Psychosocial Factors and Musculoskeletal Disorders in the Construction Industry

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Abstract: Musculoskeletal disorders (MSDs) constitute more than half of the total injuries and illnesses within the construction industry. The aim of this study was to assess the prevalence of MSD among construction workers and identify the psychosocial and physical risk factors associated with their occurrence using an on-site survey instrument. One hundred forty seven construction workers (representing three trades) participated in the study. The 1-year prevalence of MSD was high with 61.2% reporting severe symptoms and 39.7% having some functional impairment due to MSD. Physical task requirement was the most important factor associated with MSD reflecting the physical nature of construction work. Economic and performance factors were the most stressful psychosocial factors reported and significantly increased the risk of reporting MSD. The findings of this research underscore the independent role that psychosocial factors play in the health and safety of construction workers. Understanding this role is imperative for practitioners and academics alike in the quest to make construction a safer work environment for all workers.

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Introduction

Construction is probably one of the oldest trades of mankind. However, despite its long history, construction still presents a unique challenge for safety and health experts. Despite the sincere efforts and major advances in the field of occupational safety and health, construction still ranks among the most dangerous occupations with high injury and illness rates (Ringen et al. 1995). In the United States, construction employs 7 million workers accounting for 5–6% of the total workforce. In 2003 construction had the second highest incidence rate for injury and illness cases requiring days away from work and was only preceded by transportation and warehousing (U.S. Department of Labor 2003b).

According to the Bureau of Labor Statistics (BLS), musculoskeletal disorders (MSDs) accounted for more than 55% of construction injuries reported in 2003 (U.S. Department of Labor 2003a). The term "MSD" refers to conditions that involve the nerves, tendons, muscles, and supporting structures of the body (NIOSH 1997). The medical and economic burden of MSD is quite significant, resulting in more than 70 million physician office visits in the United States each year with an estimated $50 billion cost (as measured by compensation costs, lost wages, and lost productivity) (Research Council and Institute of Medicine 2001) and accounting for 33% of all injuries and illnesses with days away from work in the private industry (U.S. Department of Labor 2005).

In an effort to improve the work conditions of construction workers and decrease the economic burden associated with MSD, several studies were set to identify the underlying causes of such high prevalence among construction workers (Riihimaki et al. 1994; Arndt et al. 1996; Lipscomb et al. 2000; Dimov et al. 2000; Latza et al. 2000; Rosecrance et al. 2002). While the majority of research focused on physical job requirements including manual material handling and awkward positions, few studies considered the role of psychosocial factors. Psychosocial factors are becoming an integral part of recent epidemiologic studies on MSD as identified by the National Institute of Occupational Safety and Health and the Research Council and Institute of Medicine (NIOSH 1997; Research Council and Institute of Medicine 2001).

Psychosocial factors, as the word implies, reflect both psychological and social aspects involving the subject and his/her surrounding environment. The International Labor Office defines work-related psychosocial factors as "interactions between and among work environment, job content, organizational conditions and workers' capacities, needs, culture, personal extra-job considerations that may, through perceptions and experience, influence health, work performance, and job satisfaction" (International Labour Office 1986). A simpler definition would be conditions that lead to stress at work and associated health and safety problems.

Psychosocial factors leading to stress at work can be discussed under five major categories: job characteristics (e.g., qualitative and quantitative work load, work environment, work hours, shift work); role in the organization (e.g., role ambiguity, responsibility for persons and equipment); social aspects (e.g., worker-

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supervisor relationship, social support); career development (e.g., job insecurity, promotions, work pay); and organizational factors (e.g., management style, policies, participation in decision making).

In the past 2 decades, studies have shown that psychosocial stressors are associated with cardiovascular disease, MSD, and some immune-related disorders (Jenkins 1979; Karasek et al. 1988; Pieper et al. 1989; Kang and Fox 2001; Bongers et al. 2002; van den Heuvel et al. 2005). Several models were developed to explain how psychosocial factors can contribute to work-related stress (e.g., person-environment fit model, effort-reward imbalance model, demand-decision latitude model). Stress can produce physiological responses (which if prolonged or intensified can lead to adverse health effects) through two common pathways: the activation of the hypothalamic-pituitary-adrenal axis resulting in the release of cortisol (hormonal pathway), and the stimulation of the autonomic nervous system with the release of epinephrine and norepinephrine (nervous pathway). Changes that occur in the peripheral immune system constitute a relatively new suggested pathway for stress response (Watkins et al. 1995).

In addition to the common pathways described above, several models were proposed to explain how psychosocial factors can impact MSD. Psychosocial stressors may accentuate the mechanical loading of muscles, increasing the risk for MSD to occur as, for example, workers under time pressure may assume awkward positions, apply excessive force, and perform at a higher frequency to be able to meet a deadline (Bongers et al. 1993; Davis et al. 2002). Psychosocial factors may also impact the perception of, coping with, and reporting of MSD probably through changes in muscle tension and the release of neurotransmitters, although the mechanism is not yet fully understood (Research Council and Institute of Medicine 2001).

Construction workers are at an increased risk for many of the above mentioned psychosocial stressors. Their work tasks vary between fully mechanized operations and manual hard labor under extreme conditions of cold, heat, snow, rain, or wind. Work may be conducted during the day or night and may occur in an isolated site or in the middle of traffic (Koningsveld and van der Molen 1997). Construction sites often include several trades working at the same time, each hired as a separate subcontractor with different work and safety policies. Within the same trade, workers' location changes from day to day, and sometimes even within the same day, exposing them to potentially new hazards. The work environment also changes within the same worksite as walls are erected and weather changes, making the work environment difficult to control (Weeks 1998; Koningsveld and van der Molen 1997).

While researchers agree on the high physical demands of construction work (Schneider et al. 1998; Abdelhamid and Everett 2002), some studies have attempted to identify the role of psychosocial factors in the construction industry (Tola et al. 1988; Riihimaki et al. 1989b; Holmstrom et al. 1992a,b; Lemasters et al. 1998; Latza et al. 2002). Their findings were summarized and critically evaluated in a recent systematic review. Strong associations were found among job satisfaction, perceived job stress, and the prevalence and incidence of MSD in construction workers. Low job control and high qualitative job demands were also associated with MSD, but inconsistencies between the studies made it difficult to evaluate their role. On the other hand, low social support, low stimulus from work, and high qualitative job demands did not show any association.

Such findings are important when planning an intervention program for the prevention of MSD because most researchers tend to neglect the psychosocial aspect when considering the construction industry (Koningsveld and van der Molen 1997). The systematic review also highlighted some of the shortcomings of the individual studies, where the absence of a valid and reliable instrument for assessing psychosocial factors was a common problem among the majority of the studies. Most importantly, although some identified psychosocial factors to be statistically significant which may satisfy the researcher's curiosity, they did not provide the practitioner with enough information to set priority areas for intervention. For example, high job stress and low job satisfaction were identified as important factors but it was not clear which work characteristics have caused such low satisfaction and a sense of high job stress. In addition, the role of some work variables was not studied (e.g., economic/work pay, mental demands) since each study focused on a few psychosocial factors and no comprehensive list of the different factors was tested (Sobeih et al. 2005).

Objectives

The purpose of this work was threefold:

1. To determine the prevalence of musculoskeletal disorders (in both single and multiple body regions) and stress symptoms among construction workers to identify the magnitude of the problem;
2. To evaluate the psychosocial factors among construction workers using a standardized instrument that demonstrates high content validity (covers the entire spectrum of related psychosocial factors) and reliability; and
3. To examine the association between psychosocial factors and musculoskeletal disorders in an attempt to identify priority areas for future intervention strategies. This research focused on three construction trades (carpenters, electricians, and plumbers) in building construction in the Midwest area.

Methodology

Study Preparation

Subjects were recruited from local construction companies in the Greater Cincinnati area. A letter was sent to managers of construction companies that were listed in the local directory of Associated Builders and Contactors Inc. (ABC) Ohio Valley Chapter introducing the study to them and asking for their participation. Frequent visits were made to construction sites of companies that agreed to participate and the aim of the study was explained to their construction workers. Those who showed interest were asked to fill out the study questionnaire.

Study Population

One hundred forty seven active construction workers participated in the study. All participants were males. Table 1 provides a detailed summary of their demographic information. The study subjects were categorized into four major groups (carpenters, electricians, plumbers, and others) based on their reported trade. Electricians, on average, were the youngest group, with a lower average duration of employment and body mass index (BMI). The mean age difference between electricians and the remaining three groups was significant ($P < 0.05$, Tukey's multiple comparison

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Table 1. Descriptive Statistics of Participants

Variable (units)	Mean	Standard deviation	Number	Percentage (%)
Age (years)	30.3	10	—	—
Height (cm)	180.1	6.5	—	—
Weight (kg)	87.1	16.2	—	—
Body mass index (kg/m^2)	26.9	4.8	—	—
Duration of employment (years)	8.5	9.0	—	—
Carpenters	—	—	23	15.7
Electricians	—	—	55	37.4
Plumbers	—	—	40	27.2
Other	—	—	29	19.7
Smoker	—	—	55	37.9
Nonsmoker	—	—	90	62.1

test). No other between-group differences were significant. The mean age, duration of employment, and BMI for the different groups is presented in Fig. 1.

Questionnaire

Data were collected by means of a questionnaire that was handed out to subjects during the data collection visits. The questionnaire consisted of four parts: personal information, musculoskeletal disorders, work-related psychosocial and physical factors, and stress symptoms (Genaidy et al. 2005).

The first part consisted of nine questions about the person and his employment. The second part assessed the musculoskeletal outcomes using a modified version of the Nordic Musculoskeletal Symptom survey (Kuorinka et al. 1987), with an added question on the intensity of symptoms. Three questions used were: (1) How often have you had, at any time during the past 12 months, aches, pains or discomfort in the following body regions? (2) What is the intensity of aches, pains or discomfort, you may have experienced at any time during the last 12 months, in the following body regions? (3) Have you, at any time during the last 12 months, been prevented from doing your normal work (at home or away from home) because of aches, pains, or discomfort in any of the following body regions?

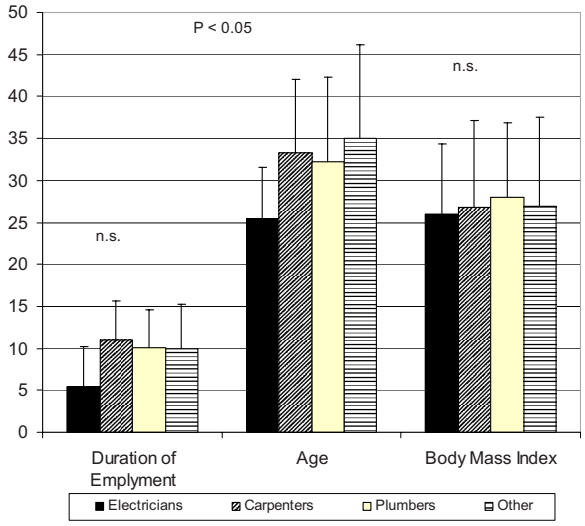

Fig. 1. Selected demographic characteristics by trade

The frequency of symptoms in the first question was assessed using a six-point scale: 0=never, 1=very rare, 2=rare, 3=moderate, 4=fairly often, and 5=very often. The intensity of symptoms in the second question was assessed also using a six-point scale: 0=none, 1=very low, 2=low, 3=moderate, 4=high, and 5=very high. The answers for the third question were quantified as "yes" or "no." These three questions were answered for ten body regions; neck, shoulders, elbows/forearms, hands/wrists, fingers, upper back, lower back, hips/thighs, knees/lower legs, and ankles/feet.

The third part evaluated the work-related psychosocial and physical factors. The "extent" to which a factor created stress was assessed using one of the following five levels: "not at all," "a little," "moderately," "a lot," and "entirely." The instrument consisted of 12 indices representing 12 psychosocial and physical factors with multiple questions for each index. In total, there were 166 questions listed under the following factors: (1) physical task content; (2) mental task content; (3) physical environment; (4) social; (5) organizational; (6) technological; (7) economic; (8) individual growth; (9) work effort; (10) experienced risk from work tasks and environment; (11) work performance; and (12) dissatisfaction (Genaidy and Karwowski 2003).

To further illustrate what each index represented/evaluated, the indices are described as follows:

1. The physical task content index represented the muscular requirements of work activities and included questions regarding the strength, endurance, and body position;
2. The mental task index evaluated job requirements of information processing, memory, and cognitive utilization;
3. The physical environment index evaluated the physical surroundings of the worker and had questions on noise, vibration, clothing, design, and chemical exposures;
4. The social index examined the social work environment and included conflict, support, praise, sense of openness, and receiving feedback;
5. The organizational index covered areas regarding time organization, autonomy, organizational role, policies, and responsibility;
6. The technological index evaluated areas like adequacy of tools, equipment, training, and supervision;
7. The economic index included questions regarding work pay, benefits, and job security;
8. The individual growth index covered the area of skill and knowledge development;
9. The work effort index included items that assessed muscular, cognitive, and emotional effort;
10. The experienced risk index evaluated how risky the work environment (physical, social, and organizational) and tasks are;
11. The work performance index included questions regarding achieving job goals and expectations; and
12. The dissatisfaction index evaluated how workers were dissatisfied with their work environment (physical, social, and organizational) and tasks.

The stress symptom questionnaire consisted of 18 questions. Participants were asked the following; "how often do you experience the following occurrences, if any, during the last 30 days?" for the following symptoms: heartburn or acid troubles, loss of appetite, nausea or vomiting, abdominal pains, diarrhea or irregular bowel function, difficulties in falling asleep, excessive perspiration without physical effort, shortness of breath without physical effort, tremor of hands, dizziness, tachycardia or irregular heart beats, headaches, nightmares, chest pain, eczema, breath-

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ing difficulties, asthma, and allergies. The frequency of symptoms was assessed using a six-point scale comprised of the following levels: 0=never, 1=very rare, 2=rare, 3=moderate, 4=fairly often, and 5=very often.

Exposure Variables

Exposure variables are 12 psychosocial and physical factors that were included in the questionnaire. A score for each index was produced by averaging the scores of the individual questions that constituted that index.

Outcome Variables

Outcome variables are the musculoskeletal and stress-symptom outcomes. Musculoskeletal outcomes were evaluated in three different ways: (1) positive cases for each of the ten body regions; (2) cumulative musculoskeletal disorder (CMSD); and (3) functional impairment (FI). The definition of a "positive case" was based on the rating of frequency and/or intensity of symptoms. Subjects rating their frequency of symptoms: 4=fairly often or 5=very often and/or their intensity 4=high or 5=very high were considered positive cases. The cumulative CMSD outcome variable was considered positive if the subject was considered a positive case in one (or more) body region(s).

The functional consequences of musculoskeletal symptoms (preventing normal work activity) were characterized using the cumulative variable labeled FI. A subject was considered FI positive if he was prevented from normal activity at work and/or home due to pain/ache/discomfort in one or more of the ten designated body regions.

Finally, stress symptoms were also dichotomized based on the frequency rating where 4=fairly often or 5=very often in which any of the 18 questions were considered stress-symptom positive.

Statistical Analysis

Questionnaire data were manually entered into a computer database generated using the statistical analysis system (SAS), which was also used for further analysis. Descriptive statistics (mean $\pm$ standard deviation and percent of cases) were produced for both exposure and outcome variables for all subjects as one group. To further understand the differences in distribution among trades (if any), data stratified by trade were presented. For between-trade comparisons, a one-way analysis of variance was performed using Tukey's multiple-range test for continuous variables. The statistical tests were conducted using a preestablished level of significance of 5%.

To study the association between the exposure variables (psychosocial factors) and outcome variables (positive cases in different body regions and the cumulative FI, CMSD, and stress symptoms), a multivariate logistic regression model with backward elimination of insignificant variables was employed to identify significant exposures while controlling for other covariates such as age, duration of employment, trade, smoking, and BMI (PROC Logistic in SAS). In such exploratory analysis, the significance level to remain in the model was set to 15%. An odds ratio (OR) above one indicated an increased risk of the outcome to occur (e.g., musculoskeletal disorder) when there was an increase in the exposure variable(s), an OR less than one implied an inverse relationship between the exposure and outcome (i.e., a protective effect).

Reliability Assessment

The reliability of a questionnaire is the extent to which results obtained by it are stable (Last 2000). Stability implies homogeneity of contents in a multi-item scale, i.e., internal consistency. Another definition of reliability can be stability over time, i.e., repeatability of results over time (Nunnally and Bernstein 1994).

In this study, the reliability of the exposure questionnaire was assessed by measuring the internal consistency of the different scales and subscales within each construct using coefficient alpha—the CORR procedure of SAS was employed for this purpose.

For outcome measures (CMSD, FI, and stress symptoms) where no scales are present, the test-retest method was used for reliability assessment. Portions of the questionnaire including all outcome measures were readministered to 31 construction workers (21%) after 2 weeks. The percent of agreement and Kappa statistic were calculated using the FREQ procedure of SAS.

Results and Analysis

Questionnaire Reliability

The outcome variable of musculoskeletal disorders among construction workers was assessed using a modified version of the Nordic Musculoskeletal Symptom Survey (Kuorinka et al. 1987). The questionnaire is widely used in epidemiologic literature (Holmstrom et al. 1992a,b; Goldsheyder et al. 2002; Merlino et al. 2003) with established validity and reliability (Kuorinka et al. 1987; Palmer et al. 1999). The agreements between the test and retest were in the moderate to substantial range (Landis and Koch 1977). Functional impairment had the highest agreement (89%, $\kappa=0.79$), followed by CMSD (80%, $\kappa=0.60$), and stress symptoms (77%, $\kappa=0.52$).

The psychosocial and physical work-related factors (exposure variables) were assessed using the demand portion of the Demand-Energizer Instrument (Genaidy and Karwowski 2003). The internal consistency of the different scales and subscales of the exposure questionnaire covering the 12 factors is presented in Table 2. All scales had a high internal consistency (alpha coefficients ranging from 0.82 to 0.95) while the subscales had a moderate to high internal consistency (alpha coefficients ranging from 0.63 to 0.95) reflecting the high reliability of the instrument.

Opposite to the musculoskeletal outcome questionnaire, this exposure variables questionnaire (psychosocial/physical factors) does not classify subjects into "positive=case" and "negative =noncase" but rather provide a continuum for different work variables between 1 and 5 that is formed by averaging the different questions assessing that work variable. For this reason the internal consistency of the questionnaire was the method chosen for assessing its reliability.

Prevalence of Musculoskeletal and Stress Outcomes

Table 3 presents the prevalence rates of functional consequences of musculoskeletal symptoms during the last 12 months, for different body regions, while those for severe musculoskeletal symptoms (based on duration and/or severity of symptoms) are presented in Table 4.

Lower back disorders were the most prevalent among construction workers with 26.5% reporting functional impairment and 39.5% reporting severe symptoms due to lower back pain/

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Table 2. Cronbach α Values as a Measure of Internal Consistency (Reliability)

Variable	Number of items	Cronbach α
Organizational	**30**	**0.92**
Time organization	8	0.65
Work responsibility	3	0.64
Organizational structure	7	0.90
Task meaningfulness	5	0.86
Control	7	0.90
Technological	**6**	**0.88**
Hardware	2	0.78
Human capital	4	0.84
Environment	**29**	**0.93**
Physical environment	20	0.89
Chemical environment	4	0.90
Biological environment	5	0.93
Economic	**6**	**0.93**
Basic	3	0.92
Advanced	3	0.92
Individual growth	**7**	**0.92**
Basic	4	0.95
Advanced	3	0.83
Social	**18**	**0.93**
Conflict	4	0.88
Support	3	0.86
Praise	2	0.75
Openness	4	0.93
Feedback	3	0.94
Knowledge of results	2	0.88
Mental task content	**18**	**0.95**
Information processing	5	0.88
Memory Related	2	0.90
Cognitive	4	0.85
Sensory	7	0.91
Physical task content	**21**	**0.94**
Strength	4	0.87
Endurance	4	0.86
Sudden handling	2	0.84
Upper body posture	5	0.88
Lower body posture	6	0.88
Effort	**3**	**0.83**
Perceived risk	**8**	**0.9**
Performance	**12**	**0.89**
Dissatisfaction	**8**	**0.83**

ache/discomfort. Knee disorders were second on both outcome measures (14.3 and 34.7%, respectively) followed by upper back, fingers, ankle/foot, and hand/wrist symptoms. Hip/thigh problems were the least prevalent on both outcome measures.

The results point to the high prevalence of musculoskeletal symptoms among construction workers and are consistent with the high incidence rates published by the BLS (U.S. Department of Labor 2003a). Lower-back pain is a common disorder in the general population with an estimated lifetime prevalence of 70% for industrialized countries (Andersson 1981). Lower-back and knee symptoms were the most prevalent disorders among this study population. This is in agreement with other studies investigating MSD among construction workers in the United States (Merlino et al. 2003; Cook et al. 1996), Sweden (Holmstrom et al. 1992a, Holmstrom and Engholm 2003), Germany (Latza et al. 2000, Rothenbacher et al. 1997, Sturmer et al. 1997), and Finland (Riihimaki et al. 1989a, 1994, Pietri-Taleb et al. 1995). This increased prevalence may follow the trend in the general population or may indicate the increased demands on the back and knee imposed by the physical work in the construction industry.

Table 3. 1-Year Prevalence Rates—Functional Consequences of Musculoskeletal Symptoms (Preventing Normal Work Activity)

Body region	Number	Percentage (%)
Neck	11	7.5
Shoulders	11	7.5
Elbows/forearms	10	6.8
Hands/wrists	15	10.2
Fingers	18	12.3
Upper back	16	10.9
Lower back	39	26.5
Hips/thighs	7	4.8
Knee/lower legs	21	14.3
Ankles/feet	12	8.2

The prevalence of different stress symptoms is presented in Table 5. Difficulties in falling asleep, headaches, heartburn or acid troubles, and allergies had the highest prevalence (9.5–15%). None of the subjects reported shortness of breath without physical effort or dizziness. In summary, 90 subjects (61.2%) reported having CMSD, 58 (39.7%) having FI, and 54 (36.7%) having stress symptoms.

Trade

The type of work and tools/equipment utilized can greatly impact the body posture and force utilized. Posture and force are well-studied risk factors for musculoskeletal disorders (NIOSH 1997; Research Council and Institute of Medicine 2001; Putz-Anderson et al. 1992; Skov et al. 1996; Stino et al. 2005) and may vary between trades resulting in different prevalence of musculoskeletal disorders and/or body region affected.

The prevalence of musculoskeletal outcomes and stress symptoms stratified by trade are presented in Figs. 2 (A and B). Lower-back and knee disorders were the most prevalent disorders among carpenters, electricians, and plumbers and were the most commonly reported body regions for musculoskeletal symptoms among carpenters in previous research (Lipscomb et al. 1997;

Table 4. 1-Year Prevalence Rates—for Musculoskeletal Cases (Based on Frequency and Intensity of Symptoms)

Body region	Number	Percentage (%)
Neck	21	14.3
Shoulders	23	15.7
Elbows/forearms	19	12.9
Hands/wrists	32	21.8
Fingers	26	17.7
Upper back	31	21.1
Lower back	58	39.5
Hips/thighs	12	8.2
Knee/lower legs	51	34.7
Ankles/feet	29	19.7

Table 5. Prevalence Rates—for Different Stress-Symptom Cases (Based on Frequency of Symptoms)

Stress symptom	Number	Percentage (%)
Heartburn or acid troubles	16	10.9
Loss of appetite	1	0.7
Nausea or vomiting	1	0.7
Abdominal pains	3	2.0
Diarrhea or irregular bowl function	10	6.8
Difficulties in falling asleep	22	15
Excessive perspiration without physical effort	7	4.8
Shortness of breath without physical effort	0	0.0
Tremor of hands	7	4.8
Dizziness	0	0.0
Tachycardia or irregular heart beats	3	2.0
Headaches	20	13.6
Nightmares	2	1.4
Chest pain	3	2.0
Eczema	3	2.0
Breathing difficulties	5	3.4
Asthma	3	2.0
Allergies	14	9.5

Dimov et al. 2000). On the other hand, neck/shoulder and elbow were reported by other studies as the site for most stressful positions and highest prevalence of self-reported symptoms among carpenters (Bhattacharya et al. 1997; Lemasters et al. 1998). This difference in prevalence may be partly due to the different data collection methods used (observational versus self-reports), the type of carpentry task being evaluated, e.g., drywall, ceiling, or formwork, (Bhattacharya et al. 1997), or the different definition of a "positive case" used by different authors. The high prevalence of back and knee symptoms among electricians was reported by other investigators (Hunting et al. 1994; Abudayyeh et al. 2003).

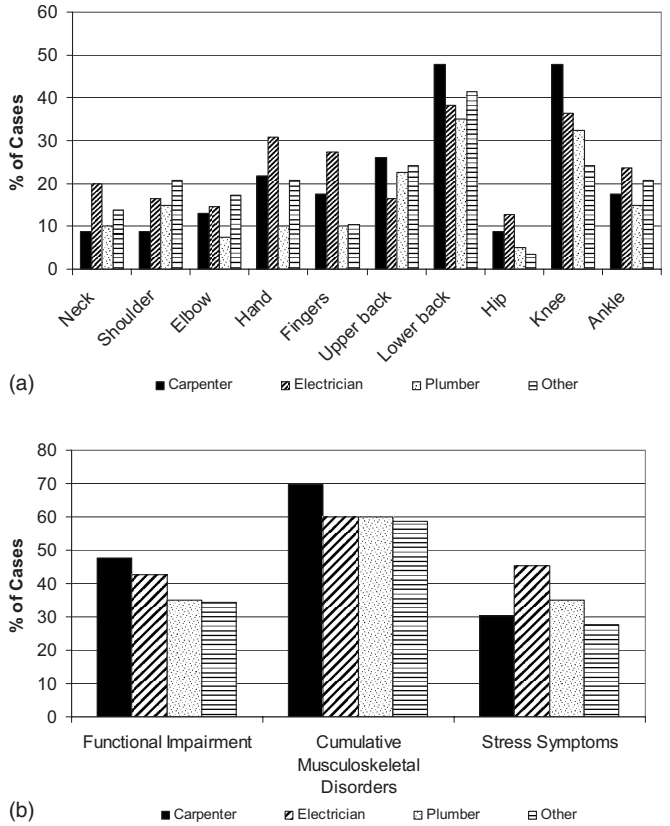

Fig. 2. A&B prevalence of musculoskeletal outcomes and stress symptoms by trade

Table 6. Mean Values of Psychosocial and Physical Stressors among Construction Workers

Variable	Mean	Standard deviation
Organizational	2.3	0.6
Technological	2.5	0.9
Environment	2.4	0.7
Economic	2.9	1.2
Individual growth	2.5	1.0
Social	2.2	0.8
Mental task content	2.1	0.8
Physical task content	2.5	0.8
Effort	2.6	1.0
Perceived risk	2.2	0.8
Performance	2.7	0.8
Dissatisfaction	2.4	0.8

Although the between-trade comparisons revealed no significant difference for the prevalence of musculoskeletal disorders in different body regions, several trends were observed. Compared to carpenters, electricians had a higher risk for developing neck, shoulder, elbow, hand, finger, hip, and ankle disorders. Electricians use different hand tools, including screwdrivers, pliers, and knives (Abudayyeh et al. 2003). This increased risk of neck and upper limb disorders among electricians may be explained partly by their overhead work and use of hand tools and was reported by other investigators among United States and Swedish electricians (Hunting et al. 1994; Holmstrom et al. 1995; Holmstrom and Engholm 2003). In one study, such disorders were found to start early during apprenticeship (Rosecrance et al. 2002).

Carpenters had a higher risk of back and knee disorders when compared to electricians and plumbers but the findings were not significant at the 5% level. Similar findings were reported among Swedish carpenters (Holmstrom et al. 1995). Carpenters can perform several tasks including ceiling, drywall, and concrete form which expose them to different potential ergonomic risk factors. Studies suggest that different carpentry tasks may strain different body regions and result in different prevalence rates (Bhattacharya et al. 1997; Lemasters et al. 1998; Dimov et al. 2000).

Psychosocial Factors

The mean scores of the different work-related psychosocial and physical factors are presented in Table 6 and ranged from 2.1 to 2.9 indicating that all the factors had a mild to moderate stressor effect on the subjects and none was rated in the low or severe category.

Economic and performance related factors had the highest values indicating that job insecurity, low wages, and trying to achieve job goals/expectations were the factors producing the greatest negative impact on workers and perceived as the highest stressors.

Despite the physical nature of construction work and the lack of control over work environment commonly reported in the literature (Ringen et al. 1995; Koningsveld and van der Molen

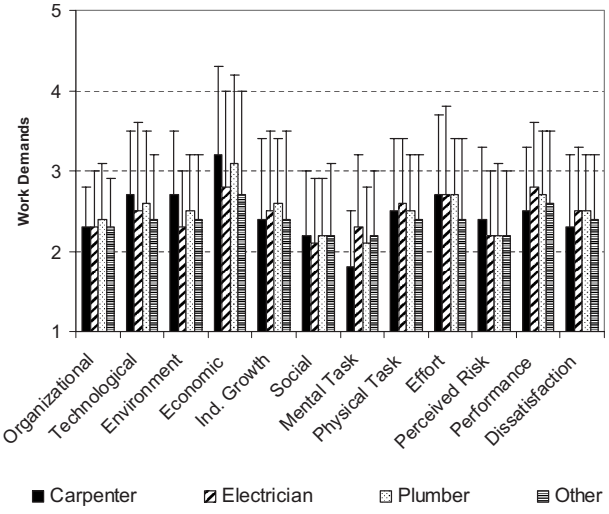

Fig. 3. Mean values for work demands by trade

1997; Abdelhamid and Everett 2002), these factors were not perceived by construction workers as high stressors. In fact, environmental and physical factors were considered as mild to moderate stressors. This difference between workers' perception and observers' or direct measurement could be due to a natural selection phenomenon similar to the healthy worker effect, wherein workers who are attracted to the construction industry and continue to work in it are the physically fit subjects who can tolerate such high requirements and actually perceive those factors as low stressors. Another explanation could be that this group of workers (due to cultural or other beliefs) will not admit to the high physical requirements posed by their job.

Mental task requirements, perceived risk, and social factors in the work environment were rated as low stressors. The low mental demands were expected among construction workers since the subjects were craftsmen and were not involved in planning or management aspects of the work. Construction workers considered their jobs to be of low risk. Construction still ranks among the most dangerous occupations with high injury and illness rates (Ringen et al. 1995) and at this point it is not clear if construction workers are aware of the health and safety hazards associated with their work but feel it is not hazardous (since they are taking all the precautionary measures needed) or they are not fully aware of the work-related hazards. This point may have important practical application and may require more health and safety training provided to construction workers if future research identifies their lack of knowledge about potential hazards in their work environment. The rating of social factors as low stressors indicates that workers have a good relationship with their supervisors and workmates with minimal conflicts.

The finding that physical environment, physical task requirements, and social factors are rated as low stressors was further confirmed by the high satisfaction reported by the study subjects when asked about these factors. In general construction workers were satisfied with their work conditions.

Stratification of data by trade produced similar results, as illustrated in Fig. 3. All trades considered economic factors their highest stressors. No between-trade differences were observed in any of the psychosocial factors indicating that psychosocial stressors have similar distribution among different trades within the construction industry.

To further validate the results, the association between psychosocial factors and musculoskeletal and stress outcomes, respectively, are presented in Tables 7 and 8. Age, years of employment, BMI, and trade were entered in the model as control variables. Certain psychosocial factors were significantly associated with musculoskeletal/stress outcomes with OR ranging from 1.43 to 15.8.

Economic factors were significantly associated with musculoskeletal outcomes; the OR ranged from 1.43 to 2.93 and was a risk factor for shoulder, elbow, hand, finger, and hip disorders. This finding, along with the rating of economic factors as high stressors, indicate that current work pay and job security conditions constitute a source of increased job stress. This level of stress significantly increases the risk for musculoskeletal disorders. These findings are in accordance with previous research that identified job insecurity and economic stressors in the construction industry as potential hazards (Ringen et al. 1995; Koningsveld and van der Molen 1997; Mitropoulos et al. 2005).

The association between economic factors and musculoskeletal outcomes was demonstrated in a study of 1,800 Swedish construction workers where anxiety about job insecurity was associated with neck/shoulder pain and severe lower-back pain (Holmstrom et al. 1992a,b). The effect of job insecurity and economic stressors on different health outcomes including musculoskeletal disorders was also reported among white and blue collar workers in different industries (Ferrie et al. 1995; Gallo et al. 2000; Kivimaki et al. 2001; Cole et al. 2005).

Physical task requirements and perceived effort were significantly associated with musculoskeletal outcomes in different body regions as well as the cumulative indices. Effort was mainly due to physical requirements of the job and not due to social or organizational factors. Similar associations of physical task requirements and musculoskeletal disorders were reported for neck/shoulder, lower back, and carpal tunnel injuries among construction workers by different researchers (Holmstrom et al. 1992a, b; Rosecrance et al. 2002; Goldsheyder et al. 2002). It is worth noting that the subjects in this study did not report physical task requirements as high stressors. In addition to the possibility of healthy worker effect or cultural beliefs as discussed earlier, it is also possible that such a strong association could reflect a "cumulative" effect of the physical requirements where workers do not perceive them as an acute "stressor," but the significant associations found are due to their repeated long-term effects. In this study, the handling of heavy material/equipment and excessive climbing stairs, kneeling, and squatting were the most demanding physical tasks reported. Climbing stairs was more often reported by electricians and kneeling and squatting were more often reported by carpenters; however, the differences were not statistically significant.

Organizational factors including time management, autonomy, and work responsibility were not rated as high demands by the study subjects and did not show any consistent association with the outcome measures. These findings point to the limited effect that organizational factors exert on construction workers when compared to other psychosocial (e.g., economic, performance) or physical factors. Other studies provided similar evidence where organizational factors were linked to neck/shoulder pain but not to severe lower-back pain (Holmstrom et al. 1992a,b; Latza et al. 2002).

It is interesting to note that some psychosocial factors that are typically considered as risk factors within construction work were not rated as high demands and did not show consistent association with musculoskeletal/stress outcomes. Most important of these were the physical environment and the experienced risk. While

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Table 7. Associations (Odds Ratios) between Psychosocial and Physical Stressors and Musculoskeletal Disorders by Body Region

	Neck	Shoulders	Elbows/forearms	Hands/wrists	Fingers	Upper back	Lower back	Hips/thighs	Knee/lower legs	Ankles/feet
Organizational	8.71 (1.8–43)	3.32 (0.9–11)	3.54 1.0–12	0.36 0.1–1.1	0.34 0.1–0.9	n.s.	n.s.	n.s.	n.s.	n.s.
Technological	0.27 (0.1–0.7)	0.34 (0.2–0.8)	n.s.	2.3 1.2–4.6	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Environment	n.s.	0.4 0.2–1.0	0.24 0.1–0.9	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Economic	n.s.	1.66 1.0–2.7	2.93 1.5–5.8	1.47 0.97–2.2	1.43 0.9–2.2	n.s.	n.s.	2.14 1.04–4.4	n.s.	n.s.
Individual growth	0.44 (0.2–1.1)	n.s.	0.41 0.2–1.1	0.49 0.2–1.0	n.s.	n.s.	n.s.	0.34 0.1–1.2	n.s.	n.s.
Social	n.s.	2.42 0.9–6.8	n.s.	n.s.	n.s.	3.11 1.3–7.4	n.s.	15.81 2.6–95.4	n.s.	n.s.
Mental task content	n.s.	0.32 0.1–0.9	n.s.	n.s.	n.s.	0.17 0.1–0.5	0.52 0.3–0.9	0.21 0.04–1.07	0.37 0.2–0.7	n.s.
Physical task content	n.s.	n.s.	n.s.	1.81 0.9–3.8	2.83 1.4–5.9	2.84 1.3–6.3	2.01 1.01–4.0	n.s.	n.s.	n.s.
Effort	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	1.54 0.9–2.5	n.s.	1.98 1.2–3.2	1.46 0.9–2.4
Perceived Risk	n.s.	n.s.	3.22 1.1–9.7	1.82 0.9–3.8	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Performance	4.0 (1.3–11)	3.41 1.5–8.0	3.5 1.3–9.4	n.s.	n.s.	1.97	n.s.	3.24 0.9–11	n.s.	n.s.
Dissatisfaction	0.5 (0.2–1.2)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.31 0.1–1.1	2.5 1.4–4.6	1.57 0.9–6.0

Note: n.s.=not significant at the 0.15 level in the multivariate regression model, which included age, years of employment, job, smoking preference, and body mass index as control variables.

Table 8. Associations (Odds Ratios) between Psychosocial and Physical Stressors and Cumulative Musculoskeletal/Stress Outcomes

	Functional impairment	Cumulative musculoskeletal disorders	Stress symptoms
Organizational	n.s.	2.4 1.04–5.5	n.s.
Technological	n.s.	n.s.	n.s.
Environment	n.s.	n.s.	n.s.
Economic	n.s.	n.s.	n.s.
Individual growth	n.s.	n.s.	n.s.
Social	n.s.	n.s.	n.s.
Mental task content	n.s.	0.34 0.2–0.7	n.s.
Physical task content	1.6 1.01–2.6	1.92 0.94–3.9	n.s.
Effort	n.s.	1.52 0.90–2.56	1.71 1.2–2.5
Perceived risk	n.s.	n.s.	n.s.
Performance	n.s.	n.s.	n.s.
Dissatisfaction	n.s.	n.s.	n.s.

Note: n.s.=not significant at the 0.15 level in the multivariate regression model, which included age, years of employment, job, smoking status, and body mass index as control variables.

often described as uncontrollable, open to weather changes, and always in a "dynamic" state, the study group did not perceive their work environment to be demanding nor expose them to higher risk of injury. This was further confirmed by the lack of association with the outcome health variables.

Social work environment and work relationships are always suspected as potential risk factors for work strain and health outcomes. In this study such a variable was not rated as a high stressor and no consistent association with musculoskeletal/stress outcomes was established, indicating that the social work environment is not a priority area for intervention. This is also in accordance with the findings of Holmstrom et al. (1992a, b) and Latza et al. (2002) who reported some inconclusive evidence to the effect of social factors on musculoskeletal outcomes in construction workers.

Some psychosocial factors when evaluated as stressors appeared to have a protective rather than the expected hazardous effect when associated with the outcome measures. This was seen with mental task demands and individual growth factors. One explanation for the protective effect seen with individual growth is that subjects who had a high need and felt a strong demand to improve and develop their career were "willing" to tolerate more "strain" and reported "less" symptoms than others. While this may sound plausible, the explanation falls short in explaining why mental demands had a consistent "protective" effect. It becomes even harder to explain the effects seen with organizational and technological factors that appeared to have both a "protective" and "hazardous" effect on different body regions and outcome indices.

The different models linking psychosocial variables to health outcomes in general, and to musculoskeletal disorders in particular, if simplified, underline the same pathway(s) and mechanism(s) of action. While the exact mechanism is yet to be discovered, researchers agree that psychosocial factors all pertain to the stress process which when combined with a physical demand on the job can affect the final outcome of musculoskeletal/stress symptoms. Under this general agreement, most researchers tend to divide psychosocial factors into stressors (risk factors) and moderators (protective factors), and test them accordingly. This traditional method allows the different psychosocial factors to be tested only in one "predetermined" direction, while in this study the different factors were allowed to be tested in both directions (risk and/or protective). The findings indicate that the association between psychosocial factors and MSD is multidirectional, and further work is needed to fully explore this complex relationship.

Limitations

This study is limited by its cross-sectional design where both the exposure and outcome were evaluated at the same point in time, hence no causal relationship can be inferred despite some strong statistical significance. Study participants were primarily younger in age and do not represent the entire construction workforce. Although generalization of results cannot be made, the high prevalence of musculoskeletal disorders among such a younger population points to the magnitude of the problem. Finally, the subjects belonged to the building construction sector and no heavy or highway construction workers were included. Future studies should include such sectors of the industry.

Conclusions

This study investigated the prevalence of musculoskeletal disorders, stress symptoms, and psychosocial stressors among construction workers and their possible association using a questionnaire that demonstrated high reliability and validity.

The questionnaire which was utilized to capture work demands (physical and psychosocial) is designed in such a way that allows safety experts to set priority areas for intervention. Once a work variable is identified to be a high stressor, further analysis can be done to examine the specific components that resulted in such high stress. In this study, effort was mainly exerted on physical task requirements which differed between trades (e.g., climbing stairs was more frequently reported by electricians while kneeling and squatting were more frequently reported by carpenters). Such findings can be very helpful in assigning priority areas for evaluation and intervention either through modifying the work techniques, providing different tools, or providing worker training on best practice techniques.

Recent safety studies reveal that training provided by in-house personnel can be more effective (Hinze and Gambatese 2003). The findings of this study further builds on that finding by identifying priority areas for safety training that are trade specific. The high prevalence of back and knee disorders provide a priority area for further studies and interventions while the different patterns of injuries seen among different trades provide the opportunity for some trade-specific programs.

Several operational definitions exist for musculoskeletal disorders. For this research a more conservative one based on the frequency and severity of symptoms and their impact on normal activities was used. Musculoskeletal disorders had a high prevalence among the different trades of construction with lower back and knee being the body regions mostly affected. Between-trade analyses revealed the tendency of electricians to have more neck and upper limb disorders while carpenters reported a higher prevalence of lower back and knee disorders. These trends were not statistically significant but may reflect the different type of work/tools utilized by each trade.

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Physical task requirements showed the strongest association with musculoskeletal disorders but were not rated as the highest stressor supporting previous studies on construction workers. This further indicates that their effects may be cumulative rather than acute.

Economic and performance related factors were the most stressful psychosocial factors perceived by construction workers while mental and social factors were the least stressful. The traditional physical and environmental factors of the work were not rated as high stressors and may reflect a healthy worker effect-like phenomenon. No between-trade differences were observed for the prevalence of psychosocial factors.

Psychosocial factors were significantly associated with musculoskeletal and stress outcomes. These associations remained significant even after controlling for personal characteristics and physical requirements of the work performed, indicating the independent role psychosocial factors play. Economic and performance factors were the most consistent risk factors significantly associated with the health outcomes among construction workers. Some psychosocial factors had a protective effect while others demonstrated both protective and hazardous effects. These findings suggest that the direction of the effect psychosocial factors play on health outcomes should not be predetermined (as risk or protective) but rather both aspects should be investigated and integrated in some form of a relationship. Further research utilizing valid and reliable instruments is needed to fully understand the multidirectional role of psychosocial factors in MSD.

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