Musculoskeletal Disorders in Construction

Practical Solutions From the Literature

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IN BRIEF

- **This review study addresses work-related musculoskeletal injuries and disorders and practical solutions in seven construction trades/occupations (carpenters, masons, electricians, sheet metal workers, roofers, ironworkers, plumbers).**
- **By identifying risk factors for these injuries and disorders, OSH professionals can offer effective interventions to meet the challenges that contractors face in the field.**
- **The simple good practices solutions summarized can help mitigate potential ergonomic hazards and increase productivity at construction job sites.**

Construction is one of the largest industries in the U.S. and it is a vital part of the nation's economy. Construction employment is expected to grow by approximately 2 million wage-and-salary jobs between 2010 and 2020, more than double the growth rate projected for the overall U.S. economy (CPWR, 2013). The industry consistently ranks among the most hazardous occupations and it accounts for a disproportionately large percentage of all work-related injuries and illnesses.

Work-related musculoskeletal disorders (WMSDs) and injuries are among the most frequently reported causes of lost or restricted work time, accounting for 33% of all injury and illness cases (OSHA, 2015). MSDs involve the muscles, nerves, tendons, joints, cartilage and supporting structures of the upper and lower limbs, neck and lower back; they are caused, precipitated or exacerbated by sudden exertion or prolonged exposure to physical factors such as high force, repetition, awkward body posture or vibration (NIOSH, 2015).

Construction work often involves forceful exertions that are excessive or prolonged, such as heavy manual lifting or prolonged grasping; awkward body postures maintained for extended periods; pressure from hard surfaces or sharp edges on body tissues; vibration from tools and machinery; and environmental factors such as extreme temperatures and humidity. Laborers' Health & Safety Fund of North America (LHSFNA, 2006) reports that 40% of construction workers surveyed said working while hurt reduces productivity and results in disabling injuries. Sprains/strains, low back pain, and neck/shoulder and knee injuries are common MSDs in the construction industry.

Contractors and workers are searching for evidence of potential, cost-effective solutions that do not slow the job or reduce productivity (Schneider, 2012). Protecting construction workers from ergonomic hazards that contribute to WMSDs is a growing concern. In 2007, ANSI/ASSE A10.40, Reduction of Musculoskeletal Problems in Construction, was adopted; it was reaffirmed in 2013. NIOSH's National Occupational Research Agenda (NORA) began in 1996 and the Construction Agenda was established in 2008. Its Strategic Goal 7.0 is to "reduce the incidence and severity of work-related MSDs among construction workers in the U.S." (NORA, 2014).

Each construction trade utilizes different skills and completes different tasks. Some jobs/tasks require employees to work close to the ground or floor, while others require performing overhead tasks. The nature of physical work and characteristics of the specific job sites or trades can expose employees to various ergonomic risks and hazards that could result in different WMSDs and injuries. This article reviews and synthesizes the findings of

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recent literature addressing WMSDs and practical solutions in the construction industry.

A Review of the Literature

The study team used a systematic approach to search the literature and defined keywords to guide the identification of relevant studies. Keywords used in the electronic search included *musculoskeletal, injury, illness, disorder, MSDs, ergonomics, construction, trade, occupation, worker, workplace, safety* and *health.* Combinations of keywords and terms such as *practical solution, intervention* or *prevention* were also used. Studies published in English were drawn from peer-reviewed journals, conference proceedings, edited books and various web-based sources. Electronic resources searched included ABI/Inform, Academic Search, ACM Digital Library, Applied Science Full Text, Business Full Text, CINAHL, Emerald, Google Scholar, NetLibrary, ProQuest, PsycINFO, PubMed, ScienceDirect, WilsonWeb and Web of Science. During a preliminary review, duplicates and studies considered less relevant were discarded. In addition, the team reviewed MSD information from Bureau of Labor Statistics (BLS), OSHA and NIOSH.

Searches provided three main categories of WMSD risk factors faced by construction workers in general: 1) documentation of the problem; 2) research on WMSDs in construction; and 3) research and evaluation of ergonomic work practice interventions.

Construction-Related Musculoskeletal Problems

Following is a summary of MSD hazards and risks faced by workers in seven construction trades/occupations 1) carpenters; 2) cement masons and terrazzo workers; 3) electricians; 4) sheet metal workers; 5) roofers; 6) ironworkers; and 7) plumbers/pipefitters/steamfitters. These trades conduct tasks that pose well-documented risks of WMSDs and injuries.

Carpenters

Carpenters make up the largest proportion of building trades occupations. They work both indoors and outdoors, and are involved in many types of construction, from building highways and bridges to installing kitchen cabinets. Carpenters have a higher rate of injury and illness than the national average, with the most common injuries being strains/sprains due to manually lifting heavy materials (BLS, 2015a). Major occupational MSD risk factors include static and/or awkward postures for extended periods, heavy manual material handling, excessive and repetitive motions of tool usage, and extreme weather conditions (Cheung, Hight, Hurley, et al., 2009a). Within the carpenter group, drywall installers are involved in handling of heavy and bulky materials, repetitive screw-driving motions and awkward body positions (Yuan & Buchholz, 2014).

The body parts most commonly injured are the axial skeleton and shoulder, where back sprains, simultaneous sprains to the back and neck, and shoulder strains occur frequently (Lipscomb, Dement, Gaal, et al., 2000). For example, home building is physically demanding work and manual material handling may be the most difficult part of the job. The term *manual material handling* encompasses those tasks that require employees to lift, lower, push, pull, hold or carry materials. These activities can increase the risk of painful strains and sprains and more serious soft-tissue injuries (NIOSH, 2013b).

The nature of physical work and characteristics of the specific job sites or trades can expose employees to various ergonomic risks and hazards that could result in different WMSDs and injuries.

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Carpet installers are another carpenter subgroup. These workers spend much of their working time in knee-straining positions, including kneeling, knee-supporting (weight-bearing on the knees) and squatting. In addition, carpet installers use their knees as a power source for the knee-kicker to stretch and fit carpet on the floor and against walls and door thresholds. Using the knee-kicker is physically demanding and this action is repeated frequently during a typical installation (Jensen, Mikkelsen, Loft, et al., 2000; Village, Morrison & Leyland, 1993).

Cement Masons & Terrazzo Workers

Concrete and terrazzo work is fast paced and strenuous, and it often involves kneeling, bending and reaching because most finishing is done at floor or ground level. Cement masons and terrazzo workers may suffer chemical burns from uncured concrete and may experience sore knees from frequent kneeling and crouching. Work is generally performed outdoors and stops in wet weather (BLS, 2015b).

Common ergonomic-related risk factors include awkward body positions that strain the arms and back (e.g., squatting, twisting with load in one hand, bending at the waist, reaching with load in one or both hands, and working with hands and shoulders above the head) (Batson, 2012). Manually lifting heavy materials, such as manipulating concrete, mortar or terrazzo mixtures, can also cause low-back injury (Cheung, et al., 2009b).

Electricians

Electricians work both indoors and outdoors, at construction sites, and in homes, businesses and factories. An electrician's job is physical in nature, and physical job demands are affected by postures used and environmental factors. Work may be strenuous and may include bending conduit, lifting heavy objects and standing, stooping or kneeling for long periods. Workers may encounter inclement weather, cramped spaces and tasks that require standing or kneeling for long periods (BLS, 2015c).

Workers in this group report musculoskeletal symptoms of the back, neck/shoulders, hands/wrists and knees (Cheung, et al., 2009c). Working overhead or at/above shoulder level is an essential component of electrical work and it is a risk factor for shoulder injury. Additional risk factors for shoulder injuries are inadequate rest, static loads, vibration and awkward postures.

Installation and repair tasks performed around a work site can be demanding as well. Electricians often dig trenches or pull long runs of heavy gauge wire. According to OSHA (2014), these tasks may require workers to assume awkward postures since much of the work is done at ceiling height, close to the floor or in cramped service areas. Working in these postures increases the amount of force employees must exert to perform these tasks.

Sheet Metal Workers

Sheet metal workers must often stand for long periods and manually lift heavy raw materials and finished pieces. Installation work requires bending, lifting, standing, climbing or squatting, sometimes in close quarters or awkward positions. These workers install duct systems and kitchen equipment indoors, and encounter various weather conditions when installing siding, roofs and gutters outdoors (BLS, 2015f).

Common MSD symptoms among this group of workers involve the back, wrists/hands, knees and neck/shoulders (Cheung, et al., 2009d). Welch, Hunting and Kellogg (1995) state that MSD symptoms of neck, arm and hand pain are common among sheet metal workers in the shop, and that shoulder injuries are associated with work overhead (e.g., hanging ducts). Merlino, Rosecrance, Anton, et al. (2003), studied union apprentice sheet metal workers, electricians, plumbers and operating engineers in Iowa, Illinois, Oregon and Washington, and found that lower back musculoskeletal symptoms were reported most often. The number of years worked in the trade was significantly associated with knee and wrist/hand MSD symptoms and was suggestive of an association with low-back pain. The construction apprentices rated "working in the same position for long periods" as a moderate or major problem contributing to musculoskeletal symptoms (Merlino, et al., 2003).

Roofers

Roofers conduct strenuous physical, manual work that involves heavy lifting, climbing, bending and kneeling. Typically, both residential and commercial roofers work outdoors in all types of weather, particularly when making repairs. Roofers have a higher rate of injury and illness than the national average. Roofing workers risk slips or falls from scaffolds, ladders or roofs, as well as burns from hot bitumen. Roofs can become extremely hot during the summer, placing roofers at risk of heat-related illnesses (BLS, 2015e).

Musculoskeletal symptoms among roofers are strongly associated with work limitation, missed work and reduced physical functioning (Welch, et al., 2009). Common MSDs associated with roofers involve the back, shoulders, hands/fingers, knees and feet/ankles (Fredericks, Abudayyeh, Choi, et al., 2005; Welch, et al., 2009). Roof work also entails manual material handling activity at different roof inclinations. Residential roofers experience greater feet/ankle discomfort and pain with an increase in slope/pitch (Choi, 2008b).

Ironworkers

Ironworkers perform structural and reinforcing work that involves placing and installing iron or steel girders, columns and other construction materials to form buildings, bridges and other structures. They also position and secure steel bars or mesh in concrete forms to reinforce the concrete used in highways, buildings, bridges, tunnels and other structures. Ironworkers usually work outside in various weather conditions (BLS, 2015g).

Fatal falls are an ongoing concern among this worker group. In addition, workers may suffer cuts

from sharp metal edges and equipment, strain muscles and experience other injuries as a result of moving and guiding heavy structural steel. Reinforcing iron and rebar workers, sometimes called *rod busters,* set reinforcing bars (often called rebar) in concrete forms following blueprints that show the location, size and number of bars. They then fasten the bars together by tying wire around them with pliers. Ironworkers usually lift and carry heavy loads, work in severely awkward positions in confined spaces or from kneeling positions. They use heavy vibrating pneumatic tools overhead that can cause discomfort and require them to apply high force while in static positions. Common WMSDs among ironworkers involve the back, shoulders, elbows, hands/fingers and knees (Buchholz, Paquet, Wellman, et al., 2003; Choi, 2007; Forde, Punnett & Wegman, 2005).

Plumbers, Pipefitters & Steamfitters

Plumbers, pipefitters, and steamfitters work in factories, homes, businesses and other workplaces. They install, maintain and repair many types of pipe systems, and have a higher rate of injuries and illnesses than the national average (BLS, 2015g). Plumbers and fitters often must manually lift heavy materials, climb ladders and work in tight spaces.

According to Hunting, Welch, Nessel-Stephens, et al. (1999), eye injuries and falls from ladders were more common for plumbers than for carpenters, electricians and ironworkers. Research also indicates that plumbers and pipefitters have the highest percentage of musculoskeletal symptoms related to the knees (Kirkeskov & Eenberg, 1996; Merlino, et al., 2003).

Musculoskeletal Injury Prevention Strategies & Practical Solutions

The literature contains information on several practical and simple solutions to mitigate WMSDs and injuries in the select construction trades. These strategies include site-specific ergonomics programs, work process improvement, engineering controls, tool selection/use, and stretch and flex exercise programs.

Site-Specific Ergonomics Programs

Ergonomic interventions entail matching tasks, tools and the environment to workers' needs to achieve a healthy, productive workplace. Ergonomic solutions/interventions to reduce MSD risk factors range from simple tool modification to elaborate material handling (lifting) devices or automation of construction processes. Because manual lifting hazards can vary from site to site, employers should create site-specific lifting programs (Choi, 2008a). The key to an effective lifting program is setting up the site properly from the start (LHSFNA, 2006). In addition, providing mechanical material handling equipment will reduce the temptation to lift manually (Choi, Hudson, Kangas, et al., 2007).

Training is another preventive measure. Before developing an ergonomics training program, company OSH personnel should evaluate materials that will be used throughout the project. Employee training should cover ergonomic hazards associated with the material handling, use of the material handling equipment, as well as the specific types of materials to be used and the hazards associated with their use (Choi, 2008a; LHSFNA, 2006).

Construction firms and contractors can also implement a task-specific program that restricts the weight an individual can lift or carry at one time (e.g., no one lifts more than 50 lb). Factors to consider include a worker's strength, fitness and underlying medical conditions; the weight to be lifted and distance to be carried; nature of the load or the postures to be assumed or the availability of equipment to facilitate the lift (HSE, 2015).

Work Process Improvement

Changing the way work is performed may decrease labor intensity, reduce the amount of time it takes to complete a job and minimize the amount of reaching or overhead work required. For example, installing embedded concrete inserts into the ceiling forms would eliminate the need for the prolonged overhead drilling required to place all-thread rods for a ceiling system (Albers & Estill, 2007). Another example is requiring employees to use a mechanical lift or hoist to get closer to their work to eliminate raising their arms above their shoulders.

Another effective solution is to use material handling tools (e.g., mechanical, hydraulic or vacuum lifts) to replace manual material handling (Albers & Estill, 2007). Photo 1 depicts on-site modularization of residential house wall panels. In this case, wall sections for a residential house were built on the floor (instead of framing wall segments on the deck from ladders), then the sections were lifted and positioned. Taking this idea further, these segments could be manufactured in a factory, then shipped to the work site where they could then be hoisted and positioned (Photo 2).

From top: Photo 1 shows an example of on-site built modularization while Photo 2 shows workers hoisting a prefabricated module.

Engineering Controls

Engineering controls eliminate the risk factors present in specific construction tasks. To encourage these types of controls in construction, NIOSH (2011) launched its national prevention through design (PTD) initiative and issued several construction-specific PTD publications (NIOSH, 2013a). Engineering controls are usually the most effective long-term approach to reducing WMSD risk factors.

Manufacturers can also employ such controls to modify the size or design of materials. Consider the example of kerbs in the U.K. Kerbs accentuate the boundary between the carriageway and adjacent highway areas and can have an important function concerning drainage or structural support of the carriageway (Bust, Gibb & Haslam, 2005). It is a common practice to manually carry the concrete kerbs to be installed along the roadsides because it is cheaper than using equipment to move them.

Based on focus group feedback, the kerbs were redesigned by reducing their size, using a lighter concrete and adding handholds (Bust, et al., 2005). Engineering controls also include using mechanical devices to hold a heavy tool in place while it is in use as this reduces the physical burden placed on the worker (Albers & Estill, 2007).

Hand Tool Selection & Use

Ergonomically designed hand tools are another way to reduce some MSDs. One example is an auto-feed screw gun with an extension (Albers & Estill, 2007). Using this tool, a worker stands upright, keeping his/her spine and knees in a neutral position to minimize muscle strain and fatigue. Such tools may be more expensive (standard $200 to $400; stand-up handle $500 to $700), but for an industry in which back pain may lead to a lost-time incident, the investment may pay off in the long run (Albers & Estill, 2007).

For repetitive job tasks, a portable power tool (e.g., ergonomic rebar-tying machine) can be used instead of a manual hand tool (Albers & Hudock, 2007). When using a hand tool, employers should select a tool that has a power grip or add a power grip to an existing tool (Albers & Estill, 2007) to reduce stress on workers' hands and wrists. Another solution is a portable power tool with a larger trig-

Table 1

Work-Related Musculoskeletal Problems & Solutions in Construction

Trade/ occupation	Task condition	WMSD risk	Body part affected	Practical solutions
Carpenters	•Overhead work •Ground/floor-level work •Hand-intensive work •Manual material handling	•Forceful exertion •Awkward body postures •Pressure/pinch points •Hot/cold temperatures	•Back •Neck •Shoulders •Fingers/hands/wrists •Knees	•Pneumatic drywall finishing system, T-brace or panel lift •Power vacuum lifter •Ergonomic hand tools (e.g., easy-hold glove attached to the mud pan; screw gun with an extension) •Store materials off the ground between knee and chest height •Work site stretch and flex exercise
Masons	•Ground/floor-level work •Manual material handling	•Force •Awkward postures •Work in static position •Pressure/pinch points •Hot/cold temperatures	•Back (low back) •Legs/knees •Neck •Shoulders	•Split-level adjustable scaffolding •Limiting the weight of items or team lifting •Ergonomic tools (e.g., kneeling creeper) •Work site stretch and flex exercise •Lightweight concrete block •Skid plates (hose placing discs)
Electricians	•Overhead work •Ground/floor-level work •Hand-intensive work •Manual material handling	•Force (pushing/pulling wires, bending conduits) •Awkward body postures •Pressure/pinch points •Hot/cold temperatures	•Back •Neck/shoulders •Wrists/hands/wrists	•Mechanical lifting equipment or transport devices •Ergonomic hand tools (powered or ratcheting tools) •Lightweight material or team lifting •Mechanical wire puller •Work site stretching program
Sheet metal workers	•Overhead work •Ground/floor-level work •Hand-intensive work •Manual material handling	•Force •Awkward postures •Work in static position •Pressure/pinch points •Hot/cold temperatures	•Back •Wrists/hands •Knees •Neck/shoulders	•Using powered vacuum lift •Use the right size and type of snip (e.g., tapping into duct using upright snip) •Ergonomic hand tools (e.g., a bit extension shaft or an extension pole) •Work site stretch and flex exercise
Roofers	•Sloped/elevated-level work •Manual material handling	•Force •Awkward body postures •Pressure/pinch points •Hot/cold temperatures •Vibration	•Back •Neck/shoulders •Fingers/hands/wrists •Knees •Ankles/feet	•Limiting the weight of materials or team lifting •Ergonomic hand tools (e.g., reduced vibration power tools with antivibration gloves) •Work site stretch and flex exercise
Ironworkers	•Ground/floor- or elevated-level work •Hand-intensive work •Manual material handling	•Awkward body postures •Force •Work in static position •Hot/cold temperatures	•Back •Neck/shoulders •Elbows •Wrists/hands •Knees	•Power rebar tiers •Site-specific ergonomics programs •Ergonomic hand tools (e.g., rebar-tying tool) •Work site stretch and flex exercise
Plumbers, pipefitters, steamfitters	•Ground/floor-level work •Overhead work •Hand-intensive work •Manual material handling	•Force (upper extremities) •Awkward postures •Work in same (static) position •Pressure/pinch points •Hot/cold temperatures	•Back •Neck/shoulders •Elbows •Wrists/hands •Knees	•Use a bit extension shaft •Ergonomic hand tools •Work site stretch and flex exercise

ger. Activating a larger trigger requires the worker to use multiple fingers, which reduces stress on any one finger.

Changing the design of the tool's handle can help prevent ergonomic injuries as well (Choi, et al., 2007; LHSFNA, 2006). For example, drywall workers can use easy-hold gloves attached to mud pans. These are not just any type of gloves; they are two specific gloves. The first glove helps hold a mud pan while an employee is applying drywall compound (Albers & Estill, 2007). The second glove is a full-finger antivibration glove that meets ISO 10819 requirements; it helps absorb some of the vibrations caused by a power tool (Albers & Estill, 2007).

Stretching & Exercise Program

Athletes often stretch before and after exercise to reduce injury and increase performance. Stretching is now being applied on construction sites as well (Choi & Rajendran, 2014). Site exercise programs have been suggested and implemented as preventive measures against upper extremity MSDs (McGorry & Courtney, 2006). Holmström and Ahlborg (2005) evaluated the effects of morning warm-up exercise (a 10-minute exercise every morning at the building site) on musculoskeletal fitness in construction workers. They found a significant increase of thoracic and lower back mobility, increase of hamstring and thigh muscle stretchability in the morning warm-up exercise group.

Ludewig and Borstad (2003) studied the effects of a home exercise program (five shoulder stretching exercise with two stretches for 30 seconds, each repetition) on shoulder pain and functional status in construction workers. Participants who performed the stretching and strengthening exercises showed significantly greater improvements in shoulder function and satisfaction.

OSHA (2014) recommends that when working in a bent-over position, employees should take short and frequent breaks to stretch the back muscles. Construction companies are now taking this a step further by having workers stretch before beginning work to loosen their muscles. For the best results, stretching sessions and prejob safety/ergonomics planning (e.g., preshift huddles, toolbox safety talks) may be implemented as part of a comprehensive ergonomics program to control WMSDs.

Table 1 provides a summary of work-related musculoskeletal problems and recommended practical solutions associated with the seven construction trades/occupations.

Conclusion

WMSDs and injuries can cause workers pain, suffering and lost income as well as restrict non-work activity such as sports and hobbies. Costs to employers can include reduced productivity and increased workers' compensation premiums (NIOSH, 2013b). The literature contains information on various injury prevention strategies. Employers and joint labor-management groups should develop their own initiatives to analyze ergonomic hazards and implement site-specific MSD prevention strategies and practices (Borchardt & Choi, 2012; Choi, Borchardt & Proksch, 2012; NIOSH, 2007, 2013a, b).

More efforts to translate research into practice are needed in order to examine the effectiveness of solutions (including productivity and cost savings). This might involve, for example, executing a pilot campaign in one trade, developing contractor success stories, and increasing education and awareness. In the Netherlands, a 2-year follow-up study on a national ergonomics campaign found an increased use of ergonomic measures for reducing physical loads. The study highlighted the need to improve the availability of ergonomic equipment, along with individualized advice and training, to increase the use of ergonomic measures among construction workers (Boschman, Frings-Dresen & van der Molen, 2015).

All in all, construction-trade-specific MSD injury prevention programs can be a valuable way to improve ergonomics and worker morale, and reduce workers' compensation costs, while increasing productivity and profitability. **PS**

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