OVEREXERTION INJURIES IN CONSTRUCTION

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ABSTRACT: Overexertion injuries are the single largest classification of injury in construction, accounting for about 24% of all injuries. Overexertion injuries generally occur as a result of performing a given task as planned. While overexertion injuries are not intentional, the underlying causes of these injuries are built into the prescribed tools and work methods. If the causes can be identified, it should be possible to engineer them out of the work. This paper presents a summary of research to investigate 65 construction activities for the presence of risk factors for overexertion injuries. Each activity has been broken into its constituent tasks, and each task has been analyzed for each of seven generic risk factors for overexertion injuries: (1) repetitive exertions; (2) static exertions; (3) forceful exertions; (4) localized mechanical stresses; (5) posture stresses; (6) low temperature; and (7) vibration. Ratings for each risk factor have been made on a three point scale: insignificant, moderate, and high. This analysis shows that virtually all construction activities have moderate-to-high ratings for at least one risk factor, and thereby place craft workers at increased risk for overexertion injuries and disorders.

INTRODUCTION

Construction has one of the worst occupational health and safety records of any industry. The construction industry employs about 6% of the work force, but accounts for 10% of occupational injuries and 21% of all occupational fatalities (*Accident* 1998). Overexertion injuries resulting from work activities (e.g., low back pain, cervicobrachial disorders, and upper extremity cumulative trauma injuries) are the single largest classification of injury in construction, accounting for about 24% of all construction injuries (*Construction* 1992).

The term ''overexertion injuries'' will be used throughout this paper to refer to a number of ailments, many of which are imprecisely defined and used somewhat interchangeably, such as cumulative trauma disorders, repetitive motion injuries or disorders, repetitive stress injuries, musculoskeletal disorders, and ergonomic injuries.

Increased recognition by the medical community, insurance carriers, and by the workers themselves, has contributed to a dramatic increase in reporting of these injuries. For example, in 1981, the number of new reports of disorders associated with cumulative trauma was about 20,000, representing 18% of all illnesses for all industries. By 1992, 292,000 new cases were reported, representing 62% of all new cases (*Occupational* 1995).

In construction there is considerable disagreement about the extent of these problems. Because cumulative trauma disorders and other overexertion injuries tend to be unreported or misdiagnosed, statistics on the extent of this problem in construction are elusive (''Repeat'' 1989). Labor groups such as the Center to Protect Workers Rights (CPWR, the research arm of the AFL-CIO's Building and Trades Department), contend that construction work is fraught with ergonomic hazards. Contractor groups such as the Associated General Contractors (AGC) disagree, saying movements are not repeated often enough in construction to cause injury (Krizan et al. 1993). The AGC asserts that ''there is no objective scientific data that proves musculoskeletal disorders reported by construction workers are work-related'' (Krizan et al. 1993) and ''no method to differentiate between work-related activities and non work activities'' (''Report'' 1998).

As bad as the construction industry's safety record is, it is likely to get worse if current practices continue. Demographic projections show that the age of the civilian work force is increasing, from a median 34.3 years in 1980 to a predicted 40.6 years in 2005 (*Projections* 1988). The National Center for Construction Education and Research reports that the average age of construction craft workers is 47 years old (''The future'' 1996). While older construction craft workers generally experience lower injury rates than younger workers (*Construction* 1992), which is probably due to their increased awareness of the hazards of the work (Oglesby et al. 1989), the consequences of injuries (e.g., days of lost or restricted work) are more serious for older workers (Abraham et al. 1996).

Workers of either gender gradually lose strength as they age. The strength of an average 65-year-old person is only 75–80% of the peak strength that occurs at about age 20 (Astrand and Rodahl 1986). Older workers also have reduced postural flexibility making them more susceptible to back injuries (Helander 1981).

Demographic projections also show that the percentage of women in the workforce is increasing (Johnston and Packer 1987). Today, only about 2–3% of the construction workforce is female (''Encouraging'' 1993; ''Women'' 1993). Compared to males, females are shorter, lighter, have lower strength, and lower anaerobic power, forcing females to work at a higher percentage (compared to males at similar production rates) of their maximum capacities and making them more vulnerable to overexertion injuries (Helander 1981; Astrand and Rodahl 1986).

Once afflicted with an overexertion injury, many construction craft workers can be excessively challenged by the physical demands of their jobs. If alternative less physically demanding work cannot be found, the injured worker faces the dilemma of continuing at a job that causes excess fatigue or discomfort, or perhaps dropping out of the workforce.

The objective of this paper is to describe overexertion injuries in construction and to present an ergonomic analysis of construction tasks for risk factors for overexertion injuries. This paper summarizes the methods and results of a National Institute for Occupational Safety and Health (NIOSH) sponsored research project to identify construction activities and tasks that place craft workers at risk for overexertion injuries. It is hoped that this first-level review of overexertion injuries in construction will demonstrate the extent of the problem and inspire other researchers and practitioners to conduct their own detailed analyses and develop solutions to a major occupational health hazard.

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Overexertion Injuries

Overexertion injuries generally occur as a result of performing a given task as planned. While overexertion injuries are not intentional, the underlying causes of the injuries are built into the prescribed tools and work methods. If the causes can be identified, it may be possible to engineer them out of the work, reduce exposure to the underlying cause, or select alternative means and methods of performing the work.

Most other types of injuries (e.g., struck by object, struck against object, fall from elevation, fall at same level, etc.) occur due to an error or unplanned event. The underlying causes of these so-called traumatic accidents are not built into the work, so changing the work method may have no effect on the cause of the injury.

Construction injuries and illnesses have been categorized in many ways, including by trade (e.g., carpenters, electricians, laborers, etc.) but few attempts have been made to identify causal relationships between specific activities and tasks within a trade and the associated overexertion injuries. For example, carpenters account for 17% of all construction injuries and illnesses (*Construction* 1992), but carpenters perform many fundamentally different activities such as erecting concrete formwork, installing suspended ceilings, hanging drywall, etc. Edwin Nyhus, Business Manager of the Carpenters Union Local 512 of southeast Michigan (personal communication 1995) reports that carpenters who install formwork for concrete experience high rates of tendinitis in their elbows from banging the forms and connectors with hammers; carpenters who install suspended ceiling systems experience neck and shoulder problems from constantly looking and reaching up; and carpenters who hang drywall often suffer nerve damage in their hands from the vibration of the screwguns used to fasten the drywall to the framing system. All of these injuries fall into the general classification of overexertion injuries to carpenters, but the underlying causes are quite different and they call for fundamentally different types of workplace intervention.

Schneider and Susi (1994) performed a qualitative evaluation of the presence or absence of ergonomic hazards for several trades and tasks in new construction. Holmström et al. (1995) cite a number of studies documenting a variety of knee problems among carpet and floor layers, plumbers, and roofers. A study by the Injury Prevention Research Center at the University of Iowa, in conjunction with the CPWR, confirms this situation. Every trade in the survey listed the lower back as most associated with pain, physician visits, and missed work. When identifying other areas of the body causing pain, the responses varied by trade. For example, ironworkers reported shoulder problems, cement masons reported hand and wrist pain, and roofers and cement masons reported knee problems (Cook et al. 1996).

There are seven generic risk factors for overexertion injuries: (1) repetitive exertions; (2) static exertions; (3) forceful exertions; (4) localized mechanical stresses; (5) posture stresses; (6) low temperature; and (7) vibration. These risk factors for overexertion injuries have been well documented by many researchers. Armstrong (1993) defines the risk factors in Table 1. Other researchers package the risk factors in slightly different format. For example, Schneider and Susi (1994) evaluate awkward posture, force, weight, repetition, hand tools, static position, and vibration.

TABLE 1. Generic Risk Factors for Overexertion Injuries

Risk factor (1)	Definition (2)
Repetitive exertions	Performing same acts or motions over and over again
Static exertions	Maintenance of same position of body or some part of body throughout each work cycle or for prolonged periods
Forceful exertions	Exertion performed to overcome weight, resistance, or inertia of body or work object
Localized mechanical stresses	Mechanical tissue stresses in area of contact with external objects
Posture stresses	Positions of body that require more effort than others or result in compression or stretching of tissues in or around the joints, e.g., nerves or tendons
Low temperature	Contact of hand with air or work objects below 20°C or exposure of worker to low ambient temperatures that result in reduced peripheral circulation
Vibration	Contact of hands with vibrating objects

TABLE 2. Basic Tasks (Everett 1991)

Basic task (1)	Definition (2)	Examples (3)
Connect	Join or attach components together	Screw, nail, bolt, staple, weld
Cover	Spread or overlay sheet material over surface	Unroll carpet or single ply roofing
Cut	Penetrate or separate with sharp edge	Saw wood, cut drywall, drill hole
Dig	Loosen, remove, or move soil	Excavate trench, backfill
Finish	Apply continuous mechanical treatment	Grind, bushhammer, sand, rub
Inspect	Examine critically to identify flaws or verify correctness	Read level, verify alignment of machinery
Measure	Determine or layout dimensions	Mark drywall, layout track
Place	Move small object to specified location and orientation	Set tile, lay brick, align conduit
Plan	Gather information, think about upcoming work	Read blueprints, formulate work sequence
Position	Move large object to specified location and orientation	Erect steel beam, lift drywall
Spray	Direct jet of liquid or particles, no contact with surface	Spray paint, sandblast
Spread	Distribute liquid or paste material	Paint with brush, cast concrete

RESEARCH DESIGN AND METHODS

A cursory inspection of any reasonably large construction site reveals that there are many craft workers doing many different things at the same time. Compared to many industrial settings, construction sites may appear chaotic. To bring some order to what may appear to be chaos to some observers, this paper breaks construction activities into tasks corresponding to the twelve basic tasks developed by Everett (1991). Table 2 shows the twelve basic tasks with definitions and examples. The basic tasks are: connect, cover, cut, dig, finish, inspect, measure, place, plan, position, spray, and spread.

This research focuses on basic tasks rather than a more detailed or less detailed work breakdown, because it is here that the essence of construction field operations is captured. The work is similar, yet not identical, from day-to-day, from worker-to-worker, from project-to-project, and from employer-to-employer. The nature of construction work is that the worksite and workforce are constantly changing, so the analysis and any interventions must be in the work methods, not a particular worksite or individual worker.

Construction work requires craft workers who are able to perform many different activities. However, on all but the smallest projects, craft workers tend to become specialized and spend a large fraction of their time performing essentially the same few activities over and over for weeks, months, or years. In union construction, the assignment of specific activities to members of specific trade unions is very well defined in local

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practice and in collective bargaining agreements. In any case, this research examines the work, not the workers or their organizational affiliations, so the results can be applied to any construction work.

Members of the research team contacted representatives of the building trade unions' locals in the Ann Arbor, Michigan area to identify all the activities performed by that union. In some cases, the union representatives provided a document such a collective bargaining agreement listing the activities. In other cases, the union representatives prepared lists specifically for this research.

Each union performs may different activities, but most of the man-hours are devoted to a relatively small number of activities. It was decided to focus the research efforts on all activities that union representatives estimated to consume 10% or more of all the man-hours logged by members of that union. In some cases, the research team split up activities into two or more crews, because the crews, while working together, performed fundamentally different types of work and had different exposure to risk factors for overexertion injuries. For example, structural steel erection is divided into an erection crew, a ground crew, and a detailing crew.

Local practice varies from one place to another, and specifically from one local union jurisdiction to another. In this report, activities are listed under the trade union that performs the work in the Ann Arbor, Michigan area. This organization will not be completely correct in some other locations. Again, it does not really matter to which trade or union, if any, the craft worker belongs, it is the work that is under scrutiny.

Many construction activities follow the same general pattern: formulate work sequence (basic task = plan); measure or layout the work (basic task = measure); cut, finish, or otherwise process a component to be assembled (basic task = cut or finish); place or position the component to its final location (basic task = place or position); connect the component to other components already constructed (basic task = connect); and finally inspect the work (basic task = inspect).

Many other construction activities consist of primarily one basic task after a brief period of preparation. For example, once a painter gets set up to paint with a brush or roller, he/she can paint (basic task = spread) for hours. Drywall finishers spend virtually all of their time either applying joint compound (basic task = spread) or sanding joints (basic task = finish). In many cases, there is a primary cycle that is repeated over and over, with an occasional interruption to measure, relocate tools and materials, etc.

There are also some activities that do not lend themselves well to this type of analysis. Elevator constructors, for example, spend a great deal of their time installing rails and assembling the elevator cab, but after that they do lots of little things that are difficult to characterize using the methods of this research.

Every attempt was made to find and analyze craft workers performing ''typical'' work. However, each worker and employer has his/her own style, and there is often more than one way to perform an activity. Different tools can be used, some more automated than others. The availability of lifting devices varies. Elevated work can be performed from different types of ladders, scaffolding, cherry pickers, etc. The level of prefabrication of materials varies. These and other factors make it difficult to cover every possible situation.

Most activities require the craft worker to move about as the work progresses. This in itself can be physically demanding. Climbing up and down ladders and stairs contributes to the overall demands of the work. Sitting or standing all day is a well-established postural stress. Only when the moving about itself is particularly stressful is a separate line on a table entered. For example, iron workers installing rebar in a high wall or column often must climb up the rebar and hook themselves to the formwork or previously installed rebar as part of their work.

Nevertheless, most construction work is cyclical or repetitive and is well suited for this type of analysis. Sixty-five of the most common building construction activities were analyzed in this research. They are listed in Table 3 under the building trade union that typically performs the activity.

TABLE 3. Building Trade Unions and Corresponding Activities

Trade union (1)	Activity (2)
International Association of Heat and Frost Insulators and Asbestos Workers	Install duct insulation
	Install pipe insulation covers
International Brotherhood of Boiler Makers, Iron Ship Builders, Blacksmiths, Forgers, and Helpers	Install boiler
International Union of Bricklayers and Allied Craftsmen	Lay Brick (wall)
	Lay block
	Wash down brickwork/blockwork
	Install stone panels
	Tile Setting (floor)
	Tile (hard) Setting (wall)
	Grout tile (wall and floor)
	Install brick pavers
United Brotherhood of Carpenters and Joiners of America	Light gauge steel partition framing
	Install drywall
	Install suspended and acoustic ceiling grid
	Install suspended and acoustic ceiling tiles
	Build modular concrete forms
	Install millwork
	Residential framing
	Interior trim
	Erect scaffolding
	Pile driving
	Resilient tile setting
	Install carpet
	Install wood flooring
International Brotherhood of Electrical Workers	Install conduit
	Install wiring
	Install lighting systems and fixtures
International Union of Elevator Constructors	Install rails
	Install cab/equipment
International Association of Bridge, Structural, and Ornamental Iron Workers	Install rebar for slab or footing
	Install wall or column rebar in place
	Build rebar cages/mats at work station
	Structural steel erection (ground crew)
	Structural steel erection (erection crew)
	Structural steel erection (detailing crew)
	Metal deck installation
	Precast concrete erection (ground crew)
	Precast concrete erection (erection crew)
Laborer's International Union of North America	Place Concrete—slabs
	Place Concrete—walls, columns, beams
	Supply masons with brick/block
	Mix/transport mortar for masons
International Union of Operating Engineers	Operate cranes, dozers, scrapers, loaders, trucks, etc.
	Operation of elevators
Operative Plasterers and Cement Masons International Association of the United States and Canada	Manual concrete screeding
	Mechanical concrete screeding
	Cement finishing
	Sawcut concrete
International Brotherhood of Painters and Allied Trades	Spray painting
	Brush and Roller Painting
	Drywall taping and finishing
	Paper/wall cover hanging
	Abrasive blasting
United Union of Roofers, Waterproofers and Allied Workers	Install rigid insulation
	Install single ply roof membrane
	Install asphalt shingle roof
	Tear off built up roofing
	Install built–up roof
Sheet metal workers International Association	Install duct hangers
	Install ductwork
	Install equipment
International Brotherhood of Teamsters	Operate trucks
United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States and Canada	Install pipe hangers
	Install domestic water pipes, sanitary sewers, gas pipes, etc.
	Install fixtures

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Each construction activity was broken into its constituent task as described above. For each generic risk factor, each task is rated on a scale of 1 to 3, corresponding to an ordinal scoring system (Keyserling and Wittig 1988) where:

1. 1 = Insignificant: The job is free of potentially harmful ergonomic stresses in the risk factor of interest. No corrective actions are necessary.
2. 2 = Moderate: The job has stresses in the risk factor of interest that could be problematic (i.e., cause fatigue and/or injury) for some workers. Additional analyses using more precise methods should be used to determine the necessity for intervention.
3. 3 = High: The job has significant stresses in the risk factor of interest that are likely to cause fatigue and/or injury in some workers. Additional analyses and interventions should be taken at a high priority.

The procedure used in this research is not intended to be diagnostic. It will not provide any insight to specific causes of the risk factors nor will it offer any suggestions as to appropriate interventions. The objective here is to help identify problem areas for further detailed investigation.

Obviously, a three-point scoring system cannot capture much detail about the activities and tasks being analyzed. However, this type of analysis is quite appropriate for construction managers or craft workers who do not have advanced training in occupational ergonomics. Similar scoring schemes have been used successfully in a number of industrial applications and compared to results obtained by ''experts.'' The three-point checklist type of analysis is usually in close agreement or overestimates the risk factors when compared to the expert findings (Keyserling et al. 1992). Presumably, the problem jobs will be further scrutinized using more sophisticated methods and the false positives will be weeded out.

RESULTS AND DISCUSSION

Space does not permit the results for all 65 activities to be shown. Full results are published in Everett (1996). The results for four activities typically performed in installing interior drywall partitions are shown in Tables 4–7. The activities are: light gauge steel partition framing (carpenters), install drywall (carpenters), drywall taping and finishing (painters), and brush and roller painting (painters). On the right side of each table are columns corresponding to the seven risk factors. Each task has a score of 1 to 3 for each risk factor. Every effort was made to find craft workers performing typical work sequences. Most of the activities were videotaped and reviewed by at least three independent observers. However, each project is differ-

TABLE 4. Light Gauge Steel Partition Framing (United Brotherhood of Carpenters and Joiners of America)

Basic task (1)	Task description (2)	Repetitive exertions (3)	Static exertions (4)	Forceful exertions (5)	Local mechanical stresses (6)	Posture stresses (7)	Low temperatures (8)	Vibration (9)
Plan	Formulate work sequence	1	1	1	1	1	1	1
Position	Carry materials to work location	1	2	2	1	3	1	1
Measure	Measure and layout	1	1	1	1	2	1	1
Position	Carry materials to work location	1	2	2	2	3	1	1
Cut	Cut track	1	2	2	2	2	1	3
Position	Position track	1	2	2	2	3	1	1
Connect	Connect track to slab, deck	3	2	2	2	3	1	3
Cut	Cut studs	1	2	2	2	2	1	3
Position	Position studs	1	2	2	2	3	1	1
Connect	Connect studs to track	3	2	2	2	3	1	3
Inspect	Inspect work	1	1	1	1	2	1	1

TABLE 5. Install Drywall (United Brotherhood of Carpenters and Joiners of America)

Basic task (1)	Task description (2)	Repetitive exertions (3)	Static exertions (4)	Forceful exertions (5)	Local mechanical stresses (6)	Posture stresses (7)	Low temperature (8)	Vibration (9)
Plan	Formulate work sequence	1	1	1	1	1	1	1
Position	Carry materials to work location	1	2	3	3	3	1	1
Measure	Measure and mark wall and drywall	1	1	1	1	2	1	1
Cut	Cut drywall	2	1	2	2	2	1	1
Position	Carry and position panel	2	3	3	3	3	1	1
Connect	Screw panel to studs	3	2	2	2	3	1	3
Inspect	Inspect work	1	1	1	1	2	1	1

TABLE 6. Drywall Taping and Finishing (International Brotherhood of Painters and Allied Trades)

Basic task (1)	Task description (2)	Repetitive exertions (3)	Static exertions (4)	Forceful exertions (5)	Local mechanical stresses (6)	Posture stresses (7)	Low temperatures (8)	Vibration (9)
Plan	Formulate work sequence	1	1	1	1	1	1	1
Position	Carry materials to work location	2	1	2	2	2	1	1
Connect	Screw protruding screws	1	2	2	2	2	1	1
Spread	Apply joint compound	3	2	2	3	3	1	1
Cover	Place tape (first coat only)	2	2	2	2	3	1	1
Finish	Sand surface	2	2	2	2	3	1	1
Inspect	Inspect work	1	1	1	1	2	1	1

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TABLE 7. Brush and Roller Painting (International Brotherhood of Painters and Allied Trades)

Basic task (1)	Task description (2)	Repetitive exertions (3)	Static exertions (4)	Forceful exertions (5)	Local mechanical stresses (6)	Posture stresses (7)	Low temperatures (8)	Vibration (9)
Plan	Formulate work sequence	1	1	1	1	1	1	1
Position	Carry materials to work location	2	1	2	2	2	1	1
Finish	Sand/scrape/clean surface	3	2	2	3	3	1	2
Place	Mask areas not to be painted	1	1	1	1	2	1	1
Spread	Paint with brush	3	3	2	3	3	1	1
Spread	Paint with roller	3	3	2	2	3	1	1
Inspect	Inspect work	1	1	1	1	2	1	1

ent, and each observer had to use some judgment in arriving at the scores, so there were occasional differences of opinion and the values shown are consensus values.

It should be noted that all scores for low temperature have been set equal to 1. It was decided to score all tasks this way because this risk factor is almost entirely weather dependent and not specifically related to the work except in a few unusual circumstances (e.g., exposure to cold exhaust air from pneumatic tools). In fact, many of the observations were made in the middle of the winter in Michigan and it was indeed very cold. However, the same work can also be performed in the middle of the summer when low temperatures would not be a problem.

A quick glance through the tables reveals many ''2s'' and ''3s'' in all but the low temperature columns. This should not come as any surprise to veterans of construction who are plagued with sore backs, wrists, elbows, and shoulders.

There are those in the construction industry who do not think overexertion/musculoskeletal/ergonomic injuries are a big problem because ''movements are not repeated often enough in construction to cause injury'' (Krizan et al. 1993). It may be true that typical construction work does not have the repetitiveness of some manufacturing or meatpacking operations where movements are repeated every few seconds, but repetitive exertions are only one of the risk factors and only one potential part of the problem. A more comprehensive analysis also considers static exertions, forceful exertions, localized mechanical stresses, posture stresses, low temperatures, and vibration. In fact, for the four activities analyzed in this paper, repetitive exertions are not the biggest problem. From the scores in Tables 4–7, it appears that posture stresses are far more significant. Static exertions, forceful exertions, and local mechanical stresses also appear to be at least as important as repetitive motions.

These rankings collectively represent a great deal of effort on the part of members of the research team, but from the beginning it was expected that many of the individual steps or basic tasks would be similar. Whether a screw gun is used to attach drywall to studs, or plywood to joists, or light fixtures to ceilings, the craft worker is exposed to vibration to the upper extremity. Whether a drywall finisher bends over to tape a joint, or an ironworker bends over to weld a shear stud, or a laborer bends over to pick up trash, all are exposed to postural stresses and risk of low back pain or injury. Whether a tile setter kneels down all day to set ceramic tile, or a cement mason kneels down to trowel concrete, or a carpet installer kneels down to lay carpet, all are exposed to similar knee and back postural stresses and localized mechanical stresses on the knees.

The similarity of individual tasks among vastly different activities not only makes this type of analysis feasible, but it also has larger implications. An intervention that improves one task within one activity may have applications for many similar tasks in many dissimilar activities.

Clearly there are many opportunities for reduction of risk factors for overexertion injuries in the construction activities and tasks analyzed in this research. Developing new workplace interventions for construction is a daunting undertaking. Countless attempts have been made to change the work or to introduce new means and methods. Schneider and Susi (1994) have conducted an extensive review of ''solutions to ergonomic problems in new construction.'' Often the solution is simply selecting a better alternative from among several existing technologies.

In most cases identifying the problem and assessing the proposed solution have been approached qualitatively. Getting the industry and the craft workers to adopt the proposed solution is a different matter. Schneider et al. (1995) describe a number of organizational and psychosocial factors that hinder implementation of proposed solutions.

CONCLUSIONS

Several earlier studies have taken a qualitative look at ergonomic problems and some of the risk factors for overexertion injuries in construction. The research reported here is an important step in starting to identify and quantify specific problems. The results of this research can help reduce overexertion injuries and have widespread application in expanding job opportunities for women, older workers, and construction workers who are partially disabled due to previously suffered overexertion injuries, as well as making construction a more attractive career choice for young workers.

This research helps achieve one of the priority objectives of *Healthy People 2000* (*Healthy* 1991), to reduce work-related injuries among construction workers. Knowledge gained in this project has also improved curricular content on occupational health and safety in construction at the University of Michigan's Construction Engineering and Management Program and will spread throughout the academic and business communities.

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