Journal of Ergonomics
ISSN: 2165-7556

Mohan, J Ergonomics 2018, 8:4
DOI: 10.4172/2165-7556.1000235

Research Article Open Access

Identifying and Controlling Ergonomic Risk Factors in Construction

Satish B Mohan*

Department of Civil, Structural and Environmental Engineering, State University of New York at Buffalo, 223 Ketter Hall, Buffalo, NY, United States

Abstract

Construction expenditures at 1.22 trillion in 2017, accounted for 6.29% of the U.S. GDP, and the construction industry employed 6.80 million, 5.34% of the total work force, that suffered 6.43% of the worksite injuries. Worker fatalities were 19.1% of the total fatalities, 3.6 times more than all other industries. A study of the 1,657 construction injuries and illnesses that occurred at the US Navy Public Works Center (Pearl), from 1987 to 1994, showed that 589 (36%) of the injuries were work-related musculoskeletal disorders (WMSDs). This real field data of 589 ergonomic injuries identified following nine ergonomic risk factors: (i) Frequent or heavy lifting, (ii) Fixed or awkward body postures, (iii) Pushing, pulling, and carrying heavy objects, (iv) Work methods, (v) Hand tools and equipment, (vi) Repetitive, forced, or prolonged exertions, (vii) Noise, (viii) Whole body vibration, and (ix) Personnel relations This paper has provided the effects of risk factors on the parts-of-body of construction workers, which include: low back, shoulder, knee, hip, neck, wrist, and fingers. Also, the causal relationships between each risk factor and work-related musculoskeletal disorder (WMSD) have been included. Some example construction occupations that suffer from each risk factor have been shown.

Section on Ergonomic Risk Controls includes three categories: (i) Engineering controls that include: work station design to fit all size of workers, and work method design to minimize static, extreme, and awkward postures, and to reduce repetitive movements and excessive forces, (ii) Administrative controls to provide rest breaks for recovery from fatigue, and job rotation to avoid using the same body part over and over, and (iii) Work practice controls, such as: keeping tools properly maintained, using low vibration tools, and storing heavy loads at waist height. Several other preventive measures have been mentioned, and a model construction ergonomics program has been suggested.

Keywords: Ergonomic risk factors; Engineering controls; Administrative controls; Ergonomic program

Introduction

In the context of construction industry, 'ergonomics' means: 'designing the various construction tasks; providing tools, equipment, and materials; and organizing the work to promote worker safety and health'. A practical ergonomics program must approach both the worker as well as the job to match each other. The work methods, equipment and tools design must match the physical and mental capacity of workers, and the environment: noise, temperature, and illumination must be designed to avoid twisting, and bending of body parts. In recent years, there has been a significant increase in the reported cases of ergonomic disorders in the workplace. The Bureau of Labor Statistics [1] reported that the number of disorders associated with repeated trauma nearly doubled in 10 years from 1986 to 1996. The possible causes of this increase can be attributed to the following:

a) A few decades ago, the trades were not strictly bounded - most jobs included a variety of activities: a carpenter, for example, would carry materials and clean the floor. These activities involved footwork and movement of other body parts. With the development of specialty trades concept, trades now use the same body part over and over again resulting in physical fatigue and cumulative trauma of heavily used body part(s).

b) Worker population is aging, and

c) Body parts are getting tired - no job rotation.

Work-Related Musculoskeletal Disorders (WMSDs)

Work-Related Musculoskeletal Disorders (WMSDs) are the health disorders arising from repeated stress to the body due to ergonomic hazards or risk factors. WMSDs develop gradually over a period of weeks, months, or years. They include damage to the tendons, bones, muscles, and nerves of the hands, wrists, elbows, shoulders, necks. Backs and legs. Some of the more frequently occurring ergonomic disorders include: low-back pain, carpal tunnel syndrome (CTS), hearing loss, and tendonitis. WMSDs represent 1 in 3 lost time injuries (LTIs) in construction [2]. Characteristics of work-related musculoskeletal disorders (WMSDs) are compared with Occupational Injuries, below:

Work-related musculoskeletal disorders (WMSD) *vs.* occupational injuries

Work-Related Musculoskeletal Disorders (WMSDs), also called Cumulative Trauma Disorders (CTDs), are the results of cumulative trauma. The occupational injuries, on the other hand, are the result of instantaneous events in the work environment. Figure 1 shows the differences between the occupational injuries and WMSDs. By their very nature, WMSDs when reported pose several problems to the employer, the health care provider, and the insurance company:

a) They could be fully, or partially psychophysical. Poor worker supervisor relationship, lack of interest (apathy) in work, monotonous or boring jobs, or other job-related frustrations may trigger pains in neck or back.

***Corresponding author:** Satish B Mohan, Department of Civil, Structural and Environmental Engineering, State University of New York at Buffalo, 223 Ketter Hall, Buffalo, NY 14260, United States, Tel: (716) 645-4357/(716) 352-5059; E-mail: smohan@buffalo.edu

Received June 07, 2018; **Accepted** June 28, 2018; **Published** July 04, 2018

Citation: Mohan SB (2018) Identifying and Controlling Ergonomic Risk Factors in Construction. J Ergonomics 8: 235. doi: 10.4172/2165-7556.1000235

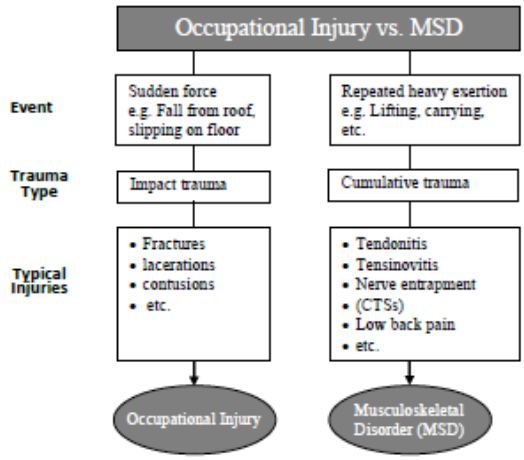

Figure 1: Occupational Injury *vs.* Musculoskeletal Disorder (MSD).

b) MSDs may not be work-related. They might be the result of other activities at home, in sports, or at other private and uninsured jobs.

c) They can be the result of normal degenerative process of: aging, and/or genetics; or might be the cause of some underlying (pre-existing) condition(s).

d) They could be completely non-existent; and might be reported with fraudulent intention, such as: back ache, head ache, etc. Most of such cases cannot be diagnosed instantly and definitively.

e) Occasional 'pains and aches of life' can cause MSDs or symptoms of MSDs.

Common WMSDs affecting construction workers

The 1988 Occupational Health Supplement to the National Interview survey [3] compiled data from 30,074 non-institutionalized civilians, the survey statistics show that the construction workers experience about twice the rates of back pain and hand discomfort both due to injury and cumulative trauma, as compared to workers in other industries. In the construction industry, 17.4% of the carpenters, 25.5% of the masons and 19.2% of the roofers suffer from back pain. 20.2% of the carpet layers, 47.5% of steel workers and 23.8% of the plumbers and pipe fitters suffer severe hand discomfort, and 6.7% of the plumbers and pipe fitters and 7.1% of electricians suffer from back pain. Exposure to ergonomic risk factors stresses the affected body parts of the workers and contributes to the development of work-related musculoskeletal disorders (WMSDs). Construction workers are exposed to several risk factors. Identifying the ergonomic risk factors on a worksite is easy with some training and experience and should be done for designing work methods to prevent WMSDs. The following types of ergonomic injuries occur in construction:

- Muscle Pain
- Joint Pain
- Swelling
- Numbness
- Repetitive Stress Injury
- Repetitive Motion Injury
- Restricted Motion

U.S. Navy PWC (Pearl) Statistics

US Navy Public Works Center (PWC Pearl) consulted with the author of this paper, in 1995, to suggest solutions to the increasing number of accidents at their PWC Pearl worksites. The various data on ergonomic injuries presented in this paper, are based on the actual injuries, 1657 in number that occurred at the U.S. Navy work sites. U.S. Navy data included the following items [4]:

- Date of Injury
- Occupation of the injured worker
- Work center
- Body-part affected
- Lost work days
- Medical cost
- Compensation cost, and
- Narrative

This data of 1,657 worksite injuries were organized in a spread sheet and analysed [5]. The narrative of each injury included the task that the injured worker was engaged in at the time of accident, and the type of injury suffered. These descriptions identified the nature of injury: Occupational injury vs. Ergonomic injury. Table 1 shows work-center wise total occupational injuries, work-related musculoskeletal disorders (WMSDs), and back injuries that occurred at the U.S. Navy worksites. Of the 1657 Occupational injuries, WMSDs totaled 589 (36%), and Back injuries 310 (19%). These percentages match with the construction safety literature which has reported that 33% of the worksite injuries are ergonomic disorders, and 20% are back injuries. Some of the results of the various analyses, performed on this real data, are provided in this paper.

Ergonomic Risk Factors

Worksite ergonomic risk factors

'Worksite risk factors' are defined as: actions in the worksite, worksite conditions, or a combination thereof that may cause or aggravate a work-related musculoskeletal disorder (WMSD). The following worksite risk factors have been known to cause WMSDs [6-9]:

- Repetitive, forceful, or prolonged exertions;

Work Center	Total Occupational Injuries	Work-Related Musculoskeletal Disorders (WMSDs)	Back Injuries
Maintenance Department	1009 (60.9%)	361 (35.5%)	190 (18.8%)
Utilities Department	257 (15.5%)	93 (36.2%)	50 (19.5%)
Business Management	170 (10.3%)	49 (28.8%)	21 (12.4%)
Transportation Department	115 (6.9%)	47 (40.9%)	29 (25.2%)
Materials department	57 (3.4%)	21 (36.8%)	10 (17.5%)
Environmental Department	25 (1.5%)	8 (32.6%)	5 (20.0%)
Engineering Department	19 (1.2%)	7 (36.8%)	4 (21.1%)
Unknown	5 (0.3%)	3 (60.0%)	1 (20.0%)
Total	**1657**	**589**	**310**

Table 1: Distribution of Total Injuries, WMSDs, and Back Injuries by Work Center (US Navy PWC (Pearl) Database 1987-1994, CSHI 1995a).

- Frequent or heavy lifting;
- Pushing, pulling, or carrying of heavy objects;
- Fixed or awkward body postures, for prolonged periods;
- Contact stress, or pinch stress;
- Localized or whole-body vibration;
- Cold or hot temperatures;
- Poor lighting (leading to awkward postures); and
- Noise.

These worksite risk factors can be intensified by work organization characteristics, such as:

- Inadequate work-rest cycles,
- Excessive work pace and/or duration,
- Unaccustomed work,
- Lack of task variability,
- Machine-paced work, and
- Piece rate

Signal risk factors

It has been suggested that five specific worksite risk factors have been most closely associated with an increased risk for the development of WMSDs. They have been designated as 'signal risk factors'. These five signal risk factors include the concept of duration of exposure. It is not the mere presence of a risk factor in the workplace that signals a potential problem, there must be presence for some period. Daily exposure to one of these factors during the work shift is likely to result in a higher risk job. They are screening mechanisms to focus attention on those jobs of greatest concern.

The signal risk factors are:

i Performance of same motion or motion pattern every few seconds for more than two (2) hours at a time;

ii A fixed or awkward work posture for more than a total of two (2) hours;

iii Use of vibrating or impact tools or equipment for more than a total of two (2) hours;

iv Forceful hand exertions for more than a total of two (2) hours; and

v Unassisted frequent or forceful manual lifting.

Table 2 shows the risk factors that caused 589 ergonomic injuries at the U.S. Navy PWC (Pearl) worksites. Manual Materials Handling caused 46% of the WMSDs, followed by Body Postures, which caused 21% of the WMSDs. Together, the two risk factors accounted for 67% of the WMSDs, and both are signal risk factors. Table 2 includes average lost workdays, and average cost per WMSD, caused by the corresponding risk factor.

Ergonomic risk factor: Part-of-body relationships

Table 3 shows the effects of risk factors on the parts of a worker's body. This knowledge can be very useful in planning job rotation to evenly distribute job stress on different body parts.

Ergonomic risk factor: WMSD-occupation relationships

Table 4 extracted from several studies reported in the literature, can be used in preventing WMSDs. A causal relationship of this type will relate each of the construction or maintenance activities to WMSDs and can be used in job designs, administrative actions and work methods that would eliminate or reduce WMSDs.

Ergonomic Risk Controls

During 1992-1994, 90% of disabled older workers, aged 51 to 61 years, had MSDs [10], costing tens of billions of dollars [11], and partially or wholly disabling thousands of construction workers. Prevention of MSDs is therefore important. Ergonomic Risk Controls can be divided in three categories:

1. Engineering Controls

2. Administrative Controls, and

3. Work Practice Controls

Tayyari F et al. [12] have described engineering controls to include: (i) Workstation design to fit all size of workers, (ii) Work method design to minimize: static, awkward and extreme postures; reducing repetitive movements, and excessive forces, (iii) Modifying the strength and endurance requirements of the tasks to be within worker's mental and physical capacities, and (iv) Ergonomically designing tools and handles to reduce the risk of cumulative trauma disorders (CTDs).

Risk Factor	Frequency		Avg Lost Workdays per Injury	Average Cost	
	Count	Percent		Med.	Comp.
Manual Materials Handling	159	27.00%	10.4	$1,057	$5.418
Frequent or Heavy Lifting	122	20.70%	10	$1.425	$43,994
Body Postures Fixed or Awkward for Prolong Periods	109	18.50%	12.7		
Manual Materials Handling				$2.048	$11,877
Pushing. Pulling, Carrying Heavy Objects	56	9.50%	14.3		
	37	6.30%	10.8		
Work Method	29	4.90%	21	$2.350	$48,046
Hand Tools & Equipment				$2.527	$13,136
Exertion	28	4.80%	15	525	NA
Repetitive Forced or Prolonged	16	2.70%	3.2		
Noise	13	2.20%	19.1	$692	NA
Whole Body	20	3.40%	12.1		$3.273
Total	589	100.00%	11.6	$1.628	$16.900

Table 2: Frequency, Average Lost Workdays, and Average Cost of Each WMSD caused by the corresponding Risk Factor [CSH! 1995a, US Navy PWC (Pearl) Database].

Cause of Injury (Risk Factor)	Part-of-Body Most affected
Lifting	Lower Back Shoulder
Awkward Postures	Knee Hip
	Shoulders Lower Back Shoulders Neck Wrists
Repetitive Motion Hand-Tool Vibration	Fingers Wrists
Noise	Ears
Heat Stress and Extreme Cold	Circulatory System

Table 3: Ergonomic Risk Factor → Part-of-Body Relationship for Construction Workers.

The administrative controls are applied to reduce the duration, frequency and/or severity of exposures to risk factors. Brook A [13] has stated some examples of administrative controls: (i) Provide rest breaks to recover from work induced fatigue, (ii) Increase number of employees assigned to a task, (iii) Use job rotation to insure the same muscle or tendon are not used over and over, (iv) Add various tasks to the employee's job, and (v) Maintain the equipment and tools.

Several other areas of ergonomic risk controls have been suggested [14]. Surveying the work area to identify potential problems, medical information of the employees, discomfort surveys, absenteeism, and turnover rates are some indicators of job stress. These job stress conditions should be studied, analysed and addressed.

Training and Education to managers and workers are an effective way to show ergonomic risks of their jobs before injuries occur. Written ergonomic safety program that addresses preventive measures, specific to the jobs in progress, can prevent injuries that might lead to CTDs. An example Ergonomics Program is shown in Figure 2.

Identification of Problem Jobs

Identifying problems in a job is the first step and can prevent WMSDs in a cost-effective manner. The identification is a three-step process:

(a) Information for employees

The employer must give each employee exposed to any signal risk factor: information about work-related musculoskeletal disorders (WMSDs). Including their signs and symptoms; the worksite risk factors that can cause or aggravate them; and ways to reduce exposure to the worksite risk factors. The primary purpose of this requirement is to increase employee awareness, giving them the background; they need to recognize illnesses as well as worksite causes so they can effectively participate in the ergonomics program in their work place.

(b) Risk factor checklists

The employer must complete job-specific risk factor checklists to examine employee exposures in the worksite and determine whether there are jobs which must be controlled. Two Risk Factor checklists, one for upper extremities, and the other for back and lower extremities should be completed.

(c) Early reporting of symptoms

It is also important that signs or symptoms of WMSDs be reported early so they can be properly assessed and treated. This may help slow the development of the disorder and speed the healing process. Study of symptoms can also guide in the job method or tools improvement. In order to ensure that this happens, employees must be aware of what symptoms they might experience. They must also know how to report those symptoms and to whom.

In addition, the employer must ensure that no policy or practice that discourages early reporting is established. The design of some incentive programs, safety competitions, or financial incentives may have the effect of discouraging reporting, depending on how they are implemented in the worksites. For example, providing rewards for employees or supervisors when safe work methods are observed would not discourage reporting. However, if employees or supervisors are given financial bonuses if there are no OSHA recordable cases; this may have the unintended but real effect of discouraging reporting of WMSDs.

Medical Management

Medical management of ergonomic injuries can control WMSDs through simple steps shown in Figure 2. The primary goals of medical management are to:

a) Eliminate or reduce musculoskeletal symptoms and conditions associated with work-related risk factors,

Musculoskeletal Disorder (MSD)	Risk Factors	Construction Occupations
Back Strain due to Repetitive work*	(i) Repetitive bending, twisting, lifting	Masons Roofers Carpenters
	(ii) Flexion with twisting	
	(iii) Vibration and impact	
	(iv) Static posture	
	(v) Force (heavy loads)	
Back Pain due to Injury		Carpenters
		Electricians
		Plumbers
Hand/Wrist	Manual tasks which are:	Steel Workers Plumbers Carpet Layers
Trauma**	(i) Repetitive and frequent	
	(ii) With local pressure on palm	
	(iii) Accompanied by vibration	
	(iv) Use non-neutral posture (bent twisted)	
	(v) Forceful	
Bursitis of Knee	Prolonged Constrained Posture, Direct Force	Carpet Layers
CTS or other CTDs affecting the wrist	Repetitive exertion	Office Workers
Bursitis of Shoulder	Awkward body posture	Workers who perform work above their heads
		- Overhead light fixtures
		- Installation of ceilings

* Occ Med STAR 7(1):147, 1992
**MMWR 29July 1989, P.48
*** Mohan 2010

Table 4: Some Example WMSD → Risk Factor → Occupation Relationships in Construction Operations.

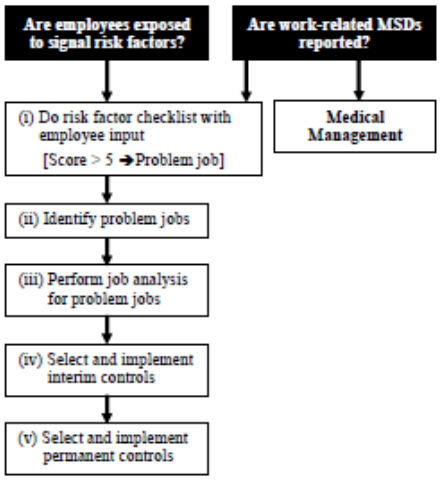

Figure 2: construction ergonomics program [9].

b) Eliminate, prevent, or reduce duration and severity of functional impairment from work-related musculoskeletal disorders,

c) Eliminate, prevent, or reduce duration and severity of disability associated with WMSDs,

d) Maintain the morale of the non-injured persons in the group through visible control of the risk factors and boost the pride of the injured person through an efficient return-to-work plan.

A proactive approach in which the employer and the employee work together with the medical practitioner can be effective in returning the injured person to work earlier, in some cases to restricted job assignment.

Summary and Conclusions

This paper has identified ergonomic risk factors that cause work-related musculoskeletal disorders (WMSDs) to construction workers. Based on the real data of 1,657 injuries that occurred at the U.S. Navy Public Works Center (PWC) Pearl, it was found that 589 (36%) of the 1,657 injuries were ergonomic injuries. An analysis of these ergonomic injuries identified the following nine (9) ergonomic risk factors:

i. Frequent or heavy lifting,

ii. Fixed or awkward body postures,

iii. Pushing, pulling, and carrying heavy objects,

iv. Work methods,

v. Hand tools and equipment,

vi. Repetitive, forced, or prolonged exertions,

vii. Noise,

viii. Whole body vibration, and

ix. Personnel relations

This paper has shown the relationship between a risk factor and the part-of-body affected. A table describes the effect of each of the risk factors in causing a work-related musculoskeletal disorder (MSD), and the effect of each of the risk factors on specific construction occupations.

Ergonomic injuries can be eliminated or minimized using three types of risk controls: (i) Engineering controls that include: work station design to fit all size of workers, and work method design to minimize static, extreme, and awkward postures, and to reduce repetitive movements and excessive forces, (ii) Administrative controls to provide rest breaks for recovery from fatigue, and job rotation to avoid using the same body part over and over, etc., and (iii) Work practice controls, such as: keeping tools properly maintained, using low vibration tools, and storing heavy loads at waist height. Several other preventive measures have been mentioned, and a model construction ergonomics program has been suggested.

References

1. Bureau of Labor Statistics (1999) US Department of Labor, most reported occupational illnesses are repeated-trauma disorders, The Economic Daily.
2. Bureau of Labor Statistics (1996) US Department of Labor, Annual Review.
3. National Institute for Occupational Safety and Health (NIOSH) (1988) The National Health Interview Survey (NHIS).
4. Construction Safety and Health Institute (CSHI 1995) Analysis of Occupational Injuries and Illnesses at the US Navy Public Works Center (Pearl), 1987-1994, Department of Civil, Structural and Environmental Engineering, State University of New York at Buffalo.
5. Construction Safety and Health Institute (CSHI 1995a), US Navy PWC (Pearl) Database 1987-1994, Department of Civil, Structural and Environmental Engineering, State University of New York at Buffalo.
6. US Department of Labor, Occupational Safety and Health Administration (OSHA), Principles of Ergonomics Applied to Work-Related Musculoskeletal Disorders, Course 225 and Washington D.C.
7. Jaffer N, Abdul-Tharim AH, Mohd K, Lop NS (2011) A literature Review of Ergonomic Risk Factors in Construction Industry. The 2nd International Building Control Conference 2011, Procedia Eng 20: 89-97.
8. Carter G, Smith SD (2006) Safety Hazard Identification on Construction Projects. J Construction Engineering Manage 132: 197.
9. Mohan Satish B (2010) Construction Ergonomics, ViTech Systems Inc, Williamsville, NY.
10. Yelin EH, Trupin LS, Sebesta DS (1999) Transition in Employment, Morbidity and Disable among Persons aged 51 to 61 with Musculoskeletal and Non-Musculoskeletal Condition in US, 1992-1994. Arthritis Rheumatism 42: 769-779.
11. Praemer A, Furner S, Rice DP (1999) Musculoskeletal Condition in the United States, Rosemond H American Academy of Orthopedic Surgeons.
12. Tayyari F, Smith JL (1997) Ergonomic Principles and Applications, Chapman Hall 11: 54-59.
13. Brooks A (1998) Ergonomic Approaches to Office Layout and Space Planning,' Prentice Papers, Meb University Press Facilities 16: 73-78.
14. Hess JA, Hecker S, Weinstein M, Lunger M (2004) A participatory ergonomics intervention to reduce risk factors for low-back disorders in concrete laborers. J Appl Ergonom 35: 427.