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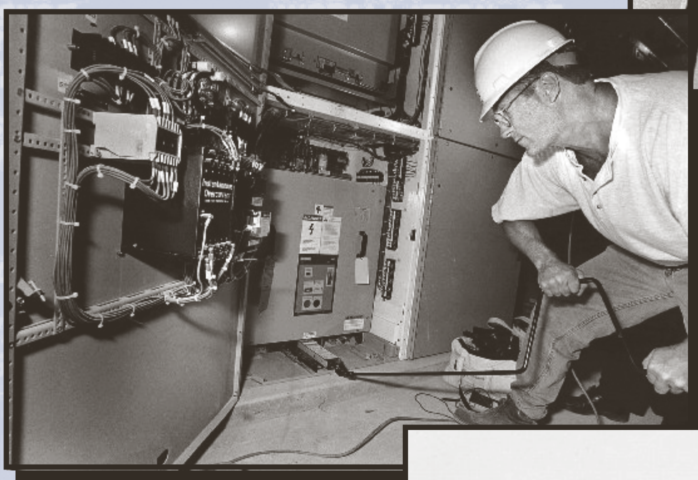
PROCEEDINGS OF A MEETING TO EXPLORE THE USE OF ERGONOMICS INTERVENTIONS FOR THE MECHANICAL AND ELECTRICAL TRADES



FEBRUARY 25-26, 2002

UA LOCAL 393
PIPE TRADES
TRAINING CENTER
SAN JOSE, CALIFORNIA

DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL AND PREVENTION
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

NIOSH

PROCEEDINGS OF A MEETING TO EXPLORE THE USE OF ERGONOMICS INTERVENTIONS FOR THE MECHANICAL AND ELECTRICAL TRADES

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Pipe Trades Training Center, San Jose, California

February 25–26, 2002

DEPARTMENT OF HEALTH AND HUMAN SERVICES (DHHS)
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health (NIOSH)

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FOREWORD

Work-related musculoskeletal disorders (WMSDs) are a major cause of injury and illness in the construction industry. In the year 2000, according to the Bureau of Labor Statistics, WMSDs accounted for 28% of the injuries and illnesses resulting in days away from work for construction workers. Disabling WMSDs deprive workers of their livelihood and self-esteem and can turn the most common daily activity into a difficult and frustrating task. These WMSDs also place significant burdens on construction firms, especially smaller contractors, in the form of lost productivity and increased workers' compensation expenses.

The construction industry presents unique obstacles for contractors and workers interested in preventing WMSDs. These obstacles include a reliance on physical strength, traditional work methods, multiple employer work sites, and the continually changing work environment. Fortunately, mounting evidence suggests that many of the above risk factors contributing to the occurrence of WMSDs in the construction industry can be decreased and, in some cases, eliminated.

Despite an increasing interest in construction ergonomics, few studies report the results of ergonomic interventions intended for the mechanical and electrical trades. This document helps to fill that gap in knowledge. The document relates the practical experience and knowledge that a group of construction contractors and trades-people developed during their efforts to control workers' exposures to WMSD risk factors. The document describes specific tasks and the varying job conditions that increase a worker's risk of developing a WMSD and recommends preventive measures for contractors and trades-people.

The National Institute for Occupational Safety and Health (NIOSH), as the national agency responsible for occupational safety and health research, is committed to reducing the toll of WMSDs work-related musculoskeletal disorders on American workers. We look forward to continuing work with our public- and private-sector partners who have similar interests in protecting American construction workers.

John Howard, M.D.
Director, National Institute for
Occupational Safety and Health
Centers for Disease Control and Prevention

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MEETING SUMMARY

In February 2002, 60 researchers, contractors, and trades people representing the piping (or plumbing), heating and air-conditioning, and electrical sectors of the U.S. construction industry attended a meeting titled, Exploring Ergonomics Interventions in the Mechanical and Electrical Construction Trades in San Jose, California. The 2-day meeting was organized by researchers at the National Institute for Occupational Safety and Health (NIOSH). The meeting attendees consisted of 39 industry trades people and 21 researchers from academia and government. The affiliations of the 39 industry attendees are shown in Table Summary 1.

Table Summary 1. Affiliation of industry attendees

Stakeholder	Union	Contractor	Joint[1]
Electrical	3	7	1
Pipe	5	6	1
Sheet metal	2	6	1
Other[2]	1	4	2

[1] Joint Labor-Management organization.
[2] Construction industry representative not exclusively involved in mechanical or electrical specialties.

The format of the meeting included presentations describing work-related musculoskeletal disorder (WMSD) risk factors and injury or illness data for the mechanical and electrical trades, as well as trade-specific breakout sessions. Edited transcripts of the presentations with questions and answers are included in the proceedings as documentation of the meeting. The content, however, might not reflect current NIOSH policy or endorsement. This summary focuses on the activities and results of the three breakout sessions.

Breakout Sessions

Breakout sessions were organized for each of the three construction trades and specialties invited to the meeting (electrical, pipe, and sheet metal). Industry representatives were assigned to the session of their respective trade or specialty. Other stakeholders were assigned to a session according to their knowledge or interest in a trade.

Participants were asked to answer the following questions related to job tasks (Table Summary 2), previously identified as presenting a high risk of developing WMSDs [Everett 1997].

- What are the potential hazards associated with each task?
- Do varying job conditions/context increase or decrease the potential hazard?
- What ergonomic interventions are available and utilized? Has the intervention been shown to be effective?
- What tasks lack an ergonomic intervention to eliminate or reduce exposure to WMSD risk factors?

Table Summary 2. Job tasks discussed in breakout sessions

Job Tasks	Electrical	Pipe	Sheet Metal
Drill holes and shoot fasteners [1]	X	X	X
Place and install mechanical and electrical systems [1]	X	X	X
Lift and carry materials and equipment [1]	X	X	X
Cut, bend, align, and position conduit	X		
Pull electrical conductors (cable or wire)	X		
Welding		X [2]	X
Cut and trim sheet metal duct joints			X

[1] Similar tasks with different titles were combined.
[2] Discussed in the pipe trades session as joining pipe, but discussion not completed

Results

Time constraints prevented participants in each breakout session from thoroughly answering all questions related to the tasks they discussed. There were also differences regarding the amount of time a trade/specialty spent on a specific question. The results described below apply to similar job tasks conducted by all three trades, although tasks unique to each trade were also discussed.

Drill Holes and Shoot Fasteners

Rotary hammer-drills are used to drill mounting holes for fasteners into concrete or metal (e.g., ceilings, walls, and metal beams) for mechanical or electrical system hangers and equipment. Fasteners are shot directly into concrete or metal using a powder-actuated tool (PAT).

- *Risk factors* for WMSDs identified for the task are task frequency (e.g., number of fasteners specified), physical exertion, repeated and sustained non-neutral postures, tool reaction forces (e.g., vibration, torque, and impact), and contact stress.

- *Body regions* identified to be at risk of developing WMSDs are the neck and back, shoulders, upper extremities, and knees.

- *Variable conditions* that can modify the actual hazard are the work location (e.g., ceiling, floor); substrate; tool type, age, and maintenance; characteristics of the job (e.g., number of holes, etc.); and site management (e.g., planning and communication).

- *Engineering interventions* in use include ergonomically improved tools (e.g., strip trigger, balanced, low vibration, and clutch driven), extension pole for PATs, and mechanical lifts for overhead work. One available upstream design improvement identified was embedded concrete inserts to eliminate the need for drilling holes or shooting fasteners.

- *Additional interventions* discussed include improved tool design and the development of an adjustable stand to hold and advance a rotary drill during overhead drilling.

Place and Install Mechanical and Electrical Systems

Commercial and industrial mechanical and electrical systems are supported by hangers, tracks, or trays attached to ceilings or walls. Powered screw guns and manual tools are used to assemble hanging systems and tighten the fasteners that secure the mechanical and electrical system components. System components must be lifted, positioned, and held in place when they are attached to the hangers, tracks, or trays. Workers sometimes need to manually position and hold components they are securing.

- *Risk factors* identified for the task are task repetition, repeated and sustained non-neutral body postures, tool reaction forces, physical exertion, and contact stress.

- *Body regions* at risk of developing WMSDs include the neck and back, shoulders, upper extremities, and knees.

- *Variable conditions* that could modify the actual hazard are the work location (e.g., ceiling, floor), standing on ladders, dimension and weight of components, job characteristics (e.g., number of hangers), and available work space.

- *Engineering interventions* in use include ergonomically improved tools (e.g., strip trigger, balanced, low vibration, and clutch driven), slip-on fasteners for threaded rod, drill bit extender, mechanical lifts for workers and material, fixtures for placing system components, and lighter system components.

- *Additional interventions* discussed include design of fixtures and attachments that can safely be used on person-lifts to hold and position system components.

Lift and Carry Materials and Equipment

Building materials and equipment used to assemble mechanical and electrical systems must be unloaded, stored until needed, and transported to the location where they will be used. Material handling (e.g., lift, carry, hold, push, and pull) can be done manually or by powered and non-powered equipment.

- *Risk factors* identified for manual material handling (MMH) include repeated handling, sustained and non-neutral postures (e.g., bend and twist), physical exertion, and contact stress.

- *Body regions* at risk of developing WMSDs include the back, shoulders, and upper extremities.

- *Variable conditions* that can modify the actual hazard include location and means of storing equipment (e.g., ground vs. racks), availability and condition of mechanical lift devices, condition of floors, walkways, and ground surfaces, hand-to-object coupling, and work on multiple floors or levels.

- *Engineering interventions* include material handling equipment (e.g., pallet jack, forklift, dolly, etc.), push/pull rolling stock (e.g., pipe rack), manual handling devices (e.g., double hook, shoulder pad, sling, suction or magnetic handles), roller conveyors, rolling scaffold with hoist, and appropriate wheels (e.g., large diameter, hard material, bearings).

- *Additional interventions* discussed include color coding materials by weight and redesigned packaging (e.g., reduce weight and size, embedded handles).

Non-engineering interventions that were endorsed in all breakout sessions include worker training, job planning and organization, communication among contractors and trades, tool and equipment maintenance programs, and good housekeeping practices.

Job tasks unique to each trade were also discussed in the breakout sessions. Examples of trade-specific tasks include hand-bending conduit or pulling electrical conductors (electricians), trimming sheet metal (sheet metal workers), and joining pipe (plumbers and pipefitters). These tasks involve materials and/or tools unique to a specific trade. Engineering interventions that participants recommended to address associated risk factors include tools and equipment to reduce biomechanical stressors. Non-engineering interventions are similar to those previously described.

Discussion

Participants agreed that the mechanical and electrical trades are at risk for developing WMSDs and identified interventions currently available to attenuate certain recognized risk factors. Site management and work organization were considered critical to reducing many problems, as well as in facilitating the implementation of interventions. Early contractor involvement in a project (e.g., design-build contractors) could influence design decisions that, in turn, could reduce worker exposures to WMSD risk factors. Factors that influenced use of commercially available interventions include the start-up costs, effects on productivity, and craft traditions. Although there was a consensus regarding the need to evaluate the effectiveness of new interventions, many participants said they would use them after less rigorous personal or anecdotal verification.

Conclusion

The discussions and recommendations that occurred during the course of the breakout sessions and the plenary sessions suggested the following conclusions:

- Workers employed in the electrical, pipe, and sheet metal trades are exposed to risk factors for WMSDs.
- WMSD risk factor conditions common to the three trades include MMH, work location (e.g., ceiling, floor), and the continuously changing building site.
- WMSD risk factor conditions unique to the three trades include the type of materials, tools, and equipment used.
- Ergonomic principles have informed the design and performance of commercial hand tools, but additional tool design is needed to reduce exposures to biomechanical stressors.
- Ergonomic interest in increasing worker productivity has resulted in greater use of powered equipment to transport materials and to lift and position workers and materials above floor level.

Interventions are not currently available for all high-risk jobs, and research should be directed to address this gap.

ABBREVIATIONS

AGC	Associated General Contractors
BLS	Bureau of Labor Statistics
CalOSHA	California Occupational Safety and Health Administration
CPWR	Center for the Protection of Workers' Rights
CSAO	Construction Safety Association of Ontario
CTS	carpal tunnel syndrome
DAW	day(s) away from work
^{o}C	degree(s) Celsius
^{o}F	degree(s) Fahrenheit
DOL	Department of Labor
eLCOSH	Electronic Library of Construction Occupational Safety and Health
EMG	Electromyogram
5 Ss	Sort, Set in order, Shine, Standardize, Sustain (Japanese methodology for a productive work environment)
FTW	full-time worker(s)
GC	general contractor(s)
GPS	global positioning system
HEPA	high-efficiency particulate air
HVAC	heating, ventilation, and air-conditioning
IBEW	International Brotherhood of Electrical Workers
IR	incidence rate
LTI	lost-time injury(ies)
MCA	Mechanical Contractors Association
MDAW	median days away from work
MMH	manual material handling
MSD	musculoskeletal disorder(s)
NAICS	North American Industrial Classification System
NASA	National Aeronautics and Space Administration
NECA	National Electrical Contractors Association
n.e.c.	not elsewhere classified
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PAT	powder-actuated tool
PI	Prevention Index
PPE	Personal protective equipment
PVC	polyvinylchloride
SHARP	Safety and Health Assessment and Research for Prevention
SIC	Standard Industrial Classification
SMACNA	Sheet Metal and Air-Conditioning Contractors National Association
SMAP	Sheet Metal, Mechanical, Air-Conditioning and Plumbing Program
SMOHIT	Sheet Metal Occupational Health Institute Trust

SMWIA	Sheet Metal Workers' International Association
SOC	Standard Occupational Classification
SOII	Survey of Occupational Injuries and Illnesses
WC	Workers' Compensation
WMSD(s)	Work-related musculoskeletal disorder(s)
WSIB	Workplace Safety and Insurance Board

Glossary

Musculoskeletal disorder (MSD). A condition or disorder that involves the muscles, nerves, tendons, ligaments, joints, cartilage or spinal discs. These disorders are not typically the result of a distinctive, singular event, but are more gradual in their development. Thus, MSDs, are cumulative-type injuries.

Acute injury. A singular, traumatic event resulting in a disruption of tissues, resulting in pain. [Kumar 2001].

MSD risk factors. Actions or conditions that increase the likelihood of injury to the musculoskeletal system. Risk factors have components of duration, frequency, and level of exposure. Exposure to risk factors leads to discomfort and pain, which over time can lead to more serious disorders of the musculoskeletal system.

Ergonomics. A discipline or science of fitting workplace conditions and job demands to the capabilities of the worker. Many consider ergonomics a multidisciplinary field of applied science where knowledge about human capabilities, skills, limitations, and needs is taken into account when examining the interactions among people, technology, and the work environment. [Westgaard and Winkel 1997; Cohen et al. 1997].

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DEDICATION

This document is dedicated to the memories of Ms. Robin Johnson and Mr. Lloyd Williams. Ms. Johnson and Mr. Williams were early supporters of the meeting described in this document and both have met sudden and unexpected deaths. Ms. Johnson was the Director for the CNA Insurance Company's Loss Control Casualty Services in Chicago, Illinois. As an early supporter of the meeting, Robin quickly offered her advice and services. She prepared two presentations describing CNA's workers' compensation insurance data for the mechanical and electrical trades. Mr. Lloyd Williams was the Business Manager for Local Union #393, United Association of Plumbers, Steamfitters & Refrigeration Fitters in San Jose, California. Mr. Williams was a long-time supporter of occupational safety and health and agreed without hesitation to host the meeting in Local 393's state-of-the-art Pipe Trades Training Center. In addition, Mr. Williams arranged for training center staff to assist with various aspects of the program. Both Ms. Johnson and Mr. Williams provided significant support that rendered the meeting a success. Both are dearly missed by family, friends, and colleagues.

*United Association of Journeymen and Apprentices of the Plumbing and Pipefitting Industry

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BACKGROUND

Building and construction activities in the United States have historically been organized around the work of relatively separate crafts or trades. Presently, 19% of U.S. construction workers are represented by a trade union. Union membership for electricians, plumbers and pipefitters and sheet metal workers is higher than average at 38%, 31%, and 41%, respectively [CPWR 2002]. Plumbers, and pipefitters install piping or plumbing systems; sheet metal workers (mechanical trades) install heating, ventilation, and air-conditioning (HVAC) systems. Electricians install electrical conduit and wiring, fixtures, controllers, and switches. Workers in these trades must complete a 4–5 year apprenticeship program.

Although not much data exists, work-related musculoskeletal disorders (WMSDs) are a large problem for the mechanical and electrical trades. Approximately one-third of injuries and illnesses that resulted in at least 1 day away from work (DAW) for mechanical and electrical workers, were due to WMSDs caused by job strain [plumbers/pipefitters (40%), and HVAC system mechanics and sheet metal duct installers (31%), and electricians (34.9%)]. These data are from the U.S. Bureau of Labor Statistics' (BLS) 2000 *Survey of Occupational Injuries and Illnesses (SOII)* [BLS 2002a]. In Oregon, more than 50% of the workers' compensation (WC) claims for the mechanical and electrical trades in 2000 were for WMSDs caused by job strain (i.e., bodily reaction, overexertion, or repetitive motion) [OR DBCS 2002]. Rosecrance recently reported high prevalence rates (8.2%) for carpal tunnel syndrome (CTS) among apprentices working in the pipe, electrical, and sheet metal trades [2002a].

All Construction Work–Related Musculoskeletal Disorders (WMSDs)

WMSDs are injuries or illnesses of the muscles, tendons, joints, and nerves that are caused or aggravated by work. Some examples of WMSDs are: inflamed tendons or joints, elbow muscle and tissue inflammation (tennis or golfer's elbow), herniated disc, rotator cuff syndrome, carpal tunnel syndrome (CTS), and back or neck strain. Workers with jobs that include some combination of physical force, repetitive motion, awkward or static body postures, contact stress, vibration, or extreme temperatures are at increased risk of developing WMSD [Bernard et al. 1997; NRC 2001]. These problems can occur suddenly (an acute injury), or over some period of time (a chronic illness). Personal factors that can increase the risk of developing a WMSD musculoskeletal disorder include diabetes, obesity, and poor physical condition.

The actual number of WMSDs that occur each year is unknown. However, the BLS conducts an annual survey that indirectly estimates the occurrence of WMSDs. In addition to BLS reports, other sources of information concerning WMSDs include WC reports, clinical and epidemiologic studies, and worker symptom surveys.

U.S. Bureau of Labor Statistics (BLS)

The BLS SOII estimates the occurrence of work-related injuries and illnesses in the United States, using data from employers' records. Injury and illness cases are described by the following Code Titles: Nature of Injury or Illness, Part of Body Affected, Source of Injury or Illness, and Event or Exposure [BLS 2001].

The SOII does not have a specific classification for WMSDs, but the information about these cases can be derived from the survey by using two or more code titles. The BLS combines the Nature of Injury or Illness and the Event or Exposure code titles to represent WMSD cases. According to the BLS [2002b], musculoskeletal disorders (MSDs):

> ...include cases where the nature of injury is: sprains, strains, tears; back pain, hurt back; soreness, pain, hurt, except back; carpal tunnel syndrome; hernia; or musculoskeletal system and connective tissue diseases and disorders; and when the event or exposure leading to the injury or illness is: bodily reaction/bending, climbing, crawling, reaching, twisting; overexertion; or repetition. Cases of Raynaud's phenomenon, tarsal tunnel syndrome, and herniated spinal discs are not included. Although these cases may be considered WMSDs, the survey classifies these cases in categories that also include non-WMSD cases.

Incidence rates for construction workers' back and upper- and lower-extremities WMSDs exceed the national all-industries average [National Institute for Occupational Safety and Health (NIOSH) 1997]. Construction workers' rates of injuries and illnesses due to bodily reaction and overexertion consistently exceeded those in all private industries during the years 1994 to 2000 (Table 1). Within the construction industry, the Special Trades Contractors [Standard Industrial Classification (SIC 17)], which is the largest sector in the industry, usually reports higher rates of overexertion and repetitive motion injuries than does General Building Contractors (SIC 15) or Heavy Construction Contractors (SIC 16) [Occupational Safety and Health Administration (OSHA) 2003]. Repetitive motion injury cases among construction workers have historically been low, as seen by comparing Tables 2 and 3 [BLS 2002c]. One recent article report found that few apprentices seek medical attention for hand symptoms characteristic of CTS, suggesting that under-reporting of CTS is common in the construction industry [Rosecrance et al. 2002a]. Unfortunately, injuries and illnesses due to bodily reaction (e.g., bending, climbing, crawling, reaching, twisting) are not counted separately in the BLS annual profile summary tables of nonfatal injuries and illnesses involving DAW by selected worker and case characteristics and industry.

Table 1. Private industry and construction injury and illness rates[1] due to bodily reaction, overexertion, and repetitive motion

	Bodily Reaction		Overexertion		Repetitive Motion	
Year	All Industries	All Construction	All Industries	All Construction	All Industries	All Construction
2000	20.5	39.6	49.5	70.6	7.4	4.6
1999	21.1	37.6	50.8	68.7	8.1	6.0
1998	21.9	37.0	53.8	66.3	7.4	4.6
1997	22.9	38.8	58.8	85.2	8.7	5.4
1996	23.4	38.6	62.7	85.7	8.8	5.9
1995	26.1	45.5	68.7	94.2	10.1	7.8
1994	29.7	52.8	76.0	110.9	11.5	7.3

Source: BLS 2002c
[1]Rates per 10,000 workers for injuries and illnesses resulting in one or more DAW

Table 2. Construction industry injury and illness rates[1] due to overexertion

Year	General Building Contractors (SIC 15)	Heavy Construction Contractors (SIC 16)	Special Trades Contractors (SIC 17)
2000	57.2	59.0	74.4
1999	58.5	54.6	75.6
1998	67.3	62.5	66.9
1997	77.5	70.2	91.6
1996	72.6	61.9	96.4
1995	86.8	81.7	100.2
1994	95.3	84.8	123.6

Source: BLS 2002c
[1]Rates per 10,000 workers for injuries and illnesses resulting in one or more DAW

Table 3. Construction industry injury and illness rates[1] due to repetitive motion

Year	General Building Contractors (SIC 15)	Heavy Construction Contractors (SIC 16)	Special Trades Contractors (SIC 17)
2000	4.6	2.7	5.0
1999	4.8	3.0	7.1
1998	5.7	2.4	4.8
1997	3.9	5.0	6.0
1996	5.6	4.0	6.5
1995	8.0	7.1	8.0
1994	8.8	4.9	7.4

Source: BLS 2002c
[1]Rates per 10,000 workers for injuries and illnesses resulting in one or more DAW

In the United States, total recordable work-related injuries and illnesses declined during the past 10 years. Construction injuries and illnesses also declined during this period, although much of the decline has been for less serious cases not resulting in lost work time [Webster 1999]. The reduction has not been steady, and between 1996 and 2000, all specialty groups experienced a rate increase in work-related injuries and illnesses at some time (Table 4).

Table 4. Special trades contractors (SIC 17) injuries and illnesses rates[1] due to overexertion

Year	Plumbing & HVAC	Painting, etc.	Electrical	Masonry, Stone, etc.	Carpentry & Floor	Roofing, Siding, etc.	Concrete Work	Water Well Drilling
2000	76.3	64.5	71.1	102.2	64.4	78.7	77.6	166.1
1999	85.0	34.9	56.4	93.6	93.5	105.8	72.0	85.9
1998	68.9	61.8	50.4	96.4	74.9	89.3	79.2	145.3
1997	103.1	53.3	63.6	116.2	99.9	121.8	77.1	108.4
1996	90.4	103.2	83.0	137.3	96.1	127.0	90.3	164.4

Source: BLS 2002c
[1]Rates per 10,000 workers for injuries and illnesses resulting in one or more DAW

The declining injury and illness rates in the construction industry have occurred simultaneously with the increasing average number of DAW for lost-time cases (Table 5).

Workers' Compensation (WC)

Workers' compensation data provides more detailed information than is available in the BLS statistics. However, care must be taken when using or comparing WC data collected from different states because programs differ significantly. For example, the period that workers must be out of work before their cases will be counted as a lost-time injury or illness ranges from three to seven days, depending on the state [AFL–CIO 2001]. The lack of standard case definitions from multiple states presents problems for interpretations of state-generated data and comparisons of state-specific data [NRC 1987].

In the state of Washington, for instance, a worker must be out of work for four or more consecutive days before the case is classified as a lost-time injury or illness for WC purposes [Center for the Protection of Workers' Rights (CPWR) 2002]. However, the BLS SOII estimates are based on one or more DAW due to all injuries and illnesses. In 1998, Washington's State Fund WC program reported 16% more lost-time construction injuries and illness than were reported by the BLS SOII for that state, despite Washington's more restrictive lost-time case definition and the exclusion of cases involving workers employed by self-insured contractors [CPWR 2002]. An analysis by Silverstein et al. [1998; 2000] of Washington State's WC claims for the years 1990–1998 found that four construction sectors—wood frame building construction; roofing; wallboard installation; and building construction, not otherwise classified—were among the top 10 industries with the highest Prevention Index (PI) scores for neck, back, and upper extremity WMSDs. The PI utilizes both the total number and the rate of injuries/illnesses in an industry to prioritize intervention activities among all industries.

Table 5. Average number of DAW [1] for private and construction industry injuries and illnesses

Year	All Private Industry	General Building (SIC 15)	Heavy Construction (SIC 16)	Special Trades (SIC 17)
2001	5	8	8	8
2000	6	8	10	8
1999	6	6	9	7
1998	5	7	9	7
1997	5	8	7	8
1996	5	7	9	7

Source: BLS 2002c
[1]Average number of DAW for all injuries and illnesses resulting in at least one DAW

In Washington, nearly all of the construction industry sectors, (shown in Table 6), ranked among the top 25 industries in need of intervention to prevent neck, back, or upper extremity WMSDs.

Research Studies

Several types of studies—including epidemiological studies and laboratory studies, and ergonomic job assessments—have been used to identify jobs that pose an increased risk of developing WMSDs. Epidemiological studies have been used to look for association between risk factors and health outcomes and may compare the injury and illness experience of one group against the experience of another. Laboratory studies have been used to measure the strain on individuals while they are exposed to physical stressors designed to mimic stressors found in industry, such as lifting heavy objects. Ergonomic job assessments are conducted at a job site and have been used to identify and measure recognized WMSD risk factors.

Epidemiological studies report a positive association between construction work in general, and the development of musculoskeletal problems [Damlund et al. 1986; Hildebrandt 1995; Ueno et al. 1999; Welch et al. 1995; Palmer et al. 2001]. Other epidemiological studies have reported increased WMSDs among workers in specific construction occupations, such as concrete reinforcement [Riihimaki et al. 1989], bricklaying [Heuer et al. 1996], carpentry [Luoma et al. 1998], carpet and floor laying [Thun et al. 1987; Kivimaki et al. 1994], and painting [Stenlund et al. 2002].

Table 6. Washington State construction industry sectors ranking in top 25 industries needing interventions to reduce upper extremity WMSDs (1990–1998)

SIC	Industry Description	Neck	Back	Upper Extremity
152	General building contractors—residential buildings	X	X	X
154	General building contractors—non-residential buildings	X	X	X
162	Heavy construction, except highway and street construction	X	X	
171	Plumbing, heating and air conditioning	X	X	X
172	Painting and paper hanging	X		
174	Masonry, stoneware, tile setting and plastering	X	X	X
175	Carpentry and floor work	X	X	X
176	Roofing, siding, and sheet metal work	X	X	X
177	Concrete work	X	X	X
179	Miscellaneous special trades contractors	X	X	X

Source: Silverstein et al., 1998; 2000

Worker Symptom Surveys

Surveys have been administered to construction workers in the United States and elsewhere to estimate the prevalence of WMSDs in the industry. (In this context, prevalence refers to the percentage of workers reporting a WMSD during a 12-month period given the number of workers at risk in the industry.) Cook et al. [1996] found that 70% of active construction workers, representing 13 trades, had reported "job-related ache, pain, discomfort, etc." during the previous year, and 32% of these workers had reported "visiting a physician" for the symptoms. In the same survey, more than 40% of workers also reported symptoms occurring during the previous year for the neck (42%), shoulders (42%), wrist/hands (43%), and knees (46%). Surveys administered to estimate the prevalence of WMSDs have been shown to be reliable and can be used to estimate the occurrence of WMSDs among construction workers [Baron et al, 1996; Booth-Jones et al. 1998; Rosecrance et al. 2002b].

Mechanical and Electrical Trades and WMSDs

Bureau of Labor Statistics Injury and Illness Statistics

In 2000, construction workers' median number of DAW for a lost-time injury or illness ranged from 8 days (SIC 15 and SIC 17) to 10 days (SIC 16), compared to the 6-day median DAW (MDAW) for all private industry workers [BLS 2002a]. Tables 7–10 show that WMSDs often result in a much larger MDAW. In 2000, BLS estimated that the injuries and illnesses incurred by 38.2% of electricians (Table 7), 40% of plumbers and pipefitters (Table 8), 36.9% of HVAC system mechanics (Table 9), and 36.9% of sheet metal duct installers (Table 10) were, as a result of events or exposures associated with WMSDs. For all private industry in 2000, WMSDs were 34.7% of all DAW injuries and illnesses, and the MDAW was seven days [BLS 2002c].

Table 7. Electricians (SOC[1] 575)—WMSDs in 2000 number and MDAW[3] by event/exposure

Code	Event/Exposure	Cases[2]	MDAW[3]
061	Rubbed, abraded, or jarred by vehicle or mobile equipment vibration	92	3
20	Bodily reaction and exertion, unspecified	93	70
211	Bending, climbing, crawling, reaching, twisting	741	13
220	Overexertion, unspecified	355	42
221	Overexertion in lifting	885	5
222	Overexertion in pulling or pushing objects	981	20
223	Overexertion in holding, carrying, turning, or wielding objects	649	40
229	Overexertion, not elsewhere classified	179	20
230	Repetitive motion, unspecified	122	22
	Total	**4,098**	

Source: BLS 2002a

[1] The Standard Occupational Classification system is "used by all Federal statistical agencies to classify workers into occupational categories for the purpose of collecting, calculating, or disseminating data" [BLS 2003]

[2] Journey-status electricians (SOC 575) in 2000 incurred an estimated 11,740 injuries and illnesses. However, only 10,706 injuries and illness were reported for electricians that identified an event or exposure associated with an incident [BLS 2002a]

[3] Median DAW

Table 8. Plumbers, pipefitters, and steamfitters (SOC[1] 585)—WMSDs in 2000 (number and MDAW[3] by nature of injury and event/exposure)

Code	Event/Exposure	Cases[2]	MDAW[3]
211	Bending, climbing, crawling, reaching, twisting	603	5
220	Overexertion, unspecified	260	3
221	Overexertion in lifting	1,860	10
222	Overexertion in pulling or pushing objects	396	12
223	Overexertion in holding, carrying, turning, or wielding objects	357	16
229	Overexertion, not elsewhere classified	172	34
232	Repetitive use of tools	103	30
	Total	**3,751**	

Source: BLS 2002a

[1] The Standard Occupational Classification system is "used by all Federal statistical agencies to classify workers into occupational categories for the purpose of collecting, calculating, or disseminating data" [BLS 2003]

[2] Journey-status plumbers, pipefitters, and steamfitters (SOC 585) incurred an estimated 9,379 DAW injuries or illnesses in 2000. However, only 8,693 injuries and illness were reported for plumbers, pipefitters, and steamfitters that identified an event or exposure associated with an incident [BLS 2002a]

[3] Median DAW

Table 9. Heating, air-conditioning, and refrigeration mechanics (SOC[1] 534) — WMSDs in 2000 (number and MDAW[3] by nature of injury and event/exposure)

Code	Event/Exposure	Cases[2]	MDAW[3]
211	Bending, climbing, crawling, reaching, twisting	557	9
220	Overexertion, unspecified	227	1
221	Overexertion in lifting	589	9
222	Overexertion in pulling or pushing objects	149	10
223	Overexertion in holding, carrying, turning, or wielding objects	407	5
	Total	**1,928**	

Source: BLS 2002a

[1] The Standard Occupational Classification system is "used by all Federal statistical agencies to classify workers into occupational categories for the purpose of collecting, calculating, or disseminating data" [BLS 2003]

[2] Journey-status heating, air-conditioning, and refrigeration (HVAC) mechanics (SOC 534) incurred an estimated 5,973 DAW injuries and illnesses in 2000. However, only 5,375 injuries and illness were reported for heating, air-conditioning, and refrigeration (HVAC)mechanics that identified an event or exposure associated with an incident [BLS 2002a].

[3] Median DAW

Table 10. Sheet metal duct installers (SOC[1] 596)—WMSDs in 2000 (number and MDAW[3] by nature of injury and event/exposure)

Code	Event/Exposure	Cases [2]	MDAW [3]
211	Bending, climbing, crawling, reaching, twisting	322	15
221	Overexertion in lifting	314	6
222	Overexertion in pulling or pushing objects	102	13
223	Overexertion in holding, carrying, turning, or wielding objects	160	10
	Total	**898**	

Source: BLS 2002a

[1] The Standard Occupational Classification system is "used by all Federal statistical agencies to classify workers into occupational categories for the purpose of collecting, calculating, or disseminating data" [BLS 2003]

[2] Journey-status sheet metal duct installers (SOC 596) incurred an estimated 3,248 DAW injuries or illnesses in 2000. However, only 2,434 injuries and illnesses were reported for sheet metal duct installers (SOC 596) that identified an event or exposure associated with an incident [BLS 2002a]

[3] Median DAW

Workers' Compensation and Insurance Reports

Data from both state WC systems and insurance providers can be used to document the incidence, nature, and costs of WMSDs for the mechanical and electrical trades. Earlier, an analysis of Washington State WC data was described. In 2000, Oregon's WC program reported that construction sector injuries and illnesses due to bodily reaction, overexertion, and repetitive motion accounted for compensable claims for electricians (52%), plumbers and pipefitters (57%), and duct installers and sheet metal workers (57%) (Table 11).

Private sector insurance companies that provide WC coverage to employers are another potential source of information concerning WMSDs for the mechanical and electrical trades. CNA Insurance workers' compensation data for the electrical and mechanical trades were presented at the 2-day meeting and are described in Session 1, Presentations 2 and 3.

Research Studies

Studies identifying WMSDs among construction workers in the electrical, pipe, and sheet metal trades are shown in Table 12. Rosecrance [2002a] found a high (8.2%) prevalence rate of CTS among more than 1,100 apprentices in the electrical, pipe, sheet metal, and operating engineering trades in the United States. All cases had a median nerve abnormality affecting a single nerve trunk, and hand-wrist symptoms consistent with CTS. Less than 12% of the apprentices with CTS had received medical attention for the condition. These results suggest that under-reporting of CTS is common in the construction industry.

Table 11. Number of disabling claims by occupation and accident or exposure/event Oregon, 2000

Occupation of claimant	All claims	Bodily reaction[1]	Over-exertion	Repetitive motion	WMSDs as % of all claims
Electrician	253 (100%)	63 (24.9%)	50 (19.8%)	18 (7.1%)	131 (51.8%)
Plumber, pipe fitter	169 (100%)	31 (18.3%)	51 (30.2%)	15 (8.9%)	97 (57.4%)
Metal duct installer & Sheet metal worker	75 (100%)	16 (21.3%)	23 (30.7%)	4 (5.3%)	43 (57.3%)

Source: OR DBCS 2002

[1] Bodily reaction includes "bending, climbing, crawling, reaching, and twisting" [BLS 2002b]

In 1997, CNA Insurance and the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) contracted an ergonomic consulting firm to conduct an ergonomics evaluation of shop and job site sheet metal tasks. Three sheet metal tasks in the knocking area of a fabrication shop and six tasks on construction job sites were evaluated. Among the findings reported, six tasks were assigned high injury risk scores and four were assigned moderate injury risk scores. In all six cases, the back was the body part at high risk of being injured. These ratings were attributed to workers' repeated, sustained forward and lateral bending, twisting, and forceful exertions. Table 13 summarizes the evaluation.

Table 12. Studies reporting WMSDs in the mechanical and electrical trades

Trade	Problem
Electrical	A case-control study of the relationship between occupation and upper-extremity MSDs found electricians were significantly over represented among orthopedic clinic patients [English et al. 1989].
	Electricians reported a high prevalence of symptoms—especially back and hand-wrist symptoms—which occurred more than three times during the past year, or lasted more than 1 week [Hunting et al. 1994].
Pipe	Dutch plumbers were found to have a relatively high rate of back pain [Hildebrandt 1995].
	Swedish pipefitters and welders had a high risk of knee-joint lesions [Ritz and Brunnholzl 1988].
Sheet metal	Relationships were found between work activities and MSDs in a small study of disabled sheet metal workers. Hanging duct was strongly associated with both neck and shoulder symptoms [Welch et al. 1995].
Across trades	Welding was found to possibly cause development of inflamed shoulder tendons, resulting in pain and tenderness, and restricted movement [Petersen et al. 1981].
	Shoulder muscles were heavily loaded when the arm was elevated, and strain on the supraspinatus muscle (muscle which allows shoulder movement) in overhead work was an important factor contributing to prolonged shoulder disability [Herberts et al. 1984].
	Study confirmed that subjective symptoms and physical signs related to the shoulder were more common among the welders [Torner et al. 1991].
	A field study found that workers installing ceiling fittings were at risk of developing chronic shoulder pain due to inflamed tendons of their rotator cuff [Sporrong et al. 1999].

Worker Symptom Surveys

In a survey of construction workers conducted by the University of Iowa, workers answered questions about the "ache, discomfort, and pain" they experienced for various body regions during the previous 12 months [Cook et al. 1996]. The results for respondents from the mechanical and electrical trades are shown in Table 14. Sheet metal workers reported higher than average prevalence rates for the neck, back, elbows, wrists, and hands. Plumbers and pipefitters reported more knee problems than average. (Prevalence refers to the proportion of workers reporting a WMSD during a 12-month period given the number of workers at risk in the industry.

Preventing WMSDs

WMSD risk factors can be addressed by using the occupational health and safety hierarchy of controls [NIOSH 1997]. While administrative controls and personal protective equipment have been used to reduce workers' exposures to WMSD risk factors, these strategies have serious limitations, because they do not directly address the source of the exposures. Engineering control technologies that eliminate or modify WMSD risk factors related to tools and equipment, building and construction materials, and work processes or practices have a better chance of generating lasting benefits.

Table 13. Ergonomic assessment of sheet metal work

Task	Body Part Affected	Overall Risk Rating[1]
Lifting ductwork onto lift assists or jack[2]	Back	9
Knocking fittings using tinning hammer[3]	Back	8
Knocking fittings using air hammer[3]	Back	8
Cutting ductwork using manual shears	Back	8
Assembling or connecting ductwork on the floor	Back	8
Assembling fittings on the job site	Back	7
Drilling holes for upper hanger attachment	Neck	6
Securing lower hanger attachment	Neck, back	6
Welding (lifting)	Back	6
Welding (sitting)	Back, hand/wrist, legs	5

Source: CNA 2002

[1]The likelihood of an ergonomically related injury occurring for a specific task was scored from 0 to 10 as follows: 7–10 = high injury risk and 4–6 = moderate injury risk

[2]Risk factor: physical force required to lift, push and pull ductwork

[3]Risk factor: awkward trunk posture due to the overall working height

Table 14. Mechanical and electrical trades reported job-related symptoms during past 12 months (1994–1995)[1]

Trade	Neck	Upper Back	Low Back	Shoulder	Elbows	Wrist/ Hands	Hips/ Thighs	Knees	Ankles/ Feet
Electricians (n=375)	37.3	27.1	66.8	37.2	19.8	43.7	17.2	46.0	31.6
Plumbers/pipefitters (n=667)	42.8	29.6	69.4	40.6	21.8	43.2	16.7	51.9	31.9
Sheet metal workers (n=384)	44.8	35.1	74.0	40.9	30.7	50.0	18.7	47.2	31.1
All surveyed (n=2518)	41.9	29.6	69.9	41.6	25.1	42.8	21.1	46.2	30.9

Source: Cook et al., 1996
[1]All values are the percent of workers reporting "ache, discomfort, or pain"

Eliminating and reducing WMSD risk factors in the construction industry presents obstacles not found in most industries, including the absence of permanent work-stations, lack of control over the task location, continuously changing surroundings, and congested multi-employer work sites prone to communication and coordination problems [Schneider and Susi 1994]. In spite of these drawbacks, many engineering interventions have been developed and evaluated for various trades or specialties in the construction industry. NIOSH researchers reviewed the literature for ergonomic interventions developed for construction. Evaluated interventions were identified for:

- **Equipment** [de Jong and Vink, 2002; de Jong and Vink 2000; de Looze et al. 2001; Everett 1993; Hecker et al. 2001; Holmstrom 1987; Mirka et al. 2000; Sillanpää et al.1999].

- **Tools** [Cederquist and Ortengren 1985; de Looze et al. 2001; Hecker et al. 2001; Kilbom et al. 1993; Mirka et al. 2000; Ortengren et al. 1991; Strasser et al. 1996; Village et al. 1993; Wos et al. 1992].

- **Work Practices** [Hecker et al. 2001; Imbeau et al. 1998; Li 2000; Vink et al. 1997].

Interventions that have been evaluated and are used by the electrical, pipe, or sheet metal trades are shown in Table 15. Although many more potential interventions have been proposed, most have not been subjected to any type of evaluation [Schneider 1995].

One mechanical specialty—heating and air conditioning—was found to be proactive in working on ergonomics. The Sheet Metal Occupational Health Institute Trust (SMOHIT)—a joint labor-management organization between SMACNA and the Sheet Metal Workers' International Association (SMWIA)—published Physical Stress Injuries: Reducing Injuries through Ergonomics in 1999 [SMOHIT]. This educational program was developed for apprentices and journey-status sheet metal workers. The multi-media training program includes engineering and administrative controls to reduce exposures to WMSD risk factors in fabrication shops and construction sites, including practical recommendations from contractors. Although the materials have been widely disseminated in the unionized sector of the industry, the extent to which the recommendations have been implemented by contractors and workers is not known.

Table 15. Reported WMSD risk factor interventions for the mechanical and electrical trades

Job	Intervention	Benefit	Source
Fitting drain pipes	Lifting strap	Less strain on lower extremities, neck & shoulder	Sillanpää et al. 1999
Operate powder-actuated tool (PAT) overhead	Tool support stand	Forces at thumb & elbow reduced by 800%	Wos et al. 1992
Driving screws	Cordless screw driver & screw gun	Reduced forearm rotation and force	Ortengren et al. 1991
Manual transport of materials	Wheeled transport devices	Reduced lifting & carrying	de Jong & Vink 2002
Field assembly, welding, etc.	Stands and portable benches	Reduced kneeling and trunk flexion	de Jong & Vink 2002
Floor level assembly	Wheeled floor-level assembly seat	Reduced kneeling	de Jong & Vink 2002