install stairs	2.1	2.8	0.044*
Set pre-built stairs	2.6	3	0.129
Build and install partitions	2.2	2.2	0.875
Build basement floors	1.4	2.3	0.017*
Build exterior decks	1.8	2.1	0.373
Nail connections	1.7	2	0.189
Cut roof vents	1.3	1.6	0.158
Clean up scrap material	2.1	2.2	0.918
Roll up / put tools away	1.5	1.9	0.017*

*Significant $p < 0.05$

Table 50 Comparing Mean Task Strain Responses by Self Assessed Health Status

	Estimate of Health Status Rank					MANOVA
Carpentry Task	**Poor**	**Fair**	**Good**	**Very Good**	**Excellent**	**P-Value**
Break materials	5	3	1.8	1.6	1.9	0.004*
Sort materials	5	2.8	2.9	2.4	2	0.018*
Measure layout	5	2	1.5	1.3	1.5	0.002*
Plate beams by hand	5	2.8	3.3	2.9	2.2	0.240
Plate beams with crane	0	1.4	1.6	1.6	1.4	0.608
Install sill plates	5	1.8	2	1.6	1.7	0.024*
Frame walkouts	5	3.1	2.6	2.1	1.7	0.001*
Cut floor joists	5	2.2	1.9	2	1.8	0.068
Sort pre-cut trusses	5	2.5	2.4	2.1	1.6	0.083
Install floor joists	5	2.7	2.5	2.4	2.2	0.261
Sheet floor w/ 3/4" OSB	4	3.2	3.2	2.9	2	0.008*
Snap lines on floor	5	2.2	1.6	1.4	1.3	0.001*
Install beams by hand	5	3.2	3.3	3.3	2.5	0.132
Install beams with crane	5	1.5	1.6	1.4	1.1	0.005*
Sort wall material	0	2.8	2.6	2.3	1.9	0.037*
Layout plates	5	2.1	1.9	1.6	1.4	0.003*
Set up cut station	5	1.8	1.3	1.4	1	0.004*
Create a cut list	2	1.4	1.1	1.1	0.84	0.530
Cut material	2	2.1	2.7	2.2	2	0.207
Square wall	5	2.2	1.9	1.6	1.6	0.006*
Sheet wall on ground	5	2.4	2.5	2.2	1.7	0.012*
Sheet wall upright	5	3.1	2.7	2.8	1.7	0.012*
Stand walls	5	3	3.3	3.1	2.9	0.519
Sort trusses	5	2.7	2.7	2.8	2.5	0.340
Sheet gable ends	4	1.8	2	2	2	0.547
Rack trusses	5	2.5	2.1	2.1	1.7	0.180
Cut tails	5	2.2	2.1	1.9	2	0.266
Install roof anchors	3	2.1	1.4	1.6	1.2	0.114
Boom trusses	4	2.4	1.9	2.2	1.3	0.018*
Install truss clips	3	2.1	1.7	1.6	1.1	0.074
Brace off trusses	5	2.4	2	2	1.7	0.016*
Sheet first row on roof	5	3	2.7	2.7	2.3	0.215
Finish sheeting roof	5	2.7	2.6	2.8	2.1	0.134

Install fascia rafters	5	3	1.9	2.3	1.6	0.101
Roll out / tool set up	4	2.1	1.4	1.6	1.4	0.058
Build and install stairs	5	3	2.6	2.3	1.7	0.066
Set pre-built stairs	5	2.7	2.9	2.6	2.7	0.479
Build and install partitions	4	2.8	1.9	2.3	2	0.090
Build basement floors	5	3.1	1.4	1.9	1.3	0.027*
Build exterior decks	5	2.5	1.8	2	1.3	0.150
Nail connections	4	2	1.8	1.8	1.5	0.070
Cut roof vents	4	1.7	1.4	1.4	1.3	0.133
Clean up scrap material	4	2.4	2.1	2.3	1.8	0.311
Roll up / put tools away	5	2	1.6	1.5	1.6	0.001*

* Significant $p < 0.05$

Table 51 Comparing Mean Strain Responses by Level of Alcohol Consumption

	Number of Drinks or Beers Per Week					MANOVA
Carpentry Task	**None**	**1 to 2**	**3 to 5**	**6 to 10**	**> 10**	**P-Value**
Break materials	2	1.5	2.1	1.7	1.9	0.748
Sort materials	2.5	2.4	2.5	2.2	2.8	0.677
Measure layout	1.5	1.1	1.6	1.1	1.9	0.190
Plate beams by hand	2.9	2.6	2.9	3	3.5	0.535
Plate beams with crane	1.5	1.2	2	1.3	1.6	0.408
Install sill plates	2	1.6	1.7	1.9	2	0.897
Frame walkouts	2.2	1.8	2.3	2.7	2.5	0.445
Cut floor joists	2.1	2	1.8	1.7	2.1	0.745
Sort pre-cut trusses	2.2	2.3	2	2.7	2.4	0.725
Install floor joists	2.4	2.8	2.3	2.6	2.6	0.819
Sheet floor w/ 3/4" OSB	2.9	3.1	2.6	3	3.1	0.731
Snap lines on floor	1.9	1.2	1.4	1.3	1.8	0.218
Install beams by hand	3.2	3.5	2.8	3.2	3.5	0.460
Install beams with crane	1.8	1	1.4	1.8	1.5	0.338
Sort wall material	2.1	2.2	2.3	2.6	2.8	0.226
Lay out plates	1.9	1.4	1.7	1.7	1.9	0.749
Set up cut station	1.6	1.2	1.3	1.1	1.5	0.671
Create a cut list	1.3	0.88	1	0.9	1.2	0.586
Cut material	2.2	2.2	2.3	2.4	2.5	0.861
Square wall	1.7	1.5	1.8	1.2	2.2	0.085
Sheet wall on ground	2.1	2.2	2.1	2.6	2.5	0.506
Sheet wall upright	2.6	3.1	2.3	2.7	2.9	0.512
Stand walls	2.9	3.6	3	3.4	3.5	0.262
Sort trusses	2.6	3	2.5	3	3	0.592
Sheet gable ends	2.1	2.2	1.8	2	2.2	0.838
Rack trusses	2.1	1.6	1.9	2.3	2.5	0.502
Cut tails	2	2.4	1.6	2.1	2.2	0.584
Install roof anchors	1.7	1.4	1.3	1.8	1.5	0.743
Boom trusses	2.2	1.7	1.5	1.8	2.3	0.120
Install truss clips	1.7	1.7	1.5	1.8	1.8	0.824
Brace off trusses	2.1	2.3	1.9	2	1.9	0.800
Sheet first row on roof	2.8	2.7	2.1	1.9	2.9	0.397
Finish sheeting roof	2.8	2.5	2.3	2.8	2.8	0.659
Install fascia rafters	2.3	2.1	1.8	2	2.4	0.807
Roll out / tool set up	1.7	1.4	1.4	1.5	1.8	0.712
Build and install stairs	2.4	2	2.3	2.8	2.8	0.517
Set pre-built stairs	2.4	2.7	2.8	2.9	3.2	0.394
Build and install partitions	2.2	2.2	1.9	1.8	2.7	0.074
Build basement floors	1.9	1.3	1.6	1.5	2.1	0.697
Build exterior decks	1.7	1.8	1.5	1.8	2.5	0.253
Nail connections	1.9	1.7	1.6	1.6	2.2	0.174
Cut roof vents	1.6	1.3	1.3	1.2	1.8	0.479
Clean up scrap material	2.3	2.2	1.8	2.2	2.4	0.671
Roll up / put tools away	1.7	1.5	1.5	1.6	1.8	0.814

Table 52 Comparing Mean Task Strain Responses by Smoking Status

Carpentry Task	Smoking Status			MANOVA
	Never	Former	Present	P-Value
Break materials	1.6	1.9	2.1	0.214
Sort materials	2.1	2.7	2.8	0.031*
Measure layout	1.3	1.7	1.6	0.347
Plate beams by hand	2.6	2.5	3.6	0.019*
Plate beams with crane	1.5	1.4	1.6	0.759
Install sill plates	1.7	2	1.8	0.601
Frame walkouts	2	2.4	2.6	0.058
Cut floor joists	1.6	2	2.1	0.133
Sort pre-cut trusses	1.9	2.5	2.4	0.225
Install floor joists	2.2	2.7	2.5	0.355
Sheet floor w/ 3/4" OSB	2.7	3	3.2	0.184
Snap lines on floor	1.4	1.5	1.8	0.289
Install beams by hand	2.9	3.2	3.6	0.063
Install beams with crane	1.5	1.5	1.5	0.978
Sort wall material	2.1	2.4	2.6	0.169
Lay out plates	1.5	1.8	2	0.170
Set up cut station	1.1	1.7	1.5	0.198
Create a cut list	0.9	1.3	1.2	0.194
Cut material	2.1	2	2.6	0.051
Square wall	1.5	2	2	0.074
Sheet wall on ground	2	2.4	2.5	0.213
Sheet wall upright	2.4	3.1	2.7	0.170
Stand walls	2.9	3.4	3.5	0.109
Sort trusses	2.5	2.9	2.9	0.223
Sheet gable ends	1.8	2.5	2.1	0.190
Rack trusses	1.7	2.8	2.2	0.026*
Cut tails	1.5	2.5	2.3	0.016*
Install roof anchors	1.4	2	1.5	0.148
Boom trusses	1.8	1.9	2.2	0.343
Install truss clips	1.5	1.7	1.9	0.267
Brace off trusses	1.8	2.2	2.1	0.264
Sheet first row on roof	2.3	3	2.9	0.059
Finish sheeting roof	2.5	3	2.6	0.525
Install fascia rafters	1.7	2.8	2.2	0.079
Roll out / tool set up	1.4	1.7	1.7	0.490
Build and install stairs	2.1	2.8	2.6	0.214
Set pre-built stairs	2.4	3	3	0.175
Build and install partitions	2	2.2	2.3	0.579
Build basement floors	1.4	2.5	1.7	0.111
Build exterior decks	1.5	2.3	2	0.225
Nail connections	1.7	2	2	0.392
Cut roof vents	1.2	1.7	1.5	0.249
Clean up scrap material	1.9	2.3	2.3	0.255
Roll up / put tools away	1.4	1.9	1.7	0.189

* Significant $p < 0.05$

Table 53 Comparing Mean Task Strain Responses by Level of Physical Exhaustion

Carpentry Task	Level of Work Related Physical Exhaustion					MANOVA
	Never	Sometimes	Frequently	Almost Always	Always	P-Value
Break materials	1.5	1.6	2.1	1.8	3.2	0.009*
Sort materials	3	2.2	2.7	2.6	3.8	0.012*
Measure layout	1.5	1.2	1.5	1.4	3	< 0.001*
Plate beams by hand	2.5	2.6	3	3.5	3.8	0.328
Plate beams with crane	2	1.4	1.4	1.6	2.5	0.106
Install sill plates	1	1.7	1.7	2	3.2	0.004*
Frame walkouts	2.5	2	2.5	2.5	3.4	0.028*
Cut floor joists	1.5	1.9	1.9	2.6	3.5	< 0.001*
Sort pre-cut trusses	2.5	1.8	2.3	2.6	3.5	0.019*
Install floor joists	2.5	2.1	2.4	3	3.7	0.021*
Sheet floor w/ 3/4" OSB	4	2.5	3	3.1	4.1	0.002*
Snap lines on floor	1	1.2	1.7	1.6	3.1	< 0.001*
Install beams by hand	3.5	2.8	3.4	3.4	4.5	0.008*
Install beams with crane	1	1.3	1.4	1.3	3	0.002*
Sort wall material	3	2.1	2.5	2.4	2.5	0.613
Lay out plates	1.5	1.5	1.7	1.7	3.5	< 0.001*
Set up cut station	2.5	1.3	1.2	1	3	< 0.001*
Create a cut list	2.5	0.94	0.96	1	2.4	< 0.001*
Cut material	2.5	2	2.7	2.4	2.8	0.044*
Square wall	2.5	1.4	2	1.9	2.5	0.034*
Sheet wall on ground	1.5	2	2.4	2.3	3.4	0.010*
Sheet wall upright	2.5	2.4	2.6	3.3	3.2	0.156
Stand walls	2.5	2.8	3.4	3.3	4	0.131
Sort trusses	3.5	2.4	2.9	3	3.8	0.023*
Sheet gable ends	1.5	2	1.8	2.1	3.1	0.113
Rack trusses	3	1.6	2.2	2.5	3.7	0.001*
Cut tails	1.5	1.8	1.9	2.6	3.4	0.023*
Install roof anchors	1	1.3	1.5	1.8	2.5	0.029*
Boom trusses	1.5	1.7	1.9	2.5	3.1	0.006*
Install truss clips	1.5	1.3	1.8	2	2.4	0.020*

Brace off trusses	2	1.6	2.2	2.4	2.7	0.018*
Sheet first row on roof	2	2.3	2.7	3	4	0.009*
Finish sheeting roof	2.5	2.3	2.6	3	4	0.008*
Install fascia rafters	3	1.9	2	2.4	3.4	0.173
Roll out / tool set up	1	1.3	1.7	1.7	2.5	0.052
Build and install stairs	2.5	1.9	2.6	2.8	3.8	0.005*
Set pre-built stairs	2	2.3	3	3	4.1	0.007*
Build and install partitions	2.5	2	2	2.7	3.4	0.006*
Build basement floors	2	1.2	2.1	1.8	3.5	0.009*
Build exterior decks	2.5	1.5	1.9	2.1	3.7	0.013*
Nail connections	1.5	1.6	1.9	2	2.5	0.045*
Cut roof vents	1.5	1.1	1.4	1.7	2.7	0.006*
Clean up scrap material	2	1.8	2.2	2.5	3.5	0.003*
Roll up / put tools away	1.5	1.5	1.7	1.6	2.5	0.041*

* Significant $p < 0.05$

Table 54 Comparing Mean Task Strain Responses by Level of Mental Exhaustion

	Level of Work Related Mental Exhaustion					MANOVA
Carpentry Task	**Never**	**Sometimes**	**Frequently**	**Almost Always**	**Always**	**P-Value**
Break materials	1	1.7	2.2	1.9	3.2	0.044*
Sort materials	2.6	2.3	2.8	2.6	4.2	0.027*
Measure layout	1.3	1.3	1.5	1.8	2.7	0.034*
Plate beams by hand	3	2.9	3	2.6	4.5	0.385
Plate beams with crane	1.6	1.3	1.7	1.5	3.5	0.002*
Install sill plates	2	1.7	1.8	1.9	3.5	0.037*
Frame walkouts	2	2.2	2.5	2.4	3.2	0.417
Cut floor joists	1.6	1.8	2	2	3.7	0.022*
Sort pre-cut trusses	2.3	1.9	2.5	2.3	3.2	0.228
Install floor joists	2.6	2.4	2.3	2.6	3.2	0.715
Sheet floor w/ 3/4" OSB	3	2.7	3	3.2	4.2	0.076
Snap lines on floor	1.3	1.4	1.5	1.8	3	0.038*
Install beams by hand	4	2.9	3.1	3.6	4.7	0.029*
Install beams with crane	1.3	1.5	1.3	1.4	3	0.044*
Sort wall material	2.3	2	2.7	2.5	3.5	0.026*
Lay out plates	2	1.6	1.6	2	3	0.080
Set up cut station	2	1.2	1.4	1.2	3	0.023*
Create a cut list	0.66	0.94	1.1	1.2	2.7	0.002*
Cut material	2.3	2.1	2.3	2.6	3.2	0.220*
Square wall	2	1.6	1.8	1.7	3	0.168
Sheet wall on ground	2.3	2.2	2.1	2.5	3.5	0.129
Sheet wall upright	3.6	26	2.2	2.8	4	0.050*
Stand walls	4	3	3.2	3.3	4	0.391
Sort trusses	3.3	2.5	3	2.9	4	0.072
Sheet gable ends	3	2	1.8	2	3.7	0.016*
Rack trusses	3.3	1.8	2	2.2	4	0.019*
Cut tails	3	1.9	1.9	1.9	4	0.033*
Install roof anchors	2.6	1.4	1.2	1.7	2.5	0.034*
Boom trusses	1.3	2.1	1.6	1.9	3.7	0.003*
Install truss clips	2	1.6	1.5	1.6	3	0.053

Brace off trusses	2.3	2	1.9	2.1	3	0.339
Sheet first row on roof	3	2.5	2.5	2.9	4.2	0.061
Finish sheeting roof	3.3	2.5	2.5	2.9	4.2	0.039*
Install fascia rafters	2.6	2	2.2	1.9	4	0.168
Roll out / tool set up	1.6	1.4	1.5	1.9	3	0.026*
Build and install stairs	2.6	2.1	2.3	2.8	4.7	0.003*
Set pre-built stairs	3.3	2.5	2.8	2.8	4.7	0.018*
Build and install partitions	2.6	2.1	1.9	2.3	4	0.007*
Build basement floors	2.3	1.6	1.4	2	4.2	0.034*
Build exterior decks	2.3	1.5	1.6	2.5	4.5	0.002*
Nail connections	1.6	1.8	1.5	2	2.7	0.043*
Cut roof vents	2.3	1.3	1.4	1.6	2.7	0.040*
Clean up scrap material	2.3	1.8	2.3	2.4	4.2	< 0.001*
Roll up / put tools away	2	1.5	1.5	1.9	2.2	0.388

* Significant $p < 0.05$

Table 55 Comparing Mean Task Strain Responses by Body Weight

Carpentry Task	Body Weight in Pounds 130 - 160	161 - 190	191 - 220	> 220	MANOVA P-Value
Break materials	1.5	1.8	2.1	1.8	0.521
Sort materials	2.4	2.6	2.8	2.1	0.585
Measure layout	1.4	1.6	1.6	1	0.515
Plate beams by hand	2.2	3	3.7	2	0.017
Plate beams with crane	1.3	1.7	1.6	1.5	0.660
Install sill plates	1.5	1.9	2	1.3	0.273
Frame walkouts	2	2.4	2.4	1.5	0.136
Cut floor joists	1.9	2.1	1.9	1.8	0.856
Sort pre-cut trusses	1.9	2.4	2.2	1.5	0.309
Install floor joists	2.2	2.8	2.3	1.8	0.093
Sheet floor w/ 3/4" OSB	2.6	3.1	2.9	2.1	0.182
Snap lines on floor	1.5	1.6	1.6	1.1	0.717
Install beams by hand	2.6	3.3	3.5	2.8	0.117
Install beams with crane	1.2	1.6	1.5	1.1	0.528
Sort wall material	2.2	2.5	2.4	2	0.552
Lay out plates	1.5	1.8	1.9	1.3	0.424
Set up cut station	1.4	1.3	1.3	1.6	0.918
Create a cut list	1.1	1.2	0.95	1	0.697
Cut material	2.2	2.4	2.4	1.6	0.333
Square wall	1.6	1.7	1.9	1.5	0.717
Sheet wall on ground	2.2	2.4	2.2	1.8	0.416
Sheet wall upright	2.4	2.7	2.6	2.1	0.701
Stand walls	2.7	3.3	3.3	3	0.427
Sort trusses	2.1	3	2.9	2.3	0.056
Sheet gable ends	2	2.1	2.2	1.6	0.698
Rack trusses	1.4	2.1	2.7	1.8	0.022
Cut tails	1.8	1.9	2.4	2.1	0.541
Install roof anchors	1.4	1.5	1.6	1.6	0.926
Boom trusses	1.8	2	2	2.3	0.775
Install truss clips	1.6	1.7	1.7	1.5	0.925
Brace off trusses	1.6	2.1	2.2	1.8	0.299
Sheet first row on roof	2.4	2.7	2.8	2.8	0.762
Finish sheeting roof	2.3	2.7	2.7	2.5	0.633
Install fascia rafters	1.4	2.1	2.4	2.5	0.240
Roll out / tool set up	1.5	1.6	1.7	1.3	0.878
Build and install stairs	2.2	2.5	2.4	2	0.843
Set pre-built stairs	2.2	2.8	3	2.3	0.243
Build and install partitions	2.2	2.1	2.3	1.8	0.842
Build basement floors	1.2	1.8	1.7	1.6	0.708
Build exterior decks	1.5	2.1	1.9	1.5	0.563
Nail connections	1.6	1.8	1.8	1.8	0.917
Cut roof vents	1.1	1.5	1.7	1.5	0.418
Clean up scrap material	1.8	2.3	2.2	2	0.599
Roll up / put tools away	1.5	1.6	1.7	1.5	0.896

Table 56a Comparing Mean Task Strain Responses by Height

Carpentry Task	Height in Inches			MANOVA
	60" - 66"	67" - 72"	> 73"	P-Value
Break materials	2	1.8	2.2	0.288
Sort materials	2.2	2.6	2.7	0.532
Measure layout	1.6	1.4	1.6	0.714
Plate beams by hand	2.7	2.9	3.2	0.626
Plate beams with crane	1.6	1.6	1.4	0.812
Install sill plates	1.8	1.9	1.7	0.891
Frame walkouts	1.8	2.3	2.5	0.268
Cut floor joists	2	2	1.9	0.832
Sort pre-cut trusses	1.7	2.2	2.4	0.501
Install floor joists	2	2.5	1.6	0.414
Sheet floor w/ 3/4" OSB	2.6	2.8	3.1	0.509
Snap lines on floor	1.6	1.5	1.6	0.903
Install beams by hand	3	3.1	3.4	0.658
Install beams with crane	1.5	1.5	1.5	0.940
Sort wall material	2.1	2.5	2.1	0.383
Lay out plates	1.3	1.8	1.8	0.351
Set up cut station	1.4	1.3	1.5	0.798
Create a cut list	1.4	1	1.1	0.460
Cut material	2.4	2.3	2.2	0.908
Square wall	1.6	1.7	2	0.391
Sheet wall on ground	2	2.3	2.4	0.584
Sheet wall upright	2.8	2.6	2.7	0.809
Stand walls	2.8	3.2	2.9	0.376
Sort trusses	2.4	2.8	2.7	0.603
Sheet gable ends	1.7	2.1	2	0.669
Rack trusses	1.8	2	2.3	0.605
Cut tails	1.5	2.1	1.9	0.418
Install roof anchors	1.5	1.6	1.4	0.815
Boom trusses	2.3	1.9	2	0.649
Install truss clips	1.6	1.6	1.7	0.972
Brace off trusses	1.6	2	2.2	0.279
Sheet first row on roof	2.2	2.7	2.6	0.415
Finish sheeting roof	2.3	2.7	2.6	0.652
Install fascia rafters	1.4	2.2	2.3	0.358
Roll out / tool set up	1.7	1.5	1.7	0.722
Build and install stairs	2.8	2.2	2.6	0.310
Set pre-built stairs	3.1	2.6	2.9	0.494
Build and install partitions	2.6	2	2.3	0.306
Build basement floors	1.4	1.7	1.9	0.792
Build exterior decks	1.7	1.9	1.8	0.889
Nail connections	1.7	1.8	1.9	0.878
Cut roof vents	1.2	1.4	1.5	0.662
Clean up scrap material	2.5	2.2	1.9	0.380
Roll up / put tools away	1.5	1.6	1.8	0.672

Table 56b Comparing Mean Task Strain Responses by Quetlet

	Quetlet Range			MANOVA
Carpentry Task	**1 - 2.38**	**2.39 - 3.78**	**3.79 - 5.16**	**P-Value**
Break materials	1.385	2.119	1.889	0.125
Sort materials	2.538	2.690	2.555	0.861
Measure layout	1.385	1.690	1.370	0.353
Plate beams by hand	2.769	3.000	3.185	0.744
Plate beams with crane	1.231	1.690	1.593	0.401
Install sill plates	1.231	2.071	1.852	0.046*
Frame walkouts	2.154	2.548	2.148	0.253
Cut floor joists	1.846	2.095	2.037	0.773
Sort pre-cut trusses	2.308	2.333	2.148	0.851
Install floor joists	2.615	2.595	2.333	0.639
Sheet floor w/ 3/4" OSB	2.846	3.024	2.815	0.722
Snap lines on floor	1.615	1.619	1.630	0.999
Install beams by hand	3.000	3.095	3.555	0.237
Install beams with crane	1.692	1.476	1.519	0.808
Sort wall material	2.231	2.476	2.296	0.697
Lay out plates	1.538	1.857	1.777	0.590
Set up cut station	1.308	1.405	1.519	0.827
Create a cut list	1.231	1.143	1.074	0.871
Cut material	2.308	2.357	2.370	0.983
Square wall	1.692	1.786	1.888	0.834
Sheet wall on ground	2.385	2.381	2.222	0.796
Sheet wall upright	2.538	2.619	2.741	0.869
Stand walls	2.846	3.238	3.333	0.486
Sort trusses	2.769	2.762	2.888	0.902
Sheet gable ends	2.077	2.071	2.111	0.990
Rack trusses	1.692	1.976	2.593	0.080
Cut tails	2.077	1.905	2.259	0.572
Install roof anchors	1.615	1.357	1.852	0.121
Boom trusses	2.077	1.857	2.296	0.236
Install truss clips	1.846	1.571	1.815	0.467
Brace off trusses	2.077	1.976	2.185	0.688
Sheet first row on roof	2.769	2.619	2.815	0.785
Finish sheeting roof	2.538	2.667	2.778	0.833
Install fascia rafters	1.923	2.048	2.407	0.575
Roll out / tool set up	1.615	1.643	1.630	0.996
Build and install stairs	2.231	2.500	2.370	0.816
Set pre-built stairs	2.231	2.952	2.852	0.218
Build and install partitions	2.077	2.286	2.185	0.820
Build basement floors	2.154	1.357	2.185	0.093
Build exterior decks	2.154	1.738	2.074	0.587
Nail connections	1.769	1.762	1.926	0.714
Cut roof vents	1.615	1.405	1.556	0.746
Clean up scrap material	2.000	2.095	2.481	0.299
Roll up / put tools away	1.692	1.690	1.704	0.998

* Significant $p < 0.05$

Table 57 Comparing Mean Task Strain Responses by Worker Risk Characterization

	Level of Risk in Residential Carpentry					MANOVA
Carpentry Task	No Risk	Slight Risk	Moderate Risk	High Risk	Severe Risk	P-Value
Break materials	2.5	1.8	1.8	1.9	2	0.962
Sort materials	2	2.3	2.4	3	3.6	0.117
Measure layout	1.5	1.5	1.3	1.8	1.6	0.654
Plate beams by hand	1.5	2.6	2.8	3.5	4	0.235
Plate beams with crane	1	1.3	1.4	1.9	3	0.05*
Install sill plates	2	1.6	1.8	2	2.3	0.862
Frame walkouts	2.5	2.3	2.2	2.5	2.3	0.940
Cut floor joists	1	1.7	2	2	3	0.293
Sort pre-cut trusses	1	1.7	2.2	2.6	2.3	0.327
Install floor joists	1	2	2.4	3	2.6	0.049*
Sheet floor w/ 3/4" OSB	3	2.5	2.7	3.5	3.3	0.060
Snap lines on floor	1	1.7	1.5	1.7	2	0.643
Install beams by hand	3	2.9	3	3.8	4	0.066
Install beams with crane	1.5	1.3	1.4	1.6	3	0.100
Sort wall material	2	2.3	2.2	2.9	2.6	0.180
Lay out plates	1	1.5	1.7	1.9	2.3	0.509
Set up cut station	1	1.1	1.3	1.5	2.3	0.441
Create a cut list	1	1.1	0.9	1.4	1.6	0.164
Cut material	1.5	1.9	2.3	2.6	3	0.155
Square wall	1	1.6	1.6	2.3	2	0.118
Sheet wall on ground	1.5	2	2.2	2.6	2.6	0.239
Sheet wall upright	3.5	2.4	2.4	3	3.6	0.144
Stand walls	2	3.1	3.1	3.3	4.3	0.316
Sort trusses	2	2.5	2.5	3.5	3.6	0.001*
Sheet gable ends	1	1.8	2	2.2	3.3	0.200
Rack trusses	2	1.9	1.9	2.4	3.6	0.199
Cut tails	1.5	1.5	2.1	2.1	3.6	0.163
Install roof anchors	1.5	1.2	1.4	1.9	2.6	0.065
Boom trusses	2	1.7	1.9	2.2	3.3	0.178
Install truss clips	1.5	1.6	1.5	1.7	2.6	0.400

Brace off trusses	2	1.6	1.9	2.3	3	0.132
Sheet first row on roof	2	2.2	2.7	2.8	4	0.161
Finish sheeting roof	2.5	2.1	2.5	3.1	4	0.048*
Install fascia rafters	1.5	1.6	2.1	2.4	3.3	0.487
Roll out / tool set up	1	1.3	1.5	1.7	3	0.082
Build and install stairs	3	2	2.1	2.9	4.3	0.017*
Set pre-built stairs	2	2.5	2.6	3.1	4.3	0.124
Build and install partitions	2	2	2	2.4	4	0.035*
Build basement floors	1.5	0.92	1.5	2.5	4.3	0.003*
Build exterior decks	1.5	1.3	1.6	2.6	4.3	0.003*
Nail connections	2.5	1.3	1.7	2.1	2.6	0.024*
Cut roof vents	1	1.5	1.2	1.8	2	0.180
Clean up scrap material	1.5	1.9	2	2.6	4	0.011*
Roll up / put tools away	1.5	1.4	1.6	1.8	2	0.750

Significant $p < 0.05$

Table 58 Comparing Mean Task Strain Responses by Worker Job Satisfaction

Carpentry Task	Level of Job Satisfaction					MANOVA
	Not at All	Very Little	Some	Mostly	Very	P-Value
Break materials	3.3	3.5	1.6	1.9	1.6	0.028*
Sort materials	4.3	4	3.1	2.4	2.3	0.003*
Measure layout	2.6	2	1.6	1.4	1.3	0.265
Plate beams by hand	4	5	3.1	2.7	3	0.256
Plate beams with crane	2.3	2	2.1	1.3	1.5	0.103
Install sill plates	3.6	3	2.2	1.6	1.6	0.004*
Frame walkouts	3.6	4	2.3	2.3	2	0.031*
Cut floor joists	4	2.5	2.2	1.9	1.6	0.007*
Sort pre-cut trusses	3.3	3	2	2.1	2.2	0.589
Install floor joists	3.3	2.5	2.8	2.3	2.5	0.491
Sheet floor w/ 3/4" OSB	3.6	4	3.3	2.7	2.7	0.186
Snap lines on floor	3	3	1.6	1.6	1.2	0.011*
Install beams by hand	4.3	5	3	3	3.4	0.079
Install beams with crane	4	2.5	1.7	1.3	1.2	< 0.001*
Sort wall material	2	3	2.7	2.4	2.1	0.458
Lay out plates	3	2	1.9	1.6	1.6	0.208
Set up cut station	3.3	1	1.4	1.4	1	0.007*
Create a cut list	2	1.5	1.2	1	0.84	0.183
Cut material	2.6	3.5	2.3	2.2	2.3	0.541
Square wall	3	3	1.8	1.7	1.7	0.108
Sheet wall on ground	3.6	3.5	2.4	2.1	2.1	0.035*
Sheet wall upright	4	4	2.9	2.5	2.4	0.103
Stand walls	4.6	3.5	3.3	3	3.1	0.287
Sort trusses	3.6	3	2.7	2.7	2.8	0.760
Sheet gable ends	3.6	2	2.3	1.9	1.9	0.142
Rack trusses	3	2.5	2	2.1	2	0.824
Cut tails	3.6	1.5	2	2.1	1.7	0.227
Install roof anchors	3	0	1.8	1.5	1.2	0.004*
Boom trusses	3.3	2.5	1.9	2	1.8	0.152
Install truss clips	3	3	1.7	1.5	1.4	0.009*
Brace off trusses	4	2.5	1.9	2	1.7	0.003*
Sheet first row on roof	4	3	2.9	2.7	2.2	0.144
Finish sheeting roof	4	2.5	2.7	2.6	2.5	0.379

Install fascia rafters	3.6	2	2.3	2.2	1.4	0.245
Roll out / tool set up	3.6	2	1.7	1.5	1.2	0.002*
Build and install stairs	4.3	4.5	2.3	2.2	2.5	0.018*
Set pre-built stairs	4.3	4.5	2.9	2.5	2.7	0.055
Build and install partitions	3.6	2	2	2.1	2.2	0.190
Build basement floors	3.3	1	1.6	1.8	1.6	0.564
Build exterior decks	4.3	1.5	1.7	1.8	1.9	0.111
Nail connections	3	2.5	1.8	1.7	1.7	0.120
Cut roof vents	1.6	2	1.6	1.4	1.2	0.708
Clean up scrap material	4.6	1.5	2.1	2	2.2	0.002*
Roll up / put tools away	3	2	1.6	1.6	1.3	0.025*

* Significant $p < 0.05$

Table 59 Comparing Mean Task Strain Responses by Level of Monotony & Boredom

Carpentry Task	Level of Work Related Monotony & Boredom					MANOVA
	Not at All	Very Little	Sometimes	Most of the Time	All of the Time	P-Value
Break materials	1.9	1.8	2	2.2	0	0.807
Sort materials	2.6	2.3	2.6	3.2	0	0.299
Measure layout	1.2	1.3	1.6	2.2	0	0.101
Plate beams by hand	3	2.8	2.9	3.8	0	0.508
Plate beams with crane	1.5	1.2	1.8	1.8	0	0.181
Install sill plates	1.9	1.5	2	2.2	0	0.233
Frame walkouts	2.4	2	2.4	3.4	0	0.026*
Cut floor joists	1.9	1.6	2.3	2.5	0	0.072
Sort pre-cut trusses	2	2.1	2.3	2.7	0	0.601
Install floor joists	2.2	2.3	2.6	3	0	0.346
Sheet floor w/ 3/4" OSB	2.8	2.7	2	3.7	0	0.158
Snap lines on floor	1.6	1.5	1.7	1.7	0	0.831
Install beams by hand	3.4	3.1	3.2	3.7	0	0.604
Install beams with crane	1.8	1.1	1.7	1.7	0	0.090
Sort wall material	2.4	2.2	2.3	3	0	0.438
Lay out plates	1.8	1.6	1.7	2.5	0	0.129
Set up cut station	1.3	1.2	1.3	2.4	0	0.068
Create a cut list	1.1	1	1.1	1.7	0	0.300
Cut material	2.4	2.1	2.5	2.4	0	0.639
Square wall	1.4	1.8	1.6	3.2	0	< 0.001*
Sheet wall on ground	2.3	2.1	2.3	3	0	0.192
Sheet wall upright	2.6	2.5	2.7	3.2	0	0.489
Stand walls	3.2	3	3.2	3.8	0	0.431
Sort trusses	2.8	2.5	2.9	3.5	0	0.138
Sheet gable ends	2	1.8	2.1	2.5	0	0.466
Rack trusses	2.2	2	2	3.1	0	0.224
Cut tails	1.8	1.8	2.1	3.1	0	0.136
Install roof anchors	1.6	1.3	1.5	2.5	0	0.024*
Boom trusses	2.2	1.7	2.1	2.1	0	0.456
Install truss clips	1.6	1.5	1.6	2.5	0	0.062
Brace off trusses	1.8	1.9	2	3	0	0.045*
Sheet first row on roof	2.6	2.5	2.7	3.2	0	0.503
Finish sheeting roof	2.8	2.5	2.6	3.2	0	0.517

Install fascia rafters	2	2	2.1	3.4	0	0.183
Roll out / tool set up	1.6	1.3	1.6	2.4	0	0.110
Build and install stairs	2.4	2.2	2.4	3.1	0	0.497
Set pre-built stairs	2.4	2.5	3	3.5	0	0.122
Build and install partitions	2	2.1	2.3	2.5	0	0.599
Build basement floors	2.2	1.7	1.5	2.4	0	0.491
Build exterior decks	2.1	1.8	1.5	3.4	0	0.039*
Nail connections	1.8	1.7	1.8	2.4	0	0.261
Cut roof vents	1.1	1.3	1.6	2.1	0	0.115
Clean up scrap material	2.3	2	2	3.4	0	0.019*
Roll up / put tools away	1.6	1.5	1.6	2.5	0	0.032*

* Significant $p < 0.05$

Table 60 Comparing Mean Task Strain Responses by Presence of Time Pressure

	Presence of Work Related Time Pressure					MANOVA
Carpentry Task	Not at all	Very Little	Sometimes	Most of the Time	All of the Time	P-Value
Break materials	2.6	1.7	2	1.8	2	0.702
Sort materials	2.8	2.5	2.5	2.6	3	0.920
Measure layout	1	1.6	1.5	1.5	1.7	0.769
Plate beams by hand	2.2	2.8	3.2	2.8	3.5	0.544
Plate beams with crane	1.4	0.9	1.8	1.5	1.8	0.125
Install sill plates	2	1.3	2.1	1.7	1.8	0.295
Frame walkouts	2.6	2.3	2.4	2.2	2.8	0.750
Cut floor joists	2.2	1.9	1.9	2.2	2.1	0.826
Sort pre-cut trusses	1.2	2.5	2.1	2.3	2.5	0.383
Install floor joists	1.8	2.7	2.3	2.7	2.5	0.523
Sheet floor W / 3/4" OSB	3	2.9	2.7	3.1	3.4	0.561
Snap lines on floor	1.4	1.6	1.6	1.6	1.4	0.957
Install beams by hand	3.6	3.1	3.1	3.2	3.7	0.825
Install beams with crane	2	1.6	1.6	1.2	1.5	0.529
Sort wall material	1.8	2	2.3	2.5	2.8	0.339
Layout plates	1.4	1.8	1.9	1.6	2.2	0.402
Set up cut station	1.2	1.7	1.4	1.2	1.8	0.597
Create a cut list	1	1	1	1.1	1.4	0.869
Cut material	2	2	2.3	2.5	2.7	0.599
Square wall	1.4	2	1.8	1.7	2.1	0.692
Sheet wall on ground	2	2.5	2.3	2.2	2.2	0.883
Sheet wall upright	2.8	2.8	2.7	2.5	2.8	0.968
Stand walls	2.8	2.9	3.1	3.3	3.5	0.710
Sort Trusses	2.6	2.9	2.5	2.9	3.7	0.140
Sheet gable ends	2.2	2.1	2	2.1	1.8	0.971
Rack trusses	2.4	2.3	1.8	2	3.1	0.230
Cut tails	2.2	2.1	1.9	2.2	2	0.901
Install roof anchors	2	1.5	1.4	1.6	1.5	0.858
Boom trusses	2.6	2.2	1.8	2	2.1	0.534
Install truss clips	1.8	1.7	1.7	1.6	1.5	0.983
Brace off trusses	2.4	2.1	2	1.9	2.2	0.837
Sheet first row on roof	2.4	2.7	2.6	2.7	3	0.918
Finish sheeting roof	2.8	2.8	2.4	2.7	3.1	0.642

Install fascia rafters	1.4	2.8	1.8	2.2	2.8	0.217
Roll - out / set up	1.8	1.7	1.5	1.6	1.7	0.965
Build and install stairs	2.8	2.1	2.2	2.5	3.1	0.559
Set pre-built stairs	2.4	2.5	2.7	3	3	0.727
Build and install partitions	2.4	2.1	2.1	2.2	2.7	0.797
Build basement floors	1.6	2.4	1.4	1.8	2.7	0.242
Build exterior decks	1.4	2.4	1.5	2	3	0.126
Nail connections	2.2	1.6	1.8	1.8	2	0.783
Cut roof vents	1.2	1.5	1.3	1.6	1.5	0.830
Cleanup scrap material	2.2	2.3	2	2.2	2.7	0.664
Roll up / tool put away	1.6	1.8	1.5	1.8	1.8	0.682

Table 61 Comparing Mean Task Strain Responses by Co-worker Caring and Concern

Carpentry Task	Level of Caring and Concern					MANOVA
	Not at All	Very Little	Some	Mostly	Very	P-Value
Break materials	4	3	1.8	2.1	1.6	0.024*
Sort materials	5	4	2.9	2.5	2.3	0.002*
Measure layout	3.5	1	1.6	1.5	1.4	0.057
Plate beams by hand	4	4	3.3	2.7	2.9	0.557
Plate beams with crane	2	1	1.8	1.5	1.5	0.666
Install sill plates	4.5	2	2	1.8	1.7	0.008*
Frame walkouts	3.5	2	2.5	2.4	2.2	0.533
Cut floor joists	5	2	2	2.2	1.6	< 0.001*
Sort pre-cut trusses	3.5	1	2.7	2.2	1.9	0.125
Install floor joists	4	2.5	2.7	2.5	2.2	0.339
Sheet floor w/ 3/4" OSB	4	2.5	3	2.9	2.8	0.663
Snap lines on floor	4	1.5	1.7	1.6	1.3	0.006*
Install beams by hand	5	4	3.1	3.4	3	0.171
Install beams with crane	5	1.5	1.6	1.5	1.9	< 0.001*
Sort wall material	1.5	2	2.6	2.5	2.2	0.431
Lay out plates	3.5	2	1.9	1.7	1.6	0.134
Set up cut station	4	2	1.6	1.4	1	0.001*
Create a cut list	2.5	1.5	1.3	1	0.87	0.073
Cut material	3	2	2.3	2.3	2.5	0.763
Square wall	3.5	2	1.9	1.6	1.8	0.164
Sheet wall on ground	4	2.5	2.5	2.2	2.1	0.131
Sheet wall upright	4.5	3.5	2.7	2.7	2.5	0.224
Stand walls	5	3	3.2	3.2	3.1	0.330
Sort trusses	4.5	3	2.7	2.8	2.7	0.304
Sheet gable ends	4.5	2	2.1	1.9	2	0.053
Rack trusses	4.5	2.5	2.2	2.2	1.8	0.097
Cut tails	4.5	2	2.4	2	1.7	0.050*
Install roof anchors	3.5	2	1.5	1.5	1.4	0.062
Boom trusses	4.5	2.5	1.8	2	2	0.012*
Install truss clips	3.5	1.5	1.9	1.6	1.5	0.028*
Brace off trusses	4.5	3	2.2	1.8	2	0.001*
Sheet first row on roof	5	3.5	2.8	2.7	2.4	0.027*
Finish sheeting roof	5	3.5	2.6	2.6	2.6	0.055

Install fascia rafters	4	2.5	2.4	2.2	1.6	0.208
Roll out / tool set up	4.5	1.5	1.9	1.5	1.2	< 0.001*
Build and install stairs	5	1.5	3	2.4	1.9	0.004*
Set pre-built stairs	5	3	2.9	2.9	2.5	0.101
Build and install partitions	4.5	2	2.2	2.4	1.8	0.009*
Build basement floors	5	2	2	1.8	1.3	0.046*
Build exterior decks	5	1.5	2.2	1.8	1.5	0.043*
Nail connections	3.5	2	2	1.7	1.7	0.052
Cut roof vents	2.5	1.5	1.6	1.5	1.2	0.439
Clean up scrap material	4.5	2.5	2.4	2.1	2	0.031*
Roll up / put tools away	3.5	1.5	1.8	1.6	1.5	0.026*

* Significant $p < 0.05$

Table 62 Comparing Mean Task Strain Responses by Supervisor Caring and Concern

Carpentry Task	Level of Caring and Concern					MANOVA
	Not at All	Very Little	Some	Mostly	Very	P-Value
Break materials	0	2.5	2.2	2.1	1.6	0.236
Sort materials	0	3.7	3.5	2.4	2.4	0.003*
Measure layout	0	2.2	1.7	1.5	1.4	0.414
Plate beams by hand	0	3	3.4	2.9	2.9	0.806
Plate beams with crane	0	1.5	2.5	1.4	1.4	0.012*
Install sill plates	0	2.5	2.3	1.8	1.7	0.243
Frame walkouts	0	2.5	3	2.4	2.1	0.141
Cut floor joists	0	3	2.2	1.9	1.9	0.256
Sort pre-cut trusses	0	2.2	2.8	2.2	2.1	0.501
Install floor joists	0	3	2.9	2.4	2.4	0.542
Sheet floor w/ 3/4" OSB	0	3.2	3.5	2.9	2.8	0.239
Snap lines on floor	0	2.2	2	1.6	1.4	0.170
Install beams by hand	0	4	3.5	3.1	3.1	0.502
Install beams with crane	0	3	1.9	1.5	1.2	0.005*
Sort wall material	0	1.7	2.6	2.4	2.3	0.532
Lay out plates	0	2.2	1.8	1.8	1.7	0.803
Set up cut station	0	2.5	1.4	1.5	1.2	0.124
Create a cut list	0	1.5	1.3	1.1	1	0.508
Cut material	0	2.5	2.5	2.1	2.5	0.450
Square wall	0	2.2	2	1.6	1.8	0.620
Sheet wall on ground	0	3	2.6	2.2	2.2	0.331
Sheet wall upright	0	4	3	2.6	2.5	0.075
Stand walls	0	4.2	3.3	3	3.1	0.339
Sort trusses	0	3.5	3	2.6	2.7	0.461
Sheet gable ends	0	3.2	2.1	1.7	2.2	0.056
Rack trusses	0	3	1.8	2.2	2	0.454
Cut tails	0	3	1.8	2.1	2	0.524
Install roof anchors	0	2.2	1.3	1.6	1.5	0.477
Boom trusses	0	2.7	1.7	1.9	2.1	0.375
Install truss clips	0	2.5	1.8	1.8	1.5	0.147
Brace off trusses	0	3	2.1	2	1.9	0.211
Sheet first row on roof	0	4	2.6	2.7	2.6	0.151
Finish sheeting roof	0	3.7	2.5	2.5	2.7	0.247

Install fascia rafters	0	2.7	2.3	2.5	1.7	0.222
Roll out / tool set up	0	2.7	1.8	1.6	1.4	0.085
Build and install stairs	0	3.2	2.8	2.4	2.2	0.387
Set pre-built stairs	0	5.3	3.1	2.6	2.7	0.481
Build and install partitions	0	3.2	2	2.4	2	0.101
Build basement floors	0	3.2	1.4	2	1.6	0.231
Build exterior decks	0	4	1.7	1.9	1.7	0.055
Nail connections	0	2.5	2	1.8	1.7	0.336
Cut roof vents	0	1.7	1.5	1.6	1.3	0.763
Clean up scrap material	0	2.7	2.2	2.2	2.1	0.724
Roll up / put tools away	0	2.2	1.7	1.7	1.6	0.540

* Significant $p < 0.05$

Table 63 Comparing Mean Task Strain Responses by Hours of Safety Training

Hours of Safety Training in the Previous 12 Months				MANOVA
Carpentry Task	**0 - 5 hrs.**	**6 - 20 hrs.**	**> 20 hrs.**	**P-Value**
Break materials	1.8	2.1	1.8	0.601
Sort materials	2.7	2.5	2.4	0.589
Measure layout	1.6	1.4	1.2	0.306
Plate beams by hand	3	3	2.7	0.776
Plate beams with crane	1.7	1.4	1.4	0.391
Install sill plates	2.1	1.6	1.5	0.107
Frame walkouts	2.5	2.1	2.2	0.271
Cut floor joists	2.1	1.9	1.7	0.398
Sort pre-cut trusses	2.6	1.7	1.9	0.012
Install floor joists	2.8	1.9	2.5	0.009*
Sheet floor w/ 3/4" OSB	3	2.7	3	0.484
Snap lines on floor	1.7	1.3	1.7	0.292
Install beams by hand	3.5	3	2.9	0.156
Install beams with crane	1.6	1.2	1.4	0.270
Sort wall material	2.4	2.4	2.3	0.958
Lay out plates	1.9	1.6	1.5	0.349
Set up cut station	1.5	1.1	1.5	0.342
Create a cut list	1	1.2	1	0.766
Cut material	2.5	2.1	2	0.091
Square wall	1.9	1.6	1.7	0.619
Sheet wall on ground	2.5	1.9	2.4	0.085
Sheet wall upright	2.9	2.2	2.6	0.040*
Stand walls	3.4	2.8	3.1	0.125
Sort trusses	3	2.4	2.7	0.146
Sheet gable ends	2.3	1.6	2	0.066
Rack trusses	2.3	1.9	2	0.493
Cut tails	2.3	1.6	2.1	0.190
Install roof anchors	1.6	1.4	1.6	0.642
Boom trusses	2.9	2	1.9	0.861
Install truss clips	1.7	1.3	1.8	0.123
Brace off trusses	2.1	1.9	1.9	0.466
Sheet first row on roof	2.9	2.4	2.7	0.238
Finish sheeting roof	2.8	2.4	2.5	0.328
Install fascia rafters	2.2	1.9	2.2	0.646
Roll out / tool set up	1.7	1.4	1.6	0.464
Build and install stairs	2.7	1.9	2.5	0.063
Set pre-built stairs	3	2.3	2.9	0.094
Build and install partitions	2.5	1.7	2.2	0.024*
Build basement floors	2.1	1.3	1.8	0.178
Build exterior decks	2.3	1.3	1.7	0.057
Nail connections	2	1.5	1.8	0.098
Cut roof vents	1.5	1.2	1.7	0.198
Clean up scrap material	2.4	1.9	2	0.169
Roll up / put tools away	1.7	1.4	1.7	0.391

* Signifcant $p < 0.05$

Table 64 Comparing Mean Task Strain Responses by Safety Training Source

	Safety and Health Training Source						MANOVA
Carpentry Task	**GC**	**Foreman**	**Consultant**	**OSHA**	**HBA**	**Combination**	**P-Value**
Break materials	1.5	2	1.9	2	3	1.7	0.060
Sort materials	2	2.9	2.8	2.3	3.6	2.7	0.019*
Measure layout	0.9	1.4	1.7	2	1.7	1.5	0.329
Plate beams by hand	2.4	2.4	3.1	3.3	3.6	3.1	0.536
Plate beams with crane	1.1	1.45	1.2	2	2.5	1.5	0.043*
Install sill plates	1.6	1.4	1.7	2	2.8	1.7	0.058
Frame walkouts	1.3	2.3	2.8	2.3	3.7	2.1	<.0001*
Cut floor joists	1.8	2	1.9	2	3	1.8	0.110
Sort pre-cut trusses	1.6	2.2	2.3	1.3	2.4	2.2	0.640
Install floor joists	1.9	2.4	2.4	2	2.7	2.4	0.733
Sheet floor w/ 3/4" OSB	2.2	2.8	3.3	2.6	3.4	2.8	0.116
Snap lines on floor	1.1	1.4	1.6	2	2.2	1.5	0.184
Install beams by hand	2.7	2.8	2.9	3.3	3.8	3.4	0.185
Install beams with crane	1.1	1.3	1.4	2	2.5	1.2	0.005*
Sort wall material	2	2.4	2	2.3	2.9	2.5	0.265
Lay out plates	1.6	1.5	1.9	2	2.2	1.6	0.587
Set up cut station	1.1	1.5	1.7	1.3	2	1.2	0.333
Create a cut list	0.8	1	1.5	1	1.8	0.93	0.034*
Cut material	0.7	2.5	2.1	2	2.6	2.5	0.203
Square wall	1.3	1.9	2.2	2	2.4	1.7	0.181
Sheet wall on ground	2	2.2	2.3	2.33	3	2.2	0.252
Sheet wall upright	2.2	2.4	2.7	2	3.8	2.6	0.036*
Stand walls	2.5	3	2.8	3.3	3.6	3.1	0.163
Sort trusses	2.1	2.3	2.9	2.3	3.2	3.1	0.093
Sheet gable ends	1.8	2	2	1.6	2.3	2.2	0.894
Rack trusses	1.5	2.2	2.7	1.6	2.3	2	0.450
Cut tails	1.3	2	2.4	2	1.8	2.2	0.457
Install roof anchors	1.1	1.5	1.4	1.6	1.9	1.6	0.503
Boom trusses	1.9	2	2	1.6	2.6	1.9	0.628
Install truss clips	1.2	1.7	1.8	1.6	2.1	1.5	0.214

Brace off trusses	1.6	1.9	2.1	2	2.7	2	0.131
Sheet first row on roof	0.8	2.4	2.7	3	3.1	2.7	0.157
Finish sheeting roof	2	2.9	2.7	2.3	3.1	2.6	0.391
Install fascia rafters	1.4	2.2	2.8	2	2.8	1.8	0.246
Roll out / tool set up	1.1	1.5	1.8	2.3	1.9	1.6	0.420
Build and install stairs	1.5	1.8	2.7	2.6	3.2	2.5	0.061
Set pre-built stairs	1.9	2.4	2.7	2.6	3.4	3	0.148
Build and install partitions	1.6	1.9	2.2	3.3	2.8	2.2	0.074
Build basement floors	0.8	2.1	1.6	1.6	2.3	1.7	0.425
Build exterior decks	0.9	2	2.1	2.6	2.2	1.8	0.405
Nail connections	1.3	1.7	1.7	2.6	2.1	1.8	0.165
Cut roof vents	1.3	1.2	1.7	2	1.3	1.4	0.778
Clean up scrap material	2	1.8	2.1	2	2.7	2.3	0.624
Roll up / put tools away	1.1	1.6	2.2	1.6	1.8	1.6	0.104

* Significant $p < 0.05$

Table 65 Comparing Mean Task Strain Responses by Age

Carpentry Task	Age of Worker in Years						MANOVA
	18 - 24	25 - 30	31 - 35	36 - 40	41 - 45	> 45	P-Value
Break materials	1.4	1.5	2.1	2.1	2	2.5	0.095
Sort materials	2.3	2.4	2.8	2.1	3	3	0.281
Measure layout	1.4	1.4	1.4	1.1	1.6	2	0.245
Plate beams by hand	2.8	2.8	4.2	2	2.5	3.4	0.011*
Plate beams with crane	1.2	1.3	1.8	1.4	2	1.8	0.279
Install sill plates	1.6	1.7	2	1.6	1.8	2.2	0.547
Frame walkouts	2.1	2.3	2.1	2	2.6	2.9	0.266
Cut floor joists	1.7	1.5	2.4	2.3	1.9	2.4	0.113
Sort pre-cut trusses	1.8	2.2	2.5	1.5	2.8	2.6	0.202
Install floor joists	2.1	2.2	2.7	2.2	2.8	2.8	0.414
Sheet floor w/ 3/4" OSB	2.4	2.8	3.4	2.3	3.4	3.2	0.023*
Snap lines on floor	1.3	1.5	1.6	1.2	1.8	2.1	0.168
Install beams by hand	2.8	2.6	4	2.5	3.8	3.7	< 0.001*
Install beams with crane	1.4	1.3	1.7	1.2	1.7	1.8	0.642
Sort wall material	2.2	2.2	2.7	2.1	2.6	2.4	0.722
Lay out plates	1.6	1.4	2	1.3	1.8	2.3	0.051
Set up cut station	1.5	1	1.5	1.2	1.6	1.8	0.323
Create a cut list	1.2	1	1.1	0.91	1.1	1.3	0.886
Cut material	2.4	2.2	2.6	1.7	2.6	2.4	0.245
Square wall	2	1.4	1.8	1.4	1.6	2.4	0.063
Sheet wall on ground	2.2	2.1	2.5	1.9	2.5	2.7	0.278
Sheet wall upright	2.5	2.3	2.7	2.5	2.6	3.3	0.311
Stand walls	2.7	2.7	3.5	2.8	3.6	3.8	0.044*
Sort trusses	2.3	2.5	3.1	2.5	3.3	3	0.188
Sheet gable ends	1.8	1.7	2.4	1.7	2.4	2.4	0.218
Rack trusses	1.6	1.9	2.4	1.6	2.5	2.7	0.164
Cut tails	1.7	1.8	2	2.1	2.4	2.2	0.793
Install roof anchors	1.2	1.5	1.6	1.3	1.6	2	0.230
Boom trusses	1.8	1.9	2	2.3	1.9	2.2	0.794
Install truss clips	1.5	1.5	1.9	1.5	1.6	2	0.605

Brace off trusses	1.6	2	2.1	2	2	2.5	0.273
Sheet first row on roof	2.1	2.4	3	2.8	2.8	3.1	0.203
Finish sheeting roof	2	2.5	2.9	2.5	3.1	3	0.164
Install fascia rafters	1.1	1.7	2.3	2.7	2.8	2.6	0.033*
Roll out / tool set up	1.4	1.4	1.9	1.3	1.9	1.9	0.344
Build and install stairs	2.4	2.2	2.5	1.5	2.4	3.3	0.027*
Set pre-built stairs	2.6	2.4	2.8	2.2	3.1	3.5	0.114
Build and install partitions	2	1.9	2.1	2	2.2	2.9	0.124
Build basement floors	1.1	1.2	1.9	1.5	2.8	2.4	0.077
Build exterior decks	1.2	1.3	2.1	1.9	2.5	2.6	0.073
Nail connections	1.6	1.5	2	1.9	1.9	2.1	0.340
Cut roof vents	1.3	1.4	1.4	1.2	1.6	1.8	0.658
Clean up scrap material	2	1.8	2.6	1.7	2.2	2.8	0.056
Roll up / put tools away	1.4	1.5	1.5	1.5	2	2	0.275

* Significant $p < 0.05$

Table 66 Comparing Mean Task Strain Responses by Years in Residential Construction

Carpentry Task	Years in Residential Construction 1 - 5 yrs.	6 - 10 yrs.	11 - 15 yrs.	16 - 20 yrs.	21 - 25 yrs.	> 25 yrs.	MANOVA P-Value
Break materials	1.3	1.7	1.6	1.7	3.5	2.5	< 0.001*
Sort materials	2	2.7	2.6	2.7	3.3	3	0.090
Measure layout	1.3	1.3	1.8	1.6	1.6	2.1	0.158
Plate beams by hand	2.5	3.4	3.4	3	2.1	3	0.382
Plate beams with crane	1.2	1.5	2.4	1.8	1.5	1.9	0.184
Install sill plates	1.5	1.8	2.2	1.7	2	2.2	0.635
Frame walkouts	2	2.2	2.6	2.5	3	2.9	0.146
Cut floor joists	1.7	2.1	2	2	2.1	2.4	0.682
Sort pre-cut trusses	1.7	2.3	1.8	2.8	2.1	2.5	0.361
Install floor joists	2	2.5	2.6	3.1	2.3	2.8	0.243
Sheet floor w/ 3/4" OSB	2.2	3	3.2	3.4	2.8	3.3	0.027*
Snap lines on floor	1.2	1.6	1.6	1.6	1.6	2.1	0.196
Install beams by hand	2.5	3.3	3.8	3.7	3.3	3.5	0.067
Install beams with crane	1.3	1.4	1.8	1.7	1.3	1.8	0.720
Sort wall material	2.1	2.4	2.6	2.7	2.5	2.4	0.792
Lay out plates	1.5	1.6	1.8	2.1	1.6	2.2	0.329
Set up cut station	1.3	1.1	1.8	1.6	1.5	1.6	0.485
Create a cut list	1	1	1	1	1	1.5	0.651
Cut material	2.1	2.4	2.4	2.6	2.3	2.3	0.792
Square wall	1.6	1.6	2.2	1.8	1.6	2.4	0.421
Sheet wall on ground	2	2.2	2.4	2.6	2.3	2.7	0.345
Sheet wall upright	2.1	2.7	2.8	2.8	2.6	3.1	0.338
Stand walls	2.5	3.3	4	3.4	3.1	3.5	0.124
Sort trusses	2	3.1	2.8	3.3	2.6	3.1	0.013*
Sheet gable ends	1.6	2.1	2.8	2.4	2	2.3	0.272
Rack trusses	1.5	2.1	2.4	2.6	2.5	2.6	0.166
Cut tails	1.5	2	2.6	2.8	2.5	2.6	0.171
Install roof anchors	1.2	1.6	2.2	1.5	2.6	2	0.425
Boom trusses	1.6	2.2	1.8	1.8	2.1	2.4	0.297
Install truss clips	1.5	1.7	1.8	1.8	1.6	1.6	0.952

Brace off trusses	1.6	2.1	2	2.1	2.3	2.4	0.261
Sheet first row on roof	2	2.7	3.6	3	2.6	3	0.053
Finish sheeting roof	1.9	2.8	3	3.1	2.8	3	0.039*
Install fascia rafters	1.5	2	2.4	3	2.5	2.6	0.209
Roll out / tool set up	1.3	1.5	2	1.7	1.6	1.8	0.732
Build and install stairs	2	2.4	2.6	2.3	2.1	3.3	0.223
Set pre-built stairs	2.2	2.9	3	2.8	2.8	3.3	0.410
Build and install partitions	1.8	2.1	3	2.2	2	2.9	0.052
Build basement floors	0.89	1.4	2.4	2.6	3	2.7	0.004*
Build exterior decks	1.2	1.4	2.8	2.7	2.1	3	0.005*
Nail connections	1.5	1.8	2.2	2	2.1	2	0.414
Cut roof vents	1	1.4	1.8	1.7	1.5	1.8	0.284
Clean up scrap material	1.8	2.3	1.8	2.4	2.1	2.6	0.460
Roll up / put tools away	1.4	1.6	1.8	1.7	2	1.8	0.714

Significant $p < 0.05$

Table 67 Comparing Mean Task Strain Responses by Years in Residential Framing Carpentry

	Years in Residential Framing Carpentry						MANOVA
Carpentry Task	**1 - 5 yrs.**	**6 - 10 yrs.**	**11 - 15 yrs.**	**16 - 20 yrs.**	**21 - 25 yrs.**	**> 25 yrs.**	**P-Value**
Break materials	1.3	1.8	1.8	1.8	3.6	2.5	< 0.001*
Sort materials	2.2	2.6	3	2.7	3.2	3	0.302
Measure layout	1.2	1.4	1.2	1.7	1.8	2.1	0.138
Plate beams by hand	2.5	3.8	2.4	2.8	2.4	3	0.061
Plate beams with crane	1.2	1.6	1.8	1.8	1.6	1.9	0.515
Install sill plates	1.6	2	1.4	1.8	2.2	2.2	0.490
Frame walkouts	2	2.3	2.4	2.6	3	2.9	0.119
Cut floor joists	1.8	2.1	1.6	2.1	2.4	2.4	0.522
Sort pre-cut trusses	1.9	2.3	1.6	3	2.4	2.5	0.307
Install floor joists	2.2	2.4	2.4	3.2	2.6	2.8	0.383
Sheet floor w/ 3/4" OSB	2.6	2.9	3	3.6	3	3.3	0.165
Snap lines on floor	1.3	1.6	1.2	1.7	1.8	2.1	0.199
Install beams by hand	2.8	3.4	3.2	3.8	3.4	3.5	0.186
Install beams with crane	1.3	1.6	1.4	1.7	1.4	1.8	0.721
Sort wall material	2.1	2.5	2.2	2.8	2.8	2.4	0.517
Lay out plates	1.5	1.7	1.2	2.1	1.8	2.2	0.235
Set up cut station	1.3	1	1.4	1.6	1.6	1.6	0.614
Create a cut list	1	1	1.2	1	1	1.5	0.629
Cut material	2.1	2.5	2.2	2.7	2.4	2.3	0.725
Square wall	1.7	1.6	2.2	1.8	1.6	2.3	0.398
Sheet wall on ground	2.1	2.1	2.2	2.7	2.4	2.7	0.384
Sheet wall upright	2.5	2.5	2	2.7	3.2	3.1	0.450
Stand walls	2.7	3.5	3.4	3.3	3.4	3.5	0.230
Sort trusses	2.3	3.1	2.4	3.3	3	3.1	0.059
Sheet gable ends	1.9	2	2	2.5	2	2.3	0.834
Rack trusses	1.6	2.3	1.6	2.6	2.6	2.6	0.148
Cut tails	1.7	2.2	1.8	2.8	2.8	2	0.233
Install roof anchors	1.4	1.6	1.6	1.5	1.8	1.6	0.978
Boom trusses	1.7	2.2	2	1.8	2	2.4	0.485
Install truss clips	1.5	1.7	1.8	1.8	1.6	1.6	0.913

Brace off trusses	1.8	2	2	2.1	2.4	2.4	0.670
Sheet first row on roof	2.2	2.9	2.8	3	2.8	3	0.216
Finish sheeting roof	2.3	2.7	2.6	3.1	3	3	0.321
Install fascia rafters	1.8	2	1.6	3	3	2.6	0.239
Roll out / tool set up	1.4	1.5	2	1.7	1.8	1.8	0.750
Build and install stairs	2	2.6	2.2	2.2	2.6	3.3	0.139
Set pre-built stairs	2.3	3.1	2	2.8	3.4	3.2	0.092
Build and install partitions	1.9	2.3	1.8	2.1	2.4	2.9	0.160
Build basement floors	0.96	1.6	2.2	2.6	3.6	2.7	0.001*
Build exterior decks	1.2	1.6	2	2.7	2.6	3	0.014*
Nail connections	1.6	1.8	2.2	2	2.2	2	0.383
Cut roof vents	1.2	1.5	1.2	1.7	1.8	1.8	0.425
Clean up scrap material	1.9	2.3	1.6	2.5	2.6	2.6	0.246
Roll up / put tools away	1.5	1.6	2	1.7	2	1.8	0.686

* Significant $p < 0.05$

Table 68 Comparing Mean Task Strain Responses by Hours Worked Per Week

Carpentry Task	Hours Worked Per Week			MANOVA
	20 - 39 hrs.	40 - 45 hrs.	> 45 hrs.	P-Value
Break materials	1.7	1.8	2.2	0.552
Sort materials	2.8	2.6	2.3	0.628
Measure layout	2.1	1.5	1	0.076
Plate beams by hand	4.2	2.8	2.9	0.068
Plate beams with crane	1.5	1.6	1.4	0.897
Install sill plates	2.6	1.8	1.6	0.096
Frame walkouts	2.3	2.4	2	0.493
Cut floor joists	2.3	2	1.9	0.617
Sort pre-cut trusses	2.5	2.2	1.7	0.384
Install floor joists	3.2	2.3	2.4	0.181
Sheet floor w/ 3/4" OSB	3.2	2.8	2.9	0.666
Snap lines on floor	2	1.6	1.2	0.278
Install beams by hand	4	3.1	3.1	0.178
Install beams with crane	2.2	1.4	1	0.046*
Sort wall material	2.5	2.4	2.1	0.731
Lay out plates	2.3	1.7	1.6	0.174
Set up cut station	1.7	1.3	1.3	0.601
Create a cut list	1	1.1	0.9	0.651
Cut material	2.7	2.3	1.9	0.195
Square wall	2.6	1.7	1.6	0.053
Sheet wall on ground	2.8	2.2	2.3	0.211
Sheet wall upright	3.5	2.5	2.6	0.123
Stand walls	3.2	3.1	3.4	0.768
Sort trusses	3.2	2.7	2.7	0.524
Sheet gable ends	2.8	1.9	2.1	0.100
Rack trusses	2.2	2.1	2	0.966
Cut tails	2.6	1.9	2.4	0.251
Install roof anchors	1.8	1.4	1.9	0.218
Boom trusses	2.3	1.9	2.1	0.496
Install truss clips	2.2	1.5	1.7	0.131
Brace off trusses	2.3	2	2	0.585
Sheet first row on roof	3.1	2.6	2.8	0.493
Finish sheeting roof	3	2.6	2.7	0.689
Install fascia rafters	2.2	2.1	2.1	0.983
Roll out / tool set up	1.7	1.5	1.7	0.823
Build and install stairs	2.7	2.3	2.9	0.325
Set pre-built stairs	3.3	2.5	3.3	0.075
Build and install partitions	2.5	2.1	2.3	0.603
Build basement floors	2.5	1.6	1.9	0.450
Build exterior decks	2.5	1.8	1.8	0.552
Nail connections	2.3	1.6	2.3	0.008*
Cut roof vents	2.2	1.3	1.3	0.042*
Clean up scrap material	2.3	2.1	2.5	0.490
Roll up / put tools away	2	1.5	2	0.117

* Significant < 0.05

Table 69 Comparing Mean Task Strain Responses by Time Doing Side Jobs

Carpentry Task	Hours of Side Job Work Per Month					MANOVA
	None	< 8 hrs.	9 -16 hrs.	17 - 20 hrs.	> 21 hrs.	P-Value
Break materials	2	1.8	2	2	1.6	0.873
Sort materials	2.6	2.4	2.9	2.6	2.8	0.693
Measure layout	1.2	1.6	1.7	2	1.6	0.335
Plate beams by hand	3	2.7	3.3	3.2	3	0.788
Plate beams with crane	1.6	1.2	1.7	2.4	1.8	0.231
Install sill plates	1.7	1.8	2.2	1.6	1.8	0.474
Frame walkouts	2.4	2.4	2.2	2.4	2.2	0.979
Cut floor joists	2	2.1	2	1.6	2	0.862
Sort pre-cut trusses	1.9	2.1	3	2	2.6	0.105
Install floor joists	2.3	2.5	2.7	2.8	2.4	0.880
Sheet floor w/ 3/4" OSB	3	2.8	2.9	3.2	3.4	0.824
Snap lines on floor	1.4	1.7	1.8	1.6	1.4	0.594
Install beams by hand	3.1	3	3.5	3.6	3.6	0.555
Install beams with crane	1.5	1.3	1.9	1.6	1.4	0.467
Sort wall material	2.5	2.2	2.3	2.6	2.4	0.946
Lay out plates	1.7	1.7	2	2	1.6	0.846
Set up cut station	1.5	1.3	1.5	0.8	1.6	0.641
Create a cut list	1.3	0.92	1.1	0.8	1.4	0.347
Cut material	2.1	2.3	2.5	3.2	2.4	0.226
Square wall	1.7	1.8	1.4	2.6	2.2	0.208
Sheet wall on ground	2.3	2.2	2.4	2	2.6	0.864
Sheet wall upright	2.8	2.6	2.6	2.2	3	0.831
Stand walls	3.1	3.1	3.4	3	3.4	0.888
Sort trusses	2.6	2.8	2.8	3.2	3.2	0.707
Sheet gable ends	2	2.1	2.1	2	2.2	0.990
Rack trusses	2	2.1	2.4	1.4	2.6	0.523
Cut tails	1.6	2.2	2.5	1.8	2.6	0.152
Install roof anchors	1.5	1.6	1.5	1.6	1.4	0.995
Boom trusses	1.9	2.1	1.9	2.2	2	0.900
Install truss clips	1.5	1.7	1.8	1.6	2.2	0.612

Brace off trusses	1.9	2.1	2	2.4	2.4	0.640
Sheet first row on roof	2.4	2.8	2.9	2.8	3	0.583
Finish sheeting roof	2.6	2.6	2.7	3.2	3	0.835
Install fascia rafters	1.8	2.4	2.4	1.6	2.2	0.557
Roll out / tool set up	1.4	1.7	1.7	1	2.2	0.312
Build and install stairs	2.5	2.1	2.5	2.2	3.6	0.224
Set pre-built stairs	2.6	2.8	2.9	2.8	3.4	0.766
Build and install partitions	2.1	2.4	2.1	2	2.4	0.799
Build basement floors	1.8	1.5	1.9	2.6	2	0.747
Build exterior decks	1.7	1.7	2.1	2.4	2.4	0.788
Nail connections	1.7	1.8	1.8	2.2	2.4	0.451
Cut roof vents	1.1	1.6	1.7	1.8	1.8	0.163
Clean up scrap material	2.2	2	2.2	2	3	0.551
Roll up / put tools away	1.5	1.7	1.8	1.2	2.2	0.277

* Significant $p < 0.05$

Table 70 Comparing Mean Task Strain Responses by Income Level

	Level of Annual Income					MANOVA
Carpentry Task	**< $10,000**	**$10,001-$20,000**	**$20,001-$35,000**	**$35,001-$50,000**	**> $50,000**	**P-Value**
Break materials	1.5	1.6	2.1	1.7	2.1	0.655
Sort materials	3	2.7	2.7	2.6	2.4	0.860
Measure layout	1.5	1.1	1.6	1.5	1.6	0.711
Plate beams by hand	2	3.1	3.3	2.8	3.1	0.766
Plate beams with crane	2	1.6	1.4	1.8	1.5	0.826
Install sill plates	2	1.7	2	1.8	1.8	0.913
Frame walkouts	1.5	2.2	2.3	2.5	2.5	0.697
Cut floor joists	3	2.1	2	1.9	1.8	0.691
Sort pre-cut trusses	1.5	1.8	2.4	2.5	2.2	0.715
Install floor joists	2	2.4	2.8	2.5	2.3	0.722
Sheet floor w/ 3/4" OSB	3	3	2.8	3.2	2.9	0.789
Snap lines on floor	2	1.4	1.6	1.5	1.7	0.836
Install beams by hand	3	2.8	3.4	3.2	3.3	0.842
Install beams with crane	3	1.6	1.6	1.5	1.3	0.262
Sort wall material	2	2.6	2.1	2.4	2.4	0.774
Lay out plates	1.5	2.2	1.7	1.6	1.8	0.578
Set up cut station	2	2	1.5	1.4	1.2	0.369
Create a cut list	2	1.3	1.1	1.1	1	0.683
Cut material	2.5	2.6	2.3	2	2.4	0.507
Square wall	1.5	1.7	1.9	1.7	1.8	0.920
Sheet wall on ground	2.5	2.7	2.3	2.3	2.2	0.692
Sheet wall upright	2.5	2.8	2.7	2.8	2.5	0.947
Stand walls	2.5	3.1	3	3.2	3.3	0.880
Sort trusses	2.5	1.8	2.9	3	2.8	0.138
Sheet gable ends	3	2.1	2.1	2	1.9	0.729
Rack trusses	2	0.88	2.5	2.4	2.2	0.026*
Cut tails	2.5	1.5	2.4	2.2	1.8	0.388
Install roof anchors	2.5	1.5	1.5	1.6	1.6	0.790
Boom trusses	3	1.7	2.2	1.7	2	0.252
Install truss clips	2.5	1.8	1.8	1.4	1.8	0.355

Brace off trusses	2,5	1,8	2,3	1,9	1,9	0,449
Sheet first row on roof	3	2,5	2,9	2,6	2,5	0,768
Finish sheeting roof	3	2,6	2,6	2,6	2,6	0,997
Install fascia rafters	2	1.7	2,5	2,4	1,8	0,515
Roll out / tool set up	3	2,1	1,4	1,6	1,6	0,159
Build and install stairs	3	2,2	2	2,8	2,6	0,359
Set pre-built stairs	2.5	2,1	2,7	2,8	3	0,439
Build and install partitions	3	1,8	1,9	2,4	2,4	0,365
Build basement floors	2,5	0,88	2	1,8	1,8	0,499
Build exterior decks	3	1,6	2	1,9	1,7	0,841
Nail connections	1,5	1,8	1,8	1,8	1,9	0,970
Cut roof vents	1	1	1,4	1,7	1,5	0,413
Clean up scrap material	3	2.1	2	2.2	2,4	0.648
Roll up / put tools away	2	1,7	1,7	1,6	1,6	0,970

* Significant $p < 0.05$

Table 71 Comparing Mean Task Strain Responses by Level of Education

Grade Level of Education Attained		Some	High School	Trade	Some	College	MANOVA
Carpentry Task	1 to 8	High School	Graduate	School	College	Degree	P-Value
Break materials	2.6	2	2	1.6	1.8	1.6	0.832
Sort materials	3	2.4	2.7	1.3	2.5	2.7	0.469
Measure layout	2.3	1.2	1.4	1	1.6	1.5	0.613
Plate beams by hand	3.6	3.2	3.2	2	2.8	3.3	0.720
Plate beams with crane	2	0.6	1.6	1.3	1.4	2.2	0.096
Install sill plates	2.3	0.6	1.9	1.3	1.9	2.1	0.104
Frame walkouts	3	2.6	2.4	1.6	2.4	2	0.609
Cut floor joists	2.6	1.8	1.7	1	2	2.5	0.179
Sort pre-cut trusses	3	2.4	2.1	0.66	2.3	2.5	0.361
Install floor joists	3	2.6	2.4	1.3	2.6	2.7	0.561
Sheet floor w/ 3/4" OSB	3.3	3	3	1.3	2.9	3.4	0.124
Snap lines on floor	2.3	1	1.5	0.66	1.7	1.8	0.192
Install beams by hand	3.6	2.8	3.3	1.3	3.2	3.8	0.054
Install beams with crane	1.6	1	1.6	1	1.5	1.8	0.616
Sort wall material	3	2.4	2.3	1.3	2.4	2.6	0.477
Lay out plates	3	1.6	1.8	1	1.7	1.8	0.243
Set up cut station	2.3	1.6	1.4	0	1.3	2.1	0.031*
Create a cut list	2.3	1.4	1.1	0.33	1	1.2	0.124
Cut material	2.3	2	2.4	1.3	2.3	2.6	0.440
Square wall	2.3	2.2	1.7	1.3	1.8	1.7	0.806
Sheet wall on ground	3	2	2.4	1.3	2.3	2.3	0.398
Sheet wall upright	2.3	2.4	2.8	1.6	2.6	3.1	0.540
Stand walls	3	2.6	2.9	2.3	3.4	3.8	0.192
Sort trusses	3.3	2.4	2.6	1.6	2.8	3.4	0.174
Sheet gable ends	2.3	1.4	2.1	1.3	1.9	2.7	0.211
Rack trusses	2.6	2.8	1.8	1	2	3.2	0.044*
Cut tails	2.3	1.8	1.8	1.3	2	2.8	0.386
Install roof anchors	2	1.2	1.5	0.66	1.5	2.3	0.101
Boom trusses	2.3	1.8	1.9	1.6	1.8	2.5	0.582
Install truss clips	1.6	1.8	1.8	1.6	1.5	2.2	0.459

Brace off trusses	1.6	2.4	2	1.3	1.9	2.6	0.249
Sheet first row on roof	3	2.6	2.5	2.3	2.5	3.7	0.114
Finish sheeting roof	3	2.2	2.4	2	2.7	3.5	0.172
Install fascia rafters	2	2.6	1.8	2	2	3.4	0.203
Roll out / tool set up	1	1.4	1.6	2	1.6	2	0.707
Build and install stairs	2.6	2.2	2.2	2	2.5	3.1	0.679
Set pre-built stairs	2.6	2.6	2.4	2.6	2.9	3.5	0.313
Build and install partitions	2	2	2.1	2.6	2.1	2.7	0.638
Build basement floors	1.6	2.4	1.5	0	1.8	3	0.087
Build exterior decks	2	1.8	1.8	2	1.6	3.1	0.291
Nail connections	1	1.6	1.8	2	1.8	2.3	0.268
Cut roof vents	2	1	1.4	0.66	1.6	1.7	0.433
Clean up scrap material	2.6	2	2	2.3	2.1	2.6	0.749
Roll up / put tools away	1.6	1.8	1.5	2	1.7	1.7	0.959

* Significant $p < 0.05$

Table 72 Comparing Mean Task Strain Responses by Employment Status

Company Employee			MANOVA
Carpentry Task	**No**	**Yes**	**P-Value**
Break materials	2.1	1.7	0.147
Sort materials	2.7	2.5	0.429
Measure layout	1.5	1.4	0.514
Plate beams by hand	3.1	2.7	0.283
Plate beams with crane	1.4	1.6	0.384
Install sill plates	1.9	1.7	0.425
Frame walkouts	2.5	2.2	0.237
Cut floor joists	2	1.9	0.628
Sort pre-cut trusses	2.2	2.2	0.965
Install floor joists	2.4	2.5	0.598
Sheet floor w/ 3/4" OSB	3	2.8	0.665
Snap lines on floor	1.6	1.5	0.714
Install beams by hand	3.2	3.2	0.895
Install beams with crane	1.5	1.4	0.534
Sort wall material	2.3	2.3	0.972
Lay out plates	1.7	1.8	0.449
Set up cut station	1.2	1.6	0.121
Create a cut list	0.97	1.3	0.060
Cut material	2.4	2.2	0.386
Square wall	1.6	1.9	0.130
Sheet wall on ground	2.2	2.3	0.835
Sheet wall upright	2.5	2.7	0.472
Stand walls	3.2	3.1	0.730
Sort trusses	2.7	2.8	0.789
Sheet gable ends	1.9	2.2	0.280
Rack trusses	2.1	2.2	0.746
Cut tails	1.9	2.1	0.486
Install roof anchors	1.4	1.7	0.123
Boom trusses	2	2	0.771
Install truss clips	1.6	1.6	0.991
Brace off trusses	2	2	0.878
Sheet first row on roof	2.7	2.6	0.526
Finish sheeting roof	2.7	2.6	0.783
Install fascia rafters	2	2.2	0.684
Roll out / tool set up	1.6	1.5	0.649
Build and install stairs	2.5	2.3	0.504
Set pre-built stairs	2.8	2.7	0.665
Build and install partitions	2.1	2.3	0.460
Build basement floors	1.8	1.6	0.594
Build exterior decks	1.7	2	0.514
Nail connections	1.8	1.7	0.513
Cut roof vents	1.4	1.5	0.828
Clean up scrap material	2.1	2.3	0.423
Roll up / put tools away	1.7	1.5	0.256

Table 73 Comparing Mean Task Strain Responses by Sub-Contractor Status

Self Employed Sub-Contractor			MANOVA
Carpentry Task	No	Yes	P-Value
Break materials	1.6	2	0.161
Sort materials	2.5	2.6	0.625
Measure layout	1.2	1.6	0.076
Plate beams by hand	3	2.9	0.965
Plate beams with crane	1.6	1.5	0.730
Install sill plates	1.8	1.9	0.708
Frame walkouts	2.2	2.4	0.467
Cut floor joists	2	2	0.931
Sort pre-cut trusses	2.1	2.2	0.595
Install floor joists	2.6	2.4	0.439
Sheet floor w/ 3/4" OSB	2.9	2.9	0.862
Snap lines on floor	1.5	1.6	0.740
Install beams by hand	3.4	3.1	0.301
Install beams with crane	1.5	1.5	0.954
Sort wall material	2.4	2.3	0.558
Lay out plates	1.7	1.7	0.946
Set up cut station	1.6	1.3	0.312
Create a cut list	1.1	1.1	0.853
Cut material	2.3	2.3	0.894
Square wall	1.9	1.7	0.326
Sheet wall on ground	2.5	2.2	0.218
Sheet wall upright	3	2.5	0.076
Stand walls	3.4	3	0.210
Sort trusses	2.8	2.7	0.818
Sheet gable ends	2.5	1.8	0.016*
Rack trusses	2	2.1	0.818
Cut tails	2.2	1.9	0.396
Install roof anchors	1.8	1.4	0.094
Boom trusses	2.1	1.9	0.480
Install truss clips	1.7	1.6	0.638
Brace off trusses	2.1	2	0.541
Sheet first row on roof	2.7	2.6	0.915
Finish sheeting roof	2.7	2.6	0.668
Install fascia rafters	2	2.1	0.776
Roll out / tool set up	1.7	1.5	0.582
Build and install stairs	2.4	2.4	0.937
Set pre-built stairs	2.8	2.7	0.798
Build and install partitions	2.4	2.1	0.220
Build basement floors	1.5	1.8	0.461
Build exterior decks	2	1.8	0.752
Nail connections	1.8	1.8	0.731
Cut roof vents	1.4	1.5	0.807
Clean up scrap material	2.5	2	0.193
Roll up / put tools away	1.6	1.7	0.746

* Significant $p < 0.05$

Table 74 Comparing Mean Task Strain Responses Based on W.C. Insurance

Workers' Compensation Insurance			MANOVA
Carpentry Task	**Not Covered**	**Covered**	**P-Value**
Break materials	2.2	1.7	0.074
Sort materials	2.9	2.3	0.015*
Measure layout	1.7	1.3	0.078
Plate beams by hand	3.1	2.8	0.322
Plate beams with crane	1.5	1.5	0.986
Install sill plates	2.1	21.6	0.021*
Frame walkouts	2.5	2.2	0.314
Cut floor joists	2.1	1.9	0.389
Sort pre-cut trusses	2.3	2.1	0.482
Install floor joists	2.6	2.3	0.336
Sheet floor w/ 3/4" OSB	2.8	2.9	0.714
Snap lines on floor	1.7	1.5	0.322
Install beams by hand	3.2	3.2	0.977
Install beams with crane	1.6	1.4	0.363
Sort wall material	2.2	2.4	0.329
Lay out plates	1.8	1.6	0.402
Set up cut station	1.3	1.4	0.721
Create a cut list	1.1	1.1	0.995
Cut material	2.5	2.1	0.139
Square wall	1.8	1.7	0.527
Sheet wall on ground	2.3	2.2	0.685
Sheet wall upright	2.4	2.7	0.325
Stand walls	3.2	3.1	0.747
Sort trusses	2.7	2.7	0.790
Sheet gable ends	2.2	1.8	0.181
Rack trusses	2	2.1	0.837
Cut tails	2.1	1.9	0.433
Install roof anchors	1.3	1.6	0.111
Boom trusses	2	1.9	0.571
Install truss clips	1.7	1.5	0.484
Brace off trusses	2	1.9	0.593
Sheet first row on roof	2.9	2.5	0.126
Finish sheeting roof	2.7	2.5	0.367
Install fascia rafters	1.8	2.3	0.142
Roll out / tool set up	1.6	1.5	0.745
Build and install stairs	2.3	2.3	0.984
Set pre-built stairs	2.9	2.6	0.474
Build and install partitions	2.2	2.2	0.960
Build basement floors	1.6	1.7	0.674
Build exterior decks	1.8	1.9	0.845
Nail connections	1.8	1.8	0.992
Cut roof vents	1.5	1.4	0.632
Clean up scrap material	2.1	2.2	0.689
Roll up / put tools away	1.6	1.6	0.820

* Significant $p < 0.05$

Table 75 Logistic Regression Model - Lifetime Work Related LBP
Task Variables as Predictors of LBP to .10

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
PLATEBH	0.487	0.258	0.917	0.026
FRMWALK	0.265	0.097	0.730	0.010
INSTWBC	0.230	0.078	0.676	0.008
CUTMAT	2.619	0.935	7.332	0.067
SQUAREWL	2.545	1.020	6.353	0.045
SORTTRUS	4.358	1.217	15.605	0.024
BRACETR	2.839	1.071	7.522	0.036
SETSTAIR	9.213	2.534	33.497	0.001
PARTITIO	0.361	0.124	1.049	0.061
WOODFL	2.746	1.335	5.644	0.006
CLEANSCR	0.084	0.018	0.385	0.001

No significant interactions

Table 76 Logistic Regression Model - Lifetime Work Related LBP
Personal Variables as Predictors of LBP to .10

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
HRSWK	0.897	0.819	0.983	0.019
BOSSCR	2.328	1.093	4.958	0.029
TMPRESS	1.768	0.981	3.187	0.058
WCINS	1.430	0.996	2.053	0.052
HEIGHT	1.332	1.073	1.655	0.009
EDUCATIO	1.886	1.155	3.080	0.011
STRNSUM	1.027	1.005	1.048	0.015

No significant interactions

Table 77 Logistic Regression Model - 12 Month Period Prevalence of LBP
Task Variables as Predictors of Period LBP to .10

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
INSTFLRJ	2.394	1.366	4.195	0.002
CLEANSCR	0.485	0.262	0.899	0.022
ROLLUP	2.000	0.987	4.054	0.054

No significant interactions

Table 78 Logistic Regression Model - 12 Month Period Prevalence of LBP
Personal Variables as Predictors of Period LBP to .10

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
EXHAUST	1.702	0.973	2.976	0.062
TMPRESS	1.914	1.023	3.579	0.042
HEIGHT	5.815	2.008	16.842	0.001

No significant interactions

Table 79 Logistic Regression Model - Point Prevalence of Work Related LBP Task Variables as Predictors of Recent LBP to .10

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
BUILDSTR	2.515	1.408	4.491	0.002

Table 80 Logistic Regression Model - Point Prevalence of Work Related LBP Personal Variables as Predictors of Recent LBP to .10

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
HRSWK	0.879	0.770	1.004	0.057
COWKCR	0.144	0.030	0.687	0.015
WKAWAY	2.348	1.047	5.266	0.038
RISKID	48.609	0.937	>999.999	0.054
SELFEMP	148.328	1.529	>999.999	0.032
SMOKED	3.209	0.849	12.123	0.086
QUET	0.013	<0.001	0.465	0.017
STRNSUM	1.041	1.005	1.077	0.024

No significant interactions

Table 81 Logistic Regression Model - Lifetime Work Related LBP
Task Variables as Predictors of LBP to .10

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
PLATEBH	0.520	0.308	0.881	0.015*
FRMWALK	0.294	0.112	0.771	0.013*
INSTWBC	0.346	0.118	1.013	0.053
CUTMAT	1.363	0.572	3.243	0.485
SQUAREWL	2.171	0.901	5.233	0.084
SORTTRUS	4.448	1.408	14.057	0.011*
BRACETR	2.337	0.905	6.031	0.079
SETSTAIR	4.853	1.806	13.040	0.002*
PARTITIO	0.512	0.194	1.352	0.177
WOODFL	2.212	1.180	4.145	0.013*
CLEANSCR	0.120	0.031	0.467	0.002*

Adjusted for level of physical and mental exhaustion,
health status, level of coworker caring, and job satisfaction.
* Significant $p < 0.05$

Table 82 Logistic Regression Model - 12 Month Period Prevalence of LBP
Task Variables as Predictors of Period LBP to .10

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
INSTFLRJ	2.553	1.446	4.509	0.001*
CLEANSCR	0.477	0.245	0.932	0.03*
ROLLUP	1.509	0.728	3.130	0.269

Adjusted for level of physical and mental exhaustion,
health status, level of coworker caring, and job satisfaction.
* Significant $p < 0.05$

Table 83 Logistic Regression Model - Point Prevalence of Work Related LBP
Task Variables as Predictors of Recent LBP to .10

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
BUILDSTR	2.515	1.408	4.491	0.002*

Adjusted for level of physical and mental exhaustion,
health status, level of coworker caring, and job satisfaction.
* Significant $p < 0.05$

Table 84 Integrated Model for Lifetime LBP
Task Variables and Personal Risk Factors

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
HRSWK	0.245	0.035	1.742	0.160
BOSSCR	3.937	1.091	14.209	0.036*
TMPRESS	1.053	0.447	2.479	0.906
WCINS	3.513	0.661	18.678	0.140
HEIGHT	1.124	0.188	6.705	0.898
EDUCATIO	1.412	0.76	2.623	0.275
STRNSUM	3.833	0.259	56.742	0.329
PLATEBH	0.339	0.147	0.779	0.010*
FRMWALK	0.341	0.099	1.179	0.089
INSTWBC	0.287	0.074	1.105	0.070
CUTMAT	1.732	0.547	5.485	0.350
SQUAREWL	2.185	0.729	6.55	0.163
SORTTRUS	11.454	1.777	73.825	0.010*
BRACETR	4.698	1.134	19.463	0.033*
SETSTAIR	4.522	1.246	16.413	0.022*
PARTITIO	0.366	0.114	1.176	0.091
WOODFL	2.891	1.132	7.381	0.026*
CLEANSCR	0.037	0.003	0.412	0.007*

Not adjusted for level of physical and mental exhaustion,
health status, level of coworker caring, and job satisfaction.
* Significant $p < 0.05$

Table 85 Integrated Model for Lifetime LBP - Adjusted
Task Variables and Personal Risk Factors

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
HRSWK	0.186	0.016	2.198	0.182
BOSSCR	17.295	1.851	161.606	0.012*
TMPRESS	0.743	0.268	2.06	0.568
WCINS	17.605	1.116	277.79	0.042*
HEIGHT	0.912	0.096	8.694	0.936
EDUCATIO	1.277	0.599	2.722	0.527
STRNSUM	12.8	0.426	384.766	0.142
PLATEBH	0.268	0.094	0.769	0.014*
FRMWALK	0.199	0.034	1.183	0.076
INSTWBC	0.173	0.033	0.914	0.039*
CUTMAT	4.094	0.826	20.301	0.084
SQUAREWL	2.344	0.652	8.421	0.192
SORTTRUS	38.507	2.526	586.929	0.009*
BRACETR	7.617	1.211	47.913	0.030*
SETSTAIR	4.672	0.933	23.392	0.060
PARTITIO	0.347	0.093	1.294	0.1151
WOODFL	4.036	1.132	14.384	0.031*
CLEANSCR	0.004	<0.001	0.227	0.008*

Adjusted for level of physical and mental exhaustion,
health status, level of coworker caring, and job satisfaction.
* Significant $p < 0.05$

Table 86 Integrated Model for 12-Month Period Prevalence of LBP
Task Variables and Personal Risk Factors Combined

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
EXCESSEX	1.247	0.691	2.249	0.464
TMPRESS	1.805	0.998	3.265	0.051
HEIGHT	4.142	1.411	12.157	0.010*
INSTFLRJ	2.17	1.207	3.902	0.010*
CLEANSCR	0.558	0.285	1.091	0.088
ROLLUP	1.496	0.718	3.117	0.283

Not adjusted for level of physical and mental exhaustion,
health status, level of coworker caring, and job satisfaction.
* Significant $p < 0.05$

Table 87 Integrated Model for 12-Month Period Prevalence of LBP - Adjusted
Task Variables and Personal Risk Factors Combined

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
EXCESSEX	1.394	0.693	2.806	0.352
TMPRESS	2.341	1.149	4.768	0.019*
HEIGHT	4.576	1.424	14.701	0.011*
INSTFLRJ	2.379	1.285	4.402	0.006*
CLEANSCR	0.623	0.304	1.277	0.196
ROLLUP	1.176	0.518	2.667	0.698

Adjusted for level of physical and mental exhaustion,
health status, level of coworker caring, and job satisfaction.
* Significant $p < 0.05$

Table 88 Integrated Model for Point Prevalence LBP
Task Variables and Personal Risk Factors

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
AGE	1.345	0.731	2.476	0.340
HRSWK	0.378	0.059	2.442	0.307
COWKCR	0.294	0.09	0.961	0.042*
WKAWAY	1.652	0.833	3.276	0.151
RISKID	6.275	0.404	97.386	0.189
SELFEMP	67.574	1.804	>999.999	0.023*
SMOKED	2.343	0.766	7.162	0.135
QUET	0.229	0.066	0.795	0.020*
STRNSUM	1.509	0.203	11.229	0.688
BUILDSTR	1.797	0.629	5.131	0.274

Not adjusted for level of physical and mental exhaustion, health status, and job satisfaction.
* Significant $p < 0.05$

Table 89 Integrated Model for Point Prevalence LBP - Adjusted
Task Variables and Personal Risk Factors

Variables	OR Estimate	95%CL-L	95% CL-U	P-Values
AGE	1.654	0.738	3.708	0.222
HRSWK	0.443	0.041	4.771	0.502
COWKCR	0.426	0.108	1.684	0.224
WKAWAY	1.646	0.716	3.781	0.241
RISKID	17.023	0.494	586.335	0.117
SELFEMP	277.233	2.439	>999.999	0.020*
SMOKED	2.531	0.683	9.384	0.165
QUET	0.141	0.029	0.682	0.015*
STRNSUM	0.798	0.075	8.443	0.852
BUILDSTR	2.299	0.65	8.125	0.196

Adjusted for level of physical and mental exhaustion, health status, and job satisfaction.

Table 90 Risk Factor Comparisons for LBP <.05

Lifetime LBP	OR	P-Value	12 Month Period LBP	OR	P-Value	Point Prevalence LBP	OR	P-Value
BOSSCR	17.300	0.012	TMPRESS	2.300	0.019	SELFEMP	277.000	0.020
WCINS	17.600	0.042	HEIGHT	4.600	0.011	QUET	0.100	0.015
PLATEBH	0.300	0.014	INSTFLRJ	2.400	0.006			
INSTWBC	0.173	0.039						
SORTTRUS	38.500	0.009						
BRACETR	7.600	0.031						
WOODFL	4.000	0.031						
CLEANSCR	0.004	0.008						

Adjusted for level of physical and mental exhaustion, health status, and job satisfaction.

Table 91 Correlation of Recent LBP to Personal and Workplace Factors

Personal or Workplace Variables	Correlation Coefficient	P-Values
Yrs in construction	0.182	0.086
Yrs in framing	0.195	0.065
Hrs worked per week	-0.086	0.416
Hrs of safety training	0.055	0.606
Trainer	0.126	0.262
Back strain in carpentry	0.336	0.001*
Job satisfaction	-0.214	0.041*
Coworkers caring	-0.287	0.006*
Boss caring	-0.138	0.190
Mentally exhausted	0.215	0.040*
Physically exhausted	0.232	0.027*
Boring work	0.089	0.399
Time pressure	0.154	0.144
Side jobs	0.227	0.031*
W.C. insurance	0.009	0.936
Risk and hazard id train	0.073	0.499
LBP prevention	0.065	0.543
Job-task related LBP	0.118	0.266
Temperature exposures	0.043	0.685
Noise exposures	0.145	0.172
Self employed	0.189	0.073
Employee status	-0.040	0.705
Age	0.090	0.401
Marital status	0.022	0.833
Height	0.031	0.770
Weight	-0.046	0.667
Quetlet	0.091	0.395
Education level	0.140	0.197
Income level	0.005	0.963
Smoking status	0.143	0.188
Alcohol consumption	-0.052	0.637
Exercise activity	0.022	0.843
Health problems	0.327	0.002*
Health status	-0.150	0.154
LB problem in carpentry	0.348	0.001*

* Significant < 0.05

Table 92 Correlation of 12-Month Period LBP to Personal and Workplace Factors

Personal or Workplace Variables	Correlation Coefficient	P-Values
Yrs in construction	0.100	0.349
Yrs in framing	0.089	0.402
Hrs worked per week	-0.125	0.239
Hrs of safety training	0.222	0.036*
Trainer	0.006	0.960
Back strain in carpentry	0.386	<.001*
Job satisfaction	-0.120	0.256
Coworkers caring	-0.053	0.615
Boss caring	0.010	0.924
Mentally exhausted	0.109	0.300
Physically exhausted	0.212	0.042*
Boring work	0.253	0.015*
Time pressure	0.258	0.013*
Side jobs	0.146	0.165
W.C. insurance	0.068	0.523
Risk and hazard id train	0.056	0.604
LBP prevention	-0.120	0.260
Job-task related LBP	0.225	0.031*
Temperature exposures	-0.134	0.204
Noise exposures	0.206	0.051
Self employed	0.210	0.044*
Employee status	-0.063	0.553
Age	0.024	0.821
Marital status	-0.031	0.769
Height	0.170	0.105
Weight	0.136	0.198
Quetlet	0.042	0.691
Education level	0.104	0.336
Income level	-0.124	0.251
Smoking status	0.031	0.776
Alcohol consumption	-0.098	0.367
Exercise activity	0.036	0.736
Health problems	0.138	0.203
Health status	-0.192	0.065
LB problem in carpentry	0.608	<.001*

* Significant $p < 0.05$

Table 93 Correlation of Lifetime LPB to Personal and Workplace factors

Personal or Workplace Variables	Correlation Coefficient	P-Values
Yrs in construction	0.134	0.207
Yrs in framing	0.141	0.184
Hrs worked per week	-0.077	0.470
Hrs of safety Training	0.079	0.459
Trainer	0.160	0.154
Back strain in carpentry	0.376	<.001*
Job satisfaction	-0.019	0.859
Coworkers caring	-0.005	0.964
Boss caring	0.023	0.828
Mentally exhausted	0.096	0.362
Excessively exhausted	0.199	0.057
Boring work	0.204	0.051
Time pressure	0.196	0.061
Side jobs	0.197	0.060
W.C. insurance	0.074	0.484
Risk and hazard id train	0.070	0.512
LBP prevention	-0.133	0.212
Job-task related LBP	0.231	0.027*
Temperature exposures	0.114	0.278
Noise exposures	0.309	0.003*
Self employed	0.080	0.447
Employee status	-0.044	0.682
Age	0.064	0.545
Marital status	0.054	0.609
Height	0.231	0.026*
Weight	0.147	0.165
Education level	0.152	0.157
Income level	0.049	0.652
Smoking status	0.121	0.265
Alcohol consumption	0.037	0.737
Exercise activity	-0.033	0.758
Health problems	0.142	0.190
Health status	-0.136	0.192
LB problem in carpentry	0.194	0.067

* Significant < 0.05

Table 94 Correlation of Mean Strain Scores to Recent LBP

Major Carpentry Task	Correlation Coefficient	P-Value
Break Materials	0.048	0.649
Sort Floor Materials	0.214	0.040*
Measure Layout	0.222	0.034*
Plate Beams Place by Hand	0.131	0.214
Plate Beams Place by Crane	0.161	0.125
Install Sill Plates	0.208	0.046*
Frame Walkouts	0.200	0.056
Cut Floor Joists	0.197	0.061
Sort Precut Floor Trusses	0.257	0.014*
Install Floor Joists	0.195	0.066
Sheet Floor	0.147	0.161
Snap Lines	0.264	0.011*
Install Beams by Hand	0.200	0.057
Install Beams Using Crane	0.249	0.017*
Sort Wall Material	0.134	0.205
Layout Plates	0.208	0.049*
Setup Cut Station	0.167	0.114
Create Cut List	0.249	0.017*
Cut Material	0.158	0.135
Square Wall	0.193	0.066
Sheet Exterior Wall Down	0.211	0.045*
Sheet Exterior Wall Upright	0.202	0.054
Stand Walls	0.136	0.200
Sort Trusses	0.222	0.034*
Sheet Gables	0.158	0.134
Rack Trusses	0.126	0.236
Cut Tails	0.172	0.103
Install Roof Anchor	0.066	0.533
Boom Trusses	0.190	0.070
Install Truss Clips	0.224	0.032*
Brace Trusses	0.158	0.133
Sheet First Row	0.146	0.165
Finish Sheeting	0.202	0.054
Install Fascia	0.154	0.147
Roll Out Tools - Set Up	0.263	0.012*
Build and Install Stairs	0.309	0.003*
Set Pre-built Stairs	0.200	0.056
Build and Install Partitions	0.139	0.187
Build Basement Floor	0.195	0.066
Build Exterior Deck	0.161	0.132
Nail Metal Connectors	0.209	0.046*
Cut Roof Vents	0.230	0.027*
Cleanup Scrap Material	0.178	0.090
Rollup - Tool Cleanup	0.204	0.052

* Significant $p < 0.05$

Table 95 Correlation of Mean Strain Scores to 12-Month Period LBP

Carpentry Task	Correlation Coefficient	P-Value
Break materials	0.102	0.333
Sort floor materials	0.303	0.003*
Measure layout	0.198	0.057
Plate beams place by hand	0.144	0.172
Plate beams place by crane	0.106	0.312
Install sill plates	0.223	0.032*
Frame walkouts	0.143	0.170
Cut floor joists	0.152	0.147
Sort precut floor trusses	0.272	0.008*
Install floor joists	0.360	<.001*
Sheet floor	0.356	<.001*
Snap lines	0.254	0.014*
Install beams by hand	0.192	0.066
Install beams using crane	0.172	0.102
Sort wall material	0.244	0.019*
Lay out plates	0.217	0.039*
Set up cut station	0.187	0.074
Create cut list	0.141	0.179
Cut material	0.302	0.003*
Square wall	0.207	0.048*
Sheet exterior wall down	0.262	0.012*
Sheet exterior wall upright	0.196	0.061
Stand walls	0.095	0.367
Sort trusses	0.167	0.112
Sheet gable ends	0.129	0.220
Rack trusses	0.148	0.163
Cut tails	0.122	0.247
Install roof anchors	0.186	0.075
Boom trusses	0.081	0.439
Install truss clips	0.286	0.005*
Brace trusses	0.271	0.009*
Sheet first row on roof	0.230	0.026*
Finish sheeting roof	0.290	0.005*
Install fascia rafters	0.193	0.067
Roll out / tool set up	0.201	0.055
Build and install stairs	0.223	0.032*
Set pre-built stairs	0.200	0.055
Build and install partitions	0.060	0.565
Build basement floor	0.290	0.005*
Build exterior deck	0.119	0.264
Nail metal connections	0.167	0.109
Cut roof vents	0.212	0.041*
Clean up scrap material	0.037	0.723
Roll up / put tools away	0.257	0.013*

* Significant $p < 0.05$

Table 96 Correlation of Mean Strain Scores to Lifetime LBP

Carpentry Task	Correlation Coefficient	P-Value
Break materials	0.167	0.110
Sort floor materials	0.219	0.035*
Measure layout	0.227	0.028*
Plate beams place by hand	0.077	0.464
Plate beams place by crane	0.106	0.312
Install sill plates	0.223	0.032*
Frame walkouts	0.143	0.170
Cut floor joists	0.152	0.147
Sort precut floor trusses	0.279	0.007*
Install floor joists	0.327	0.002*
Sheet floor	0.300	0.003*
Snap lines	0.259	0.012*
Install beams by hand	0.239	0.022*
Install beams using crane	0.066	0.530
Sort wall material	0.290	0.005*
Lay out plates	0.088	0.407
Set up cut station	0.085	0.421
Create cut list	0.157	0.136
Cut material	0.295	0.004*
Square wall	0.219	0.036*
Sheet exterior wall down	0.138	0.189
Sheet exterior wall upright	0.134	0.201
Stand walls	0.288	0.005*
Sort trusses	0.333	0.001*
Sheet gable ends	0.141	0.181
Rack trusses	0.243	0.020*
Cut tails	0.153	0.145
Install roof anchors	0.101	0.335
Boom trusses	0.002	0.985
Install truss clips	0.105	0.315
Brace trusses	0.242	0.020*
Sheet first row on roof	0.291	0.005*
Finish sheeting roof	0.258	0.012*
Install fascia rafters	0.199	0.059
Roll out / tool set up	0.024	0.821
Build and install stairs	0.150	0.152
Set pre-built stairs	0.327	0.001*
Build and install partitions	0.083	0.426
Build basement floor	0.297	0.004*
Build exterior deck	0.189	0.075
Nail metal connections	0.024	0.818
Cut roof vents	0.188	0.071
Clean up scrap material	0.031	0.768
Roll up / put tools away	0.099	0.347

* Significant $p < 0.05$

Table 97 Correlation of Overall Risk Perception to Personal and Workplace Factor

Personal or Workplace Variables	Correlation Coefficient	P-Values
Yrs in construction	0.020	0.852
Yrs in framing	0.002	0.987
Hrs worked per week	0.022	0.835
Hrs of safety training	-0.155	0.145
Trainer	-0.044	0.697
Back strain in carpentry	0.497	< 0.001*
Job satisfaction	-0.017	0.869
Coworkers caring	-0.178	0.094
Boss caring	-0.068	0.521
Mentally exhausted	0.226	0.031*
Physically exhausted	0.295	0.005
Boring work	-0.011	0.916
Time pressure	0.350	0.001*
Side jobs	0.205	0.051
W.C. insurance	0.143	0.180
Risk and hazard id train	-0.132	0.220
LBP prevention	-0.159	0.139
Job-task related LBP	0.194	0.067
Temperature exposures	0.015	0.892
Noise exposures	0.055	0.611
Self employed	-0.034	0.753
Employee status	0.129	0.230
Age	-0.015	0.886
Marital status	0.026	0.808
Height	0.016	0.881
Weight	0.076	0.485
Quetlet	0.077	0.471
Education level	0.175	0.106
Income level	-0.08	0.466
Smoking status	0.004	0.971
Alcohol consumption	0.219	0.044*
Exercise activity	0.132	0.224
Health problems	0.113	0.304
Health status	-0.056	0.598
LB problem in carpentry	0.126	0.232

* Significant < 0.05

Table 98 Correlation of Mean Strain Scores to Overall Risk Perception

Carpentry Task	Correlation Coefficient	P-Value
Break materials	0.311	0.003*
Sort floor materials	0.590	< 0.001*
Measure layout	0.450	< 0.001*
Plate beams place by hand	0.457	< 0.001*
Plate beams place by crane	0.339	0.001*
Install sill plates	0.375	< 0.001*
Frame walkouts	0.487	< 0.001*
Cut floor joists	0.397	< 0.001*
Sort precut floor trusses	0.420	< 0.001*
Install floor joists	0.549	< 0.001*
Sheet floor	0.531	< 0.001*
Snap lines	0.358	< 0.001*
Install beams by hand	0.540	< 0.001*
Install beams using crane	0.401	< 0.001*
Sort wall material	0.504	< 0.001*
Lay out plates	0.524	< 0.001*
Set up cut station	0.367	< 0.001*
Create cut list	0.322	0.002*
Cut material	0.484	< 0.001*
Square wall	0.497	< 0.001*
Sheet exterior wall down	0.514	< 0.001*
Sheet exterior wall upright	0.383	< 0.001*
Stand walls	0.410	< 0.001*
Sort trusses	0.568	< 0.001*
Sheet gable ends	0.397	< 0.001*
Rack trusses	0.465	< 0.001*
Cut tails	0.540	< 0.001*
Install roof anchors	0.297	0.004*
Boom trusses	0.328	0.002*
Install truss clips	0.402	< 0.001*
Brace trusses	0.502	< 0.001*
Sheet first row on roof	0.563	< 0.001*
Finish sheeting roof	0.572	< 0.001*
Install fascia rafters	0.430	< 0.001*
Roll out / tool set up	0.351	0.001*
Build and install stairs	0.557	< 0.001*
Set pre-built stairs	0.510	< 0.001*
Build and install partitions	0.408	< 0.001*
Build basement floor	0.508	< 0.001*
Build exterior deck	0.528	< 0.001*
Nail metal connections	0.455	< 0.001*
Cut roof vents	0.518	< 0.001*
Clean up scrap material	0.448	< 0.001*
Roll up / put tools away	0.400	< 0.001*

* Significant < 0.05

APPENDIX A

Low Back Strain Survey

Residential Carpentry
Physical Strain Survey
2001

Colorado State University
College of Veterinary Medicine and Biomedical Sciences
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The tabulated results of this study will be used for scientific investigation only. Your privacy is assured. The tabulated results will be shared with the National Institute for Occupational Safety and Health help develop recommendations for improving safety in the workplace.

Instructions:

This survey is designed to investigate common causes of low back pain in residential carpenters. It has two sections. Please answer all questions to the best of your ability. Please do not leave blank places in the survey. Your employer will not see your answers. Your answers are CONFIDENTIAL. If you have questions please feel free to contact Drs. Robin Herron and Dave Gilkey at the Department of Environmental Health at Colorado State University at 970-491-3695.

Thank you for completing this survey, your participation is greatly appreciated. As a result of your help, we are learning more about the strain related to your work and potential causes of low back pain in framing. Please return the completed survey to the person administering the survey.

Section I Work Related Tasks, Activities, and Experience.

Please evaluate the following job-tasks as to the amount of strain that you feel in your low back required to perform the task. This is your personal opinion, there are no wrong answers. Select or write in the appropriate answer. Please answer the remaining questions dealing with your work and personal life.

0 = Not Performed	1 = No Strain	2 = Low Strain	3 = Moderate Strain	4 = High Strain	5 = Very High Strain

	Floor framing tasks:
0 1 2 3 4 5	1. Break the materials package and begin building.
0 1 2 3 4 5	2. Sort floor material by type and length, and stack in separate piles.
0 1 2 3 4 5	3. Measure correct layout for the floor plan and snap the lines on the foundation walls.
0 1 2 3 4 5	4. Plate any beams that are in the floor plan and place them in the proper place by hand.
0 1 2 3 4 5	5. Plate any beams that are in the floor plan and place them in the proper place using a crane.
0 1 2 3 4 5	6. Install sill plates: Measure the green plate, cut it to the correct length, measure and drill holes for the foundation bolts, place sill sealer on the foundation walls, and bolt down the green plate.
0 1 2 3 4 5	7. Framing walkouts.
0 1 2 3 4 5	8. Cut the floor joists correct length.
0 1 2 3 4 5	9. Sort precut floor trusses.
0 1 2 3 4 5	10. Install the floor joists to the correct length.
0 1 2 3 4 5	11. Sheet the floor with ¾" OSB by gluing the joist and then nailing the OSB down with 8d ring shank nails.
0 1 2 3 4 5	12. Snap lines on the floor for wall placement.

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0 1 2 3 4 5 13. Install wood beams or micro-lamination beams by hand.

0 1 2 3 4 5 14. Install wood beams or micro-lamination beams using a crane.

Wall framing tasks:

0 1 2 3 4 5 15. Sort the wall material by type and length and stack in orderly piles.

0 1 2 3 4 5 16. Layout plates.

0 1 2 3 4 5 17. Set up a cut station.

0 1 2 3 4 5 18. Create a cut list for the walls.

0 1 2 3 4 5 19. Cut the material to proper length and nail the walls together at floor level.

0 1 2 3 4 5 20. Square wall at floor level.

0 1 2 3 4 5 21. Sheet the exterior walls with proper sheeting material at floor level Lying down. (thermoply or ½" OSB, fiber board, etc.)

0 1 2 3 4 5 22. Sheet the exterior walls with proper sheeting material in an upright position. (thermoply or ½" OSB, fiber board, etc.)

0 1 2 3 4 5 23. Stand walls and nail them in place, and brace them off.

Roof framing tasks and Installing trusses and rafters:

0 1 2 3 4 5 24. Sort the trusses in order of placement.

0 1 2 3 4 5 25. Sheet any gable ends.

0 1 2 3 4 5 26. Rack the trusses.

0 1 2 3 4 5 27. Cut tails.

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0 1 2 3 4 5 28. Install the roof anchor on the truss.

0 1 2 3 4 5 29. Have a crane boom the trusses in place and / or nail them off as you go.

0 1 2 3 4 5 30. Nail off and install truss clips.

0 1 2 3 4 5 31. Brace trusses off with 2 x 4s or 1 x 4s on the truss chords.

Install sheeting:

0 1 2 3 4 5 32. Sheet the first row while standing inside the trusses if possible. (Sheeting is usually ½" OSB, fiber board, etc.)

0 1 2 3 4 5 33. Finish sheeting roof.

0 1 2 3 4 5 34. Install fascia rafters / barge sub-fascia.

Other framing tasks:

0 1 2 3 4 5 35. Roll out – tool set up.

0 1 2 3 4 5 36. Build and install stairs and landings.

0 1 2 3 4 5 37. Set pre-built stairs and landings.

0 1 2 3 4 5 38. Build and install partitions, half walls, or floating walls.

0 1 2 3 4 5 39. Build wood floor basements.

0 1 2 3 4 5 40. Build exterior decks.

0 1 2 3 4 5 41. Nail / connections / metal hangers.

0 1 2 3 4 5 42. Cut roof vents when appropriate.

0 1 2 3 4 5 43. Clean up scrap material.

0 1 2 3 4 5 44. Rolling up – tool clean up and put away.

Please answer the following questions by choosing the best answer or writing in the correct answer.

45. How many years have you been working in residential construction?
____________.

46. How many years have you been working in residential framing carpentry?
____________.

47. On the average how many hours per week do you work in framing carpentry?
____________.

48. How many hours of health and safety training have you had this past year? (write in)
____________.

49. Who provided your safety training? (Mark all appropriate answers.)
   1. General contractor
   2. Forman
   3. Safety consultant
   4. OSHA representative
   5. HBA (Home Builders Association)representative
   6. Other ___________

50. How much risk do you feel is present in residential carpentry / framing work?
   0 No risk
   1 Slight risk
   2 Moderate risk
   3 High risk
   4 Severe risk

51. How much back strain do you feel there is in framing carpentry?
   0 No Strain
   1 Low Strain
   2 Moderate Strain
   3 High Strain
   4 Very High Strain

52. Are you satisfied with your job as a framing carpenter?
   0 Not at all
   1 Very little
   2 Some satisfaction
   3 Mostly satisfied
   4 Very satisfied

53. Do you believe that your co-workers care about your safety and wellbeing?
 0 Not at all
 1 Very little
 2 Some caring
 3 Mostly they care
 4 Very concerned

54. Do you believe that your boss cares about your safety and wellbeing?
 0 Not at all
 1 Very little
 2 Some caring
 3 Mostly cares
 4 Very concerned

55. Is your work mentally exhausting?
 0 Never
 1 Sometimes
 2 Frequently
 3 Almost always
 4 Always

56. Are you excessively exhausted after a day's work?
 0 Never
 1 Sometimes
 2 Frequently
 3 Almost always
 4 Always

57. Is your work monotonous or boring?
 0 Not at all
 1 Very little
 2 Sometimes
 3 Mostly all of the time
 4 All the time

58. Do you work under time pressure?
 0 Not at all
 1 Very little time pressure
 2 Some time pressure
 3 Time pressure most of the time
 4 Time pressure all of the time

59. How many hours per month do you perform carpentry work on the side (Away from your day job)?
 0 None at all
 1 Less than 8 hours per month
 2 Between 9 and 16 hours per month.
 3 Between 17 and 20 hours per month.
 4 More than 21 hours per month.

60. Are you covered by workers' compensation insurance?
  0 Not at all.
  1 Yes, through the main General contractor.
  2 Yes, through the sub-contractor.
  3 Yes, through the company I work for.
  4 Yes, I purchase it myself as a self-employed person.

61. Did your safety training include risk and hazard identification?
  Yes or No

62. Did your safety training include low back injury prevention?
  Yes or No

63. Do you feel that certain job-tasks are associated with risk of low back injury?
  Yes or No

64. Are you exposed to very cold or hot temperatures during your work?
  Yes or No

65. Are you exposed to very loud noise in the course of your work?
  Yes or No

66. Are you a self-employed subcontractor?
  Yes or No

67. Are you an employee of the framing company?
  Yes or No

Section II Personal and Lifestyle Factors

The following questions will help in describing personal and lifestyle factors about carpenters. Please complete each question by selecting or writing in the appropriate answer.

68. What was your age at your last birthday?
  #____________.

69. What is your gender?
  0 Male 0 Female

70. What is your marital status?
  0 Married 0 Not married

71. How tall are you? (Without shoes)
  # Feet: _______ and Inches:______

72. How much do you weigh?
  #____________.

73. What is the highest-grade level that you completed in school?

1 8th grade or less	4 Trade / technical school
2 Some high school	5 Some college
3 High school graduate	6 College degree

74. Which range best describes your yearly personal income level?
- 0 $ 10,000 or less
- 1 $ 10,001 to $20,000
- 2 $ 20,001 to $35,000
- 3 $ 35,001 to $50,000
- 4 more than $50,000

75. What is your ethnic group / race?
1. African American
2. Hispanic American
3. Non Hispanic White / Caucasian American
4. Asian or Pacific Islander
5. Other______________________________

76. What is your primary language?
1. English
2. Spanish
3. Asian dialect
4. Other ________________________

77. What is your tobacco smoking status?
1. Never smoked
2. Former smoker
3. Current smoker

78. How much alcohol do you consume in the average week?
- 0 None
- 1 1 – 2 drinks or beers per week.
- 2 3 – 5 drinks or beers per week.
- 3 6 – 10 drinks or beers per week.
- 4 More than 10 drinks or beers per week.

79. How much do you exercise away from work?
- 0 No exercise away from work.
- 1 Light exercise away from work (At least 10 minutes 2 times per week).
- 2 Moderate exercise away from work (30 – 60 minutes 2-3 times per week)
- 3 Heavy exercise away from work (Greater than 60 minutes 3 times per week).
- 4 Very heavy exercise (Greater than 60 minutes 5-7 times per week).

80. Which serious health problems do you have?
    0 No serious health problem
    1. Heart disease
    2. Respiratory disease
    3. Diabetes
    4. Arthritis
    5. Depression
    6. Other (please describe)________________________________

81. How would you rate your overall health?
    0 Poor
    1 Fair
    2 Good
    3 Very Good
    4 Excellent

82. Have you ever had a low back injury / problem in your lifetime that caused you to alter some aspect of your normal living or to seek treatment?
    Yes or No

83. Was your low back injury / problem from a single incident or cumulative from activity?
    0 None
    1 Single incident of injury.
    2 From repeated activity.

84. How many days in the past year have you suffered low back pain that caused you to alter some aspect of your normal living or seek care?
    0 None
    1 1 - 5
    2 6 - 10
    3 11 - 14
    4 15 - 20
    5 Over 20 days

85. Do you live with continuous low back pain?
    Yes or No

86. Have you ever lost time from work or sought treatment due to a work-related low back injury?
    Yes or No

87. Have you had an episode of low back pain in the last year that caused you to alter some aspect of your normal living or seek treatment?
    Yes or No

88. Have you had an episode of low back pain in the past 2 weeks that caused you to alter some aspect of your normal living or seek treatment?
    Yes or No

89. Is your low back pain mostly work related?
   0 Neither - don't have pain.
   1 No
   2 Yes

90. When seeking care for your back injury / problem did you seek treatment with any of the following health professionals? (Mark all that are appropriate)
   0 No pain
   1 No professional care sought – self treatment only
   2 Chiropractor
   3 Medical Doctor
   4 Physical Therapist
   5 Other: ______________________________

91. How much do you believe that back injuries are a problem for carpenters / framers?
   0 No problem
   1 Slight problem
   2 Moderate problem
   3 Severe problem

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APPENDIX B

NIOSH Video Taping Protocols

Tray 5–H. Protocol for Videotaping Jobs for Risk Factors

The following is a guide to preparing a videotape and related task information for facilitating job analyses and assessments of risk factors for work-related musculoskeletal disorders.

Materials needed:

Video camera and blank tapes
Spare batteries (at least 2) and battery charger
Clipboard, pens, paper, blank checklists
Stopwatch, strain gauge (optional) for weighing objects

Videotaping Procedures:

1. To verify the accuracy of the video camera to record in real time, videotape a worker or job with a stopwatch running in the field of view for at least 1 min. The play-back of the tape should correspond to the lapsed time on the stopwatch.
2. Announce the name of the job on the voice channel of the video camera before the taping of any job. Restrict running time comments to the facts. Make no editorial comments.
3. Tape each job long enough to observe all aspects of the task. Tape 5 to 10 min for all jobs, including at least 10 complete cycles. Fewer cycles may be needed if all aspects of the job are recorded at least 3 to 4 times.
4. Hold the camera still, using a tripod if available. Don't walk unless absolutely necessary.
5. Begin taping each task with a whole-body shot of the worker. Include the seat/chair and the surface the worker is standing on. Hold this for 2 to 3 cycles, then zoom in on the hands/arms or other body parts which may be under stress due to the job task.
6. It is best to tape several workers to determine if workers of varying body size adopt different postures or are affected in other ways. If possible, try to tape the best and worst case situations in terms of worker "fit" to the job.

   The following suspected upper body problems suggest focusing on the parts indicated:

   — wrist problems/complaints . . . . hands/wrists/forearms
   — elbow problems/complaints . . . . arms/elbows
   — shoulder problems/complaints . . . . . arms/shoulders

   For back and lower limb problems, the focus would be on movements of the trunk of the body and leg, knee, and foot areas under stress due to task loads or other requirements.
7. Video from whatever angles are needed to capture the body part(s) under stress.
8. Briefly tape the jobs performed before and after the one under actual study to see how the targeted job fits into the total department process.
9. For each taped task, obtain the following information to the maximum extent possible:

   — if the task is continuous or sporadic
   — if the worker performs the work for the entire shift, or if there is rotation with other workers
   — measures of work surface heights and chair heights and whether adjustable
   — weight, size and shape of handles and textures for tools in use; indications of vibration in power tool usage
   — use of handwear
   — weight of objects lifted, pushed, pulled, or carried
   — nature of environment in which work is performed–(too cold or too hot?)