WORKPLACE STRESSORS AND MUSCULOSKELETAL SYMPTOMS: EXAMINING THE COMBINED IMPACT OF ERGONOMIC AND WORK ORGANIZATION FACTORS

2001

HUANG

UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES
4301 JONES BRIDGE ROAD
BETHESDA, MARYLAND 20814-4799

GRADUATE EDUCATION
(301) 295-3913
FAX: (301) 295-6772

APPROVAL SHEET

Title of Dissertation: "Workplace stressors and musculoskeletal symptoms: Examining the combined impact of ergonomic and work organization factors"

Name of Candidate: Grant Huang
Doctor of Philosophy Degree
10 April 2001

Dissertation and Abstract Approved:

David Krantz, Ph.D. — Date: 4-10-01
Department of Medical & Clinical Psychology
Committee Chairperson

Michael Feuerstein, Ph.D. — Date: 4/10/01
Department of Medical & Clinical Psychology
Committee Member

Willem Kop, Ph.D. — Date: 4/10/01
Department of Medical & Clinical Psychology
Committee Member

David Cruess, Ph.D. — Date: 4/10/01
Department of Preventive Medicine & Biometrics
Committee Member

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Examining the combined impact of ergonomic and work organization factors"

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Grant D. Huang

Grant D. Huang
Department of Medical & Clinical Psychology
Uniformed Services University of the Health Sciences

ABSTRACT

Work-related musculoskeletal symptoms are a significant public health challenge that have been associated with ergonomic and occupational psychosocial (i.e., work organization) factors. However, research still needs to delineate the specific dimensions of work organization that pose risks to workers. It is also unclear whether workplace physical and psychosocial stressors have a combined effect for these symptoms. Individuals ($\underline{n}$ = 289) from a population (U.S. Marines Corps) known to have a high rate of clinic visits associated with low back and upper extremity disorders were given a questionnaire containing items on demographics, health behaviors, level of physical exertion at work, family and life stressors, ergonomic factors, and work organization. After identifying specific work organization variables related to scheduling, job design, management style, career concerns, organizational characteristics, and interpersonal factors, logistic regression analyses were conducted to determine risks for low back symptoms only, upper extremity (UE) symptoms only, or concurrent low back and upper extremity symptoms. The occurrence of low back symptoms was associated with: age (OR = 1.09); family conflict (OR = 1.30); exposure to ergonomic stressors (OR = 1.03); time pressure at work (OR = 1.18); and, interpersonal demands at work (OR = 0.73). Risks for UE symptoms were: family conflict (OR = 1.27); exposure to ergonomic stressors (OR = 1.02); and, time pressure at work (OR = 1.16). Risk factors for the occurrence of both low back and UE symptoms were: age (OR = 1.13); exposure to ergonomic exposures (OR = 1.04); greater levels of interpersonal demands at work (OR = 1.56), work-related cognitive demands (OR = 1.20), and cognitive uncertainty (OR = 1.22); and, lower levels of skill discretion (OR = 1.09). Among the different ergonomic

and work organization combinations, the occurrence of either low back symptoms or upper extremity symptoms was associated with higher levels of both ergonomic stressors and time pressure (OR = 2.61 & 2.90, respectively). Higher levels of ergonomic stressors and lower levels of involvement in management decisions (OR = 2.50) as well as higher levels of ergonomic stressors and time pressure (OR = 2.21), cognitive demands (OR = 2.25), cognitive uncertainty (OR = 2.08), interpersonal demands (OR = 2.44), or positive organizational climate (i.e., greater perceived responsibility) (OR = 2.15) were all risks for cases with both low back and upper extremity symptoms. These findings indicate the importance of distinguishing specific aspects of work organization and the need to concurrently assess them in conjunction with ergonomic risk factors in future research. They also highlight the potential of workstation and job redesign, job stress management, and organization-based efforts that incorporate worker input/involvement in reducing the levels of ergonomic stressors and work demands associated with low back and upper extremity symptoms.

Workplace Stressors and Musculoskeletal Symptoms:

Examining the Combined Impact of Ergonomic and Work Organization Factors

By:

Grant D. Huang

Doctoral dissertation submitted to the Faculty of the Department of Medical and Clinical Psychology Graduate Program of the Uniformed Services University of the Health Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy

2001

ACKNOWLEDGMENTS

Completing this dissertation project and my graduate studies as a whole could not have been done without a number of people. Therefore, I would like to express my utmost gratitude to them for being involved with and sharing in these endeavors.

First, I would like to thank my dissertation committee, Drs. David Krantz, Michael Feuerstein, Willem Kop, and David Cruess, for their critical and helpful comments on this dissertation and for truly making this process a learning experience in scientific methods, analysis, and thinking.

Financial and organizational support for this research was provided through Col Leif Larsen, Freya Arroyo, the Safety Division, Headquarters, U.S. Marine Corps and LTC Mary Lopez at the U.S. Army Center for Health Promotion and Preventive Medicine. I am also grateful for the fellowship support made possible by John Lowe, Dr. Joe Osterman, and the Henry M. Jackson Foundation for the Advancement of Military Medicine and the USUHS Office of Graduate Education. Furthermore, I would like to thank Dr. Michael Sheridan and Janet Anastasi in the Office of Graduate Education for their support and faith in my abilities and graduate education.

One of the driving forces behind getting this research done was the organization and leadership of the U.S. Marine Corps. The few and the proud that deserve particular recognition for their efforts are: CAPT Ken Schor, CAPT Joseph Moore, Col Nancy Anderson, CDR Ann Fallon, LCDR Fred Sylvia, Capt George Anikow, Capt Mike Valencia, Sgt Maj Marc Ouellette, and Sgt Maj Joseph Sosa. Additionally, the Feuerstein lab including Caroline Ennen, Lisa Moore, Rena Nicholas, and Julie Storey helped me to get things done in a timely manner and made the entire lab experience a memorable one.

The unending support, encouragement, and understanding from my family members, Amy, Yuan Mao, and Minna Huang, Thomas and Meiyun Ko, and Patrick Chen (who is probably closer than a brother) have always been appreciated even though I may not have always told them. Additionally, I am thankful my "other family", EFC of DC, particular because of their encouragement, support, and prayers.

Special thanks go to my mentors, Drs. Michael Feuerstein and Neil Grunberg. I cannot express in such a short space how significant their influence, support, and guidance has been since I came to USUHS. However, practically everything that I have been able to acquire and accomplish and my graduate school career can be attributed to the time and energy that to these two individuals have contributed on my behalf. They have indeed shaped me professionally and personally, forever impacting my life, and for these reasons I am extremely grateful

An important person in my life whom I greatly love and cherish is Faydeana Lau, who reminded me that there is joy in the journey and went along on it with me. Not only has she been my best friend while I was a graduate student, but she has been my partner in faith. Her prayers, support, love, and encouragement are a huge part of the foundation of which our future life together will be built and I greatly look forward to sharing it with her.

Finally, I give thanks to my Lord who is the reason for my desire to expand my mind by pursuing knowledge and whose grace and strength have enabled me to endure through this pursuit.

DEDICATION

This project is dedicated to those who utilize their talents, gifts, and abilities in putting in a hard day's work and to those who have inspired me to do the same.

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INTRODUCTION

Work-related musculoskeletal disorders (WMSDs) involve fatigue, discomfort, pain, and/or functional limitations associated with the lower back, hand, wrist, arm, elbow, shoulder, and/or neck regions (Pope, Frymoyer, & Lehmann, 1991; Rempel, Harrison, & Barnhardt, 1992; Wells, 1997). These problems can have a major impact on worker health, function, performance, and productivity and place a significant burden on individuals, organizations, and society. Such costs have resulted in widespread attention from health care, legal, insurance/compensation, government, and scientific communities from around the world. In the United States, low back disorders and musculoskeletal disorders of the upper extremities have been designated by the National Institute for Occupational Safety and Health (NIOSH) as priority area for occupational research (NIOSH, 1996).

Epidemiological studies have linked a number of demographic, medical, ergonomic, and psychosocial variables to work-related musculoskeletal outcomes (Bongers, deWinter, Kompier, Hildebrandt, 1993; Burdorf & Sorock, 1997; Cherniak, 1996; Gerr, Letz, & Landrigan, 1991; Johanning, 2000; Piligian et al., 2000; Shelerud, 1998). More recently though, particular attention has been given to occupational psychosocial factors (e.g., job stressors) and the risks associated with them. While job stress in general can negatively affect worker physical and psychological health (NIOSH, 1999; Sauter, Hurrell, Fox, Tetrick, & Barling, 1999), there remains a need to delineate the specific dimensions of job stress that are involved in work-related back and upper extremity problems. There is also uncertainty regarding whether a combination of occupational psychosocial variables and physical/ergonomic factors place an individual at a greater risk for musculoskeletal symptoms and how these risk factors interact to influence work and health outcomes. Although some models on work-related musculoskeletal disorders (e.g., Feuerstein, 1996; Feuerstein, Huang, & Pransky, 1999; Melin & Lundberg, 1997; Sauter & Swanson, 1996; Smith & Carayon-Sainfort, 1989) have proposed that occupational psychosocial factors moderate and/or interact with ergonomic stressors, few investigations have specifically examined this hypothesis. Investigations that address these questions can provide specific insights into potential mechanisms and guide more focused prevention strategies. Subsequently, workers can lead more healthier and productive lives and organizations can benefit from their contributions.

Epidemiology and Costs of Work-related Musculoskeletal Disorders

Epidemiological reports on the prevalence and incidence of work-related musculoskeletal disorders provide a more descriptive understanding of the extent of these problems. Data for these reports can be obtained from several sources including: self-administered questionnaires; professional interviews; physical examinations; OSHA 200 logs; administrative records; and medical records (Silverstein, Stetson, Keyserling, & Fine, 1997). In interpreting this information, one would place them within the context of factors such as the occupation, population, case definition, duration, and/or anatomic area of interest (Feuerstein, Huang, & Pransky, 1999). Nevertheless, figures indicate that work-related low back and upper extremity disorders affect a large number of people and are attributed to significant financial, medical, psychological, and social impacts and costs (Straaton, Fine, White, and Maisiak, 1998). Consequently, these musculoskeletal problems present a considerable public health challenge.

Magnitude

Low back pain and disorders are a common problem in the general population, with as many as 60% to 90% of the population being affected in their lifetime (Frymoyer, 1988). However, it is important to distinguish between general low back problems and work-related low back pain/disorders (Shelerud, 1998). Estimates of prevalence and incidence of work-related low back pain and disorders in the U.S. have been reported across several decades (e.g., Andersson, Pope, Frymoyer, & Snook, 1991). More recent data obtained from a self-report questionnaire indicated that 43.0% of active workers in various occupational sectors have had low back pain for at least one day (Ozguler, Leclerc, Landre, Pietri-Taleb, & Niedhammer, 2000). In the same study, a case definition of low back pain for at least one day and a visual analog pain intensity rating above 3 (from 0 to 7) was met by 33.2% of these workers. Using data from working adults who participated in the 1988 Occupational Health Supplement of the National Health Interview Survey (n = 12,623,200), a 12-month prevalence for work-related back pain from repeated activities at work was reported to be about 4.5% (4.75 million workers) and 2.5% (2.62 million workers) for back pain from injury at work (Behrens, Seligman, Cameron, Mathias, & Fine, 1994). Based on occupation, this study determined 12-month prevalence rates for back pain from repeated activities at work to range from 0.5% in financial managers to 10.4% in operators of extractive, mining, material-moving, and related equipment jobs. The Bureau of Labor Statistics (BLS) (2000) reported that in

1998, over 440,000 back injury cases occurred in private industry that resulted in at least one day away from work. This figure accounted for approximately 25% of all occupational injury/illness cases for that year.

Several estimates of the frequency and prevalence of work-related upper extremity problems are also available. A study of newspaper employees found that self-reported symptom prevalence ranged from 10% for the elbow region to 26% in the neck region (Bernard, Sauter, Fine, Petersen, & Hales, 1994). A 12-month prevalence rate of 10.7% for self-reported hand discomfort in all occupational categories was obtained from the 1988 Occupational Health Supplement (Behrens, Seligman, Cameron, Mathias, & Fine, 1994). Data on self-reported carpal tunnel syndrome in an adult working population indicated a period prevalence of about 1% to 2% with women having a higher percentage than men (Tanaka et al., 1994). Over 400,000 upper extremity injury/illness cases (of which 305,800 cases were specific to the wrist, hand, or fingers) involved at least a day away from work in 1998 (BLS, 2000). Of these cases, carpal tunnel syndrome and tendonitis accounted for over 43,000 instances in which a worker lost a workday. Additionally, while the number of carpal tunnel syndrome cases involving days away from work has been decreasing from 1993 to 1998, their annual rates (based on the total number of injury/illness cases) have remained relatively constant (BLS, 2000).

Costs and Impact

Economic

Research in industrialized countries such as the United States, Canada, and the Netherlands has found that significant financial burdens associated with medical care, workers' compensation claims, and indemnity can be attributed to work-related musculoskeletal disorders (Coyte, Asche, Croxford, & Chan, 1998; Hashemi, Webster, & Clancy, 1998; Hashemi, Webster, Clancy, & Volinn, 1997; van Tulder, Koes, & Bouter, 1995; Webster & Snook, 1994). In 1995, an estimated $8.8 billion was spent in the United States on work-related low back workers' compensation claims (Murphy & Volinn, 1999). Although back claims that are chronic or long-term in duration are a relatively small proportion of total workers' compensation claims, investigations have also consistently found that they account for a large percentage of the overall costs (Hashemi et al., 1997; Hashemi et al., 1998; Williams, Feuerstein, Durbin, & Pezullo, 1998). Disc disorders and sciatica are also major predictors of back pain-related costs and total costs according to a study of health care utilization in the primary care clinics of a health maintenance organization (Engel, von Korff, & Katon, 1996).

Particularly noteworthy economic costs are also associated with work-related upper extremity disorders. In the U.S. federal government workforce, the two most common upper extremity diagnoses for Fiscal Year 1994 were mononeuritis and enthesopathies (Feuerstein, Miller, Burrell, & Berger, 1998). Health care costs (e.g., for medical evaluation/management, outpatient and inpatient services, diagnostic services, therapy) for these two problems totaled over $12 million in 1994. More specifically, $7,596,416 were associated with mononeuritis cases and $4,632,339 were attributed to enthesopathy cases. In addition, the average cost for health care and indemnity per carpal tunnel syndrome case was $7,889. For enthesopathy of the elbow cases, the average health care and indemnity cost was $6,248. Between 1987 to 1995, the median workers' compensation claim cost (i.e., medical treatment and indemnity) in Washington State for rotator cuff syndrome was \$6,774 (median claims per year = 2,282), \$4,246 for carpal tunnel syndrome (median claims per year = 3,132), and \$534 for epicondylitis (median claims per year = 1,351) (Silverstein, Welp, Nelson, & Kalat, 1998).

Health care utilization

Increased health care utilization has been reported to be among the medical consequences associated with musculoskeletal symptoms and disorders (e.g., Badley, Rasooly, & Webster, 1994; Badley, Webster, & Rasooly, 1995). Low back pain was identified as the fifth-most common diagnostic cluster associated with physician office visits from 1989 to 1990, according to data from the National Ambulatory Medical Care Survey (Hart, Deyo, & Cherkin, 1995). Mielenz et al. (1997) reported that physical therapy treatments are also more likely to be obtained by patients with acute low back pain (i.e., less than 10 weeks duration, no previous care for current episode of back pain) who have a higher rating of disability on the Roland-Morris Questionnaire (Roland & Morris, 1989). In individuals with self-reported chronic or recurrent low back pain, episodes of pain have been associated with a significantly greater amount of medication used and self-reported functional limitations for work and daily life activities (McGorry, Webster, Snook, & Hsiang, 2000). Another study examining health care utilization among patients with chronic upper extremity disorders seen at a rehabilitation clinic reported that patients who had a neuropathic upper extremity (UE) diagnosis had more new surgeries and more visits to a new health care professional than a comparison group comprised of spinal disorder patients (Mayer, Gatchel, Polatin, & Evans, 1999).

Function / Quality of life

An individual's function and activities both in and outside the work environment can also be impacted by musculoskeletal disorders. A cross-sectional investigation of patients ($\underline{n}$ = 1072) seen with low back pain indicated that 24% of the study participants reported the low back pain to have a tangible effect on their work (e.g., sick leave, change in work duties) and that 12% had to work shorter hours, changed jobs, or had lighter duties (Duquesnoy, Allaert, & Verndoncq, 1998). Besides work, the most commonly assessed domains of impact related to WMSDs include: transportation; housework; mood; recreation; self-esteem; self-care; sexual activity; sleep; and, social interactions (Duquesnoy et al., 1998; Stock, Cole, Tugwell, & Streiner, 1996). For example, low back pain was reported to impair the ability to perform daily activities of living such as toileting, driving, or doing household chores in 80% of the sample in the study by Duquesnoy and colleagues (1998). Additionally, low back pain had an impact on sports participation in 33% of the patients, sexual activity in 46% of the patients, and emotional well-being in 59% of the patients. One investigation of a randomly selected sample of Connecticut workers found that compared to controls, cases with work-related upper extremity disorders experienced significantly more difficulty in daily tasks such as writing, gripping, chores, opening jars, child care, carrying bags, brushing, bathing, and driving (Morse, Dillon, Warren, Levenstein, & Warren, 1998). These cases were also: more likely to have moved (odds ratio (OR) = 2.4), lost a home (OR = 2.4), or lost a car (OR = 2.5) because of financial reasons; more likely to have been divorced (OR = 1.9); and less likely to have been promoted (OR = 0.5). Furthermore, it has been suggested that reductions in activity levels stemming from restrictions on movement and mobility may produce a sense of powerlessness, anger, hostility, and depression (Falvo, 1991). In the Duquesnoy et al. (1998) study, approximately three-quarters of the sample reported symptoms of anxiety, irritability, and/or depression.

Work-related Musculoskeletal Outcomes: Description and Presentation

The work-related musculoskeletal problems associated with the previously described high costs and impact include a wide range of medical disorders and/or diagnoses. Table 1 provides a listing of the more commonly recognized and/or studied work-related back and upper extremity disorders by International Classification of Diseases (9^{th} ed.) (ICD-9) codes (World Health Organization (WHO), 1977). The following sections discuss the natural history, work-relatedness, symptoms, and clinical findings of occupational low back and work-related upper extremity disorders with the intent of providing a more detailed understanding of what these problems are and what they involve.

Insert Table 1 here

<u>Natural history</u>

The natural history of musculoskeletal outcomes provides a better description of what a worker may experience. Assuming a worker is initially healthy, performing certain high-risk work tasks and exposure to other risk factors, such as adverse ergonomic conditions or occupational psychosocial stressors, can result in the manifestation of symptoms such as pain, discomfort, and fatigue (Pope, Frymoyer, & Lehmann, 1991;

Rempel, Harrison, & Barnhardt, 1992; Wells, 1997). Should these symptoms persist, a worker may decide to seek medical care to obtain relief and treatment for them (Gordis, 2000).

Upon receiving medical attention, the person may be diagnosed with a work-related musculoskeletal disorder (Wells, 1997). While it may seem that the musculoskeletal problems in question should be referred to as "diseases", it is suggested that the term "disorder" is more appropriate when uncertainty exists regarding the pathogenesis and when symptoms are found without obvious physical signs (Wells, 1997).

No criteria have been specifically established in defining which symptoms constitute a work-related musculoskeletal disorder of either the back or upper extremities. However, guidelines for assessing low back disorders have been issued by the Agency for Health Care Policy and Research (Bigos et al., 1994), American College of Occupational and Environmental Medicine (Harris, 1997), and Royal College of General Practitioners (Waddell et al., 1996) among other professional organizations (Johanning, 2000). For upper extremity disorders, Silverstein and colleagues (1986) have recommended that the persistence of symptoms for a week or longer, experience of symptoms for 20 times or more over the course of a year, or both of these criteria be used. Another case definition that has been employed in research is one used by the National Institute for Occupational Safety and Health (e.g., Bernard et al., 1994; Hales et al., 1994). To have a work-related musculoskeletal disorder using this standard, a worker must meet the following criteria: 1) have no previous accident or sudden injury that was not work-related to the anatomic region; 2) have symptoms that began after the current job was started; 3) have symptoms that have lasted for more than one week or occurred at least once a month within the past year; and, 4) have symptoms that were reported as "moderate" or worse based on a five-point intensity scale.

If the symptoms and disorder do not abate, continued exposure to the physical and/or to psychosocial stressor(s) can be associated with exacerbation of the problem and its maintenance (e.g., Feuerstein et al., 1999). Subsequently, the disorder may progress to the point where the worker becomes functionally impaired and can no longer perform his/her work task(s) in a satisfactory manner (Bowers, 1998). According to the International Classification of Impairments, Disabilities, and Handicaps (WHO, 1980), the term "disability" refers to restrictions or inability to perform an activity in a way that is considered normal for a human being and should be distinguished from "impairment" which involves an abnormality of psychologic, physiological, or anatomic structure within a specific organ or body that is temporary or permanent in nature (Jette, 1989; 1994). Furthermore, based on guidelines published by the American Medical Association (1993), a physician can use information from diagnosis and evaluation to assign an impairment rating (i.e., percentage) that describes the loss of function (Spieler, Barth, Burton, Himmelstein, & Rudolph, 2000).

Work-relatedness

The "work-relatedness" of musculoskeletal outcomes refers to a multifactorial nature that includes the association between elements of the work task and/or work environment and the disorders of interest (Hagberg et al., 1995). The World Health Organization (1985) also highlights the need to consider adverse working conditions, personal characteristics, and sociocultural factors when discussing work-related disorders. Based on principles of occupational epidemiology, determination of the work-relatedness of a given musculoskeletal outcome (i.e., symptoms, disorder, disability) should utilize several criteria. These criteria include: the association between work features and the outcome; temporal relationship; consistency in the findings; association between a change in exposure to a change in outcome; absence of other plausible explanations for the observed effect; biological plausibility; and strength of relationship (National Research Council, 1999; Wells, 1997). For upper extremity musculoskeletal disorders, a four-step process has been proposed to determine the work-relatedness of upper extremity disorders (Sluiter, Rest, & Frings-Dresen, 1999). These four steps are: 1) evaluating the general criterion on the relationship of the upper extremity disorder to the present work; 2) examining the work factor criteria by body region; 3) checking non-occupational origins of the upper extremity disorder; and, 4) deciding on the level of work-relatedness (e.g., "most likely not work-related", "possibly work-related", "probably work-related") and needed action (e.g., no action, plan action, take action).

Besides the multifactorial perspective suggested by the term "work-related", medical, legal, and social implications may also stem from the nature of a musculoskeletal problem. It has been suggested that health care providers may take different approaches to diagnosing and managing musculoskeletal disorders because of debate concerning case definition and use of "work-related" (Yassi, 2000). In many states, the physician can also play a major role in determining the work-relatedness of a musculoskeletal injury/illness (Derebery, 1998; Hashimoto, 1996). However, the final decision typically is a legal one made by a third party (e.g., insurance company) (Derebery, 1998).

On the job, workers may be inappropriately restricted from performing certain tasks and place unnecessary financial strains on the workers' compensation system if their musculoskeletal problem is incorrectly deemed as work-related (Derebery, 1998). Moore (1991) found that among cases referred for a diagnostic evaluation of the work-relatedness of carpal tunnel syndrome, only 37% met the Wisconsin workers' compensation criteria for work-relatedness. Furthermore, there were no differences found between work-related and non-work-related cases on the types of exposures experienced. From these findings, it was concluded that carpal tunnel syndrome was over-diagnosed and often misattributed to work.

Conversely, if the work-relatedness of back or upper extremity morbidity is not properly identified, then the worker may have to endure a more extended course of injury/illness and/or be subject to denial of workers' compensation benefits (Derebery, 1998). Such an individual may be also be subject to being labeled a "malingerer" or "somatizer" and associated social perceptions and stigmatization if he/she is unable to perform a job in an adequate manner (Niemeyer, 1991). Reid, Ewan, and Lowy (1991) have also found that female workers with "repetitive strain injuries" experience hardships in establishing credibility regarding their problem.

<u>Work-related low back disorders</u>

Several systems exist for categorizing work-related low back pain and disorders that have, in turn, produced several difficulties relating to research, treatment, and the ability to develop a consensus impairment rating scheme (Frymoyer & Andersson, 1991). One classification scheme was developed by the Quebec Task Force (Spitzer et al., 1987) and is based on symptoms, duration, and work status at the time of evaluation. This system is comprised of 11 classification categories, with Category 1 involving the majority of people with low back problems. Specifically, inclusion in this category requires an individual to have pain without radiation.

Etiological classification is another method for conceptualizing low back problems and includes degenerative, congenital, inflammatory, neoplastic, and metabolic causes (Frymoyer & Andersson, 1991). Degenerative spinal disorders encompass a broad class of diagnoses and are the most common source of low back pain (Frymoyer & Andersson, 1991). Among these disorders are those that involve: the ligaments and musculature such as sprains and strains; intervertebral discs such as herniated nucleus pulposus; and the spinal canal such as spinal stenosis. The following descriptions of work-related low back disorders are discussed in accordance with this etiological classification scheme.

Ligament- & musculature-related disorders

Ligaments and musculature are important in the structural stability of the spine. Back sprains and strains are commonly associated with the ligaments and musculature, respectively (Andersson, Fine, & Silverstein, 1995). Another term used for a low back strain is lumbago. The tensile nature of ligaments allows them to be load-bearing elements and assist with preventing excessive motion. Ligaments also have the property of viscoelasticity, which refers to the relationship between deformation and/or failure and the rate of applying a given load (Pope et al., 1991). Muscles assist with positioning and stabilization of the spine and allow a person to have the strength and power required for lifting and carrying items. Subsequently, decreased muscle strength can produce a greater risk for a back disorder. Upon examination of a back sprain or strain, symptoms are localized, tenderness is found with palpitation to the region, no neurological deficits exist, and there may be decreased range of motion (Boden, Wiesel, & Spengler, 1996; Johanning, 2000).

Intervertebral disc-related disorders

Intervertebral discs lie between vertebral bodies and have a primary role of weight bearing. Together with the apophyseal joints, these discs comprise a complex that has a function of load bearing for shear, compression, and torsion forces. Shear loading is involved when forces act upon two facet joints in opposite directions in flexion, extension, lateral deviation, and axial rotation. In compression loading, two or more facets are pressed together and the resulting force is transmitted to the intervertebral disc. Torsion loading can be considered a twisting type of force that occurs when the torso is twisted.

Intervertebral disc herniation is a problem commonly associated with intervertebral disc lesions and are classified as protuding (bulging), extruded, and sequestered (Ljunggren, 1996). The earlier stages of disc herniation will have protruding discs that extend beyond the normal anatomical limits and can produce a mechanical pressure on the nerve root. An extruded disc is considered to be an intermediate stage of herniation that can eventually lead to a sequestered disc in which the longitudinal ligament is ruptured and fragments of the disc extrude into the spinal canal. Physical findings associated with disc herniation include muscle weakness, sensory or motor nerve defects, decreased or absent reflexes, positive MRI and/or CT-scan tests, and a positive straight leg raise test (Johanning, 2000).

A specific diagnosis involving the intervertebral discs is herniated nucleus pulposus (HNP), also commonly called a "slipped disc" (Frymoyer & Andersson, 1991). One symptom of HNP is pain that radiates from the lower back to the buttock and upper thigh called sciatica. The pain from sciatica usually involves nerve root or dorsal root ganglion compression as well as chemical stimulation. Such compression can lead to a cascade of events including changes in nerve conduction, blood flow, and formation of edemas. Pain may be experienced after prolonged injury and/or compression and eventually result in changes in nerve excitability and the generation of spontaneous nerve impulses (Waddell & Frymoyer, 1991).

Spinal canal-related disorders

One type of degenerative spinal disorder involving the spinal canal is called spinal stenosis. Spinal stenosis refers to a narrowing of the neural canal of the spine, particularly of the nerve root foraminae (Frymoyer & Andersson, 1991). Effects of spinal stenosis include pain (e.g., neurologic claudication) in standing and walking (Johanning, 2000; Waddell & Frymoyer, 1991).

Other low back disorders

Vertebral bodies are short cylindrical bones that play a major role in the load-bearing function of the spine. The apophyseal joints are posterior to the vertebral bodies and refer to the articulations between vertebral roofs that are structured in a superior/inferior manner (Moore, 1992). These joints are involved in resisting torsion and shear as well as compression of the spine. Placing a significant amount of strain on the apophyseal joints may produce a fracture and result a condition called spondylolysis (Pope et al., 1991). Upon healing of the fracture, the strength of the spine may be diminished, leading to spondylolisthesis.

Work-related upper extremity disorders

Work-related upper extremity disorders typically affect the muscle/tendons, nerves, or vasculature in the hand, wrist, arm, elbow, shoulder, and/or neck regions (Putz-Anderson, 1992; Rempel et al., 1992). The National Safety Council (1996) has proposed as many as 28 ICD-9 upper extremity diagnoses to be considered as work-related upper extremity disorders. As a group, these disorders have had several labels. In the 1960s, the International Labor Organization Advisory Committee on Salaried and Profesessional Workers called these problems "repetitive strain injuries" (Chatterjee, 1987). Since that time, references in the scientific and popular literature have included: "cumulative trauma disorders"; "occupational cervicobrachial disorders"; "overuse syndromes"; "regional musculoskeletal disorders"; "work-related disorders"; and "repetitive trauma disorders" (Derebery, 1998; Gerr, Letz, & Landrigan, 1991)

Muscle- / tendon-related disorders

An inflammation of the muscle/tendon unit is referred to as tendonitis. If the unit is not given proper time to rest and the tissues are not allowed to heal, the tendon can become permanently weakened (Vender, Pomerance, & Kasdan, 1998). There are several kinds of tendonitis that are associated with the various upper extremity locations. Bicipital tendonitis and rotator cuff tendonitis are those affecting the shoulder region (Levitz & Iannotti, 1995; Sagerman & Truppa, 1998). In the forearm area, flexor carpi radialis tendonitis, extensor tendonitis, and flexor tendonitis are common diagnoses. These three forms of tendonitis all involve muscles in the forearm that flex or extend the hands, wrist, or fingers (Moore, 1992).

Tenosynovitis is another type of inflammation that involves the synovial sheath around the tendon. Specifically, inflammation and pain stem from a production of excess synovial fluid by the sheath that subsequently accumulates in the area. Two types of tenosynovitis classified among the work-related upper extremity disorders are DeQuervain's disease and trigger finger (or flexor tenosynovitis) (Putz-Anderson, 1992; Vender, Pomerance, & Kasdan, 1998). When the tendon and tendon sheath at the junction of the wrist and thumb become abnormally thickened, movement and function of the thumb are impacted, usually resulting in a diagnosis of DeQuervain's disease (Piligian et al., 2000; Vender, Pomerance, & Kasdan, 1998). Symptoms associated with DeQuervain's disease include pain, tenderness, and/or swelling in the radial styloid area and an exacerbation of pain by abducting and extending the thumb (Piligian et al., 2000). A positive Finkelstein's maneuver, which involves difficulty/inability to hold the thumb in the palm with the fingers around it, is another method for diagnosing DeQuervain's disease. Trigger finger refers to the locking of a finger in a bent position caused by the formation of a nodule (or ganglion cyst) on a tendon.

Depending on the anatomic location, irritation at the tendon attachments in the elbow area can produce medial or lateral epicondylitis. Symptoms of either type of epicondylitis can include extreme pain when attempting to straighten the arm or bending them against resistance and tenderness to palpitation over the medial or lateral epicondyle (Burgess, 1998; Piligian et al., 2000).

Nerve-related disorders

Nerve-related disorders typically involve a form of compression on a nerve that can lead to the experience of numbness, tingling, or aching (Rempel et al., 1992). Perhaps the most commonly known upper extremity nerve disorder is carpal tunnel syndrome (CTS). CTS occurs when the median nerve is entrapped and compressed within the carpal canal. The carpal canal is formed by the bones of the wrist and transverse carpal ligament (Moore, 1992). Entrapment and compression normally occurs from an inflammation of the flexor tendon sheath within this canal (Vender, Ruder, Pomerance, & Truppa, 1998). Persons with CTS normally report pain, tingling, and/or numbness in the thumb, forefinger, middle finger, and part of the ring finger (Piligian et al., 2000; Vender et al., 1998). Nocturnal awakening can also occur as a result of symptoms. Distal sensory or motor latencies and Phalen's test, which involves wrist flexion for one minute in order to determine whether symptoms are reproduced, have also been used for diagnosing CTS (Herbert, Gerr, & Dropkin, 2000). Other nerve disorders that can affect the ulnar nerve and include: sulcus ulnaris syndrome, Guyon's Canal

Syndrome, and cubital tunnel syndrome. In cubital tunnel syndrome, paresthesias in the ring and pinky fingers may occur, in addition to an inability to separate the fingers and pick up small objects (Piligian et al., 2000).

Vasculature-related disorders

Thoracic outlet syndrome and Raynaud's disease are two disorders that impact the nerves and circulatory system around them. Thoracic outlet syndrome occurs in the shoulder and upper arm regions and is caused by a compression of the nerves and blood vessels in neck and shoulder. Weakness as well as numbness in the entire arm can result in persons with this disorder. When fingers become cold and pale because of a lack of blood attributed to blood vessel constriction, Raynaud's syndrome may be diagnosed. Another term for this phenomenon is vibration syndrome. Pain in the hand and fingers, sleep disturbances, and hand weakness are among the ways that Raynaud's syndrome may present (Piligian et al., 2000).

Muscloskeletal Injuries/Illnesses in the U.S. Military

Besides the various costs and personal consequences, musculoskeletal disorders and subsequent disability also negatively impact readiness in the military (Peake, 2000). Among military personnel, musculoskeletal injuries/illness and disability have been attributed to a large number of outpatient visits (Knapik, Ang, Reynolds, & Jones, 1993; Linenger & West, 1992) and lost time (Jones, Bovee, Harris, & Cowan, 1993; Ross & Woodward, 1994). Furthermore, musculoskeletal-related problems are the most prevalent source of disability for the U.S. Army, Navy, and Air Force (U.S. Department of Defense Injury Surveillance and Prevention Work Group, 1999; Feuerstein, Berkowitz, & Peck, 1997; Songer & LaPorte, 2000). A study of U.S. Army soldiers found that back disorders were the most prevalent source of musculoskeletal disorders that resulted in disability (Feuerstein et al., 1997). In the U.S. Navy, the broad diagnosis of degenerative arthritis, a category that includes low back pain problems, was reported to be the most prevalent source of disability in the first nine months of Fiscal Year 1995 (U.S. DoD Injury Surveillance and Prevention Work Group, 1999). This report also listed back disorder diagnoses as the second- and third- most common sources of disability.

Risk factors for back and upper extremity outcomes among U.S. Army soldiers

The significant implications of musculoskeletal disability for the U.S. military led Feuerstein and colleagues to examine potential demographic, physical, health behavior, individual psychosocial, and occupational psychosocial risk factors for disability related to back and upper extremity disorders. Specifically, data on enlisted U.S. Army soldiers from the Health Risk Appraisal (HRA) and Physical Disability Agency databases were used to conduct two separate case-control studies. Logistic regression analyses indicated that age (OR = 1.1 per year increase), lower ranks (OR = 4.1 & 3.0 for E-2 & E-3, respectively), less frequent aerobic exercise (OR = 2.2), low social support (OR = 5.1), "sometimes" having worries that interfered with life (OR = 2.2), and "often" having too much job stress (OR = 2.7) were associated with back disability status (Feuerstein, Berkowitz, & Huang, 1999). Significant risk factors for upper extremity disability were age (OR = 1.1 per year increase), "White" ethnicity (OR = 1.5), lower ranks (OR = 3.8, 4.4, & 2,2 for E-2, E-3, and E-4, respectively), and "often" having too much job stress (OR = 2.5) (Huang, Feuerstein, Berkowitz, & Peck, 1998).

A separate case-control study (Feuerstein, Berkowitz, Haufler, Lopez, & Huang, under review) examined ergonomic, health behavior, occupational and individual psychosocial, and problem-solving orientation factors among soldiers who had self-reported occupational low back pain with lost time over the previous 12 months. Significantly greater risks for having lost time associated with occupational low back pain were associated with female gender (OR = 6.6), higher education (OR = 3.6), longer time in job (OR = 1.3), infrequent aerobic exercise (OR = 4.4), higher levels of interference from worries in daily life (OR = 5.5), no social support (OR = 4.0), high levels of exposure to ergonomic risk factors (OR = 1.1), "sometimes" having too much work stress (OR = 3.5), increased peer cohesion (OR = 1.2), and greater perceived effort at work (OR =1.5). Higher innovation (OR = 0.8), supervisor support (OR = 0.8), and involvement at work (OR = 0.8) had lower odds ratios for lost time.

It is interesting that all three Army studies reported that higher levels of job stress had statistically significant associations with one of three different musculoskeletal-related outcomes (i.e., disability, lost time). Perhaps even more notable was the fact that job stress was assessed by the same single item in these investigations. While cultural differences between the services need to be considered (U.S. Department of Defense, 1987), these findings suggest that job stress may be an important area to target in military personnel. However, since only a single question was used to assess the frequency that one experienced job stress, it is not clear what particular aspect(s) of job stress placed a person at a greater risk for a poorer musculoskeletal-related outcome. Therefore, any benefit from knowing that "job stress" is a risk factor is limited because it does not provide specific direction for developing intervention or prevention efforts to assist with reducing and/or modifying workplace stressors.

Musculoskeletal disorders in U.S. Marines: burden and individual risk factors

Until recently, few reports were available on the extent and burden of musculoskeletal disorders in the United States Marine Corps (USMC). Information specific to the service was limited because relevant data was typically reported in conjunction with those for the U.S. Navy. Although research on musculoskeletal injuries and illnesses has been completed on Marines, these studies have focused primarily on problems in the lower extremity regions (Linenger & West, 1992; Shaffer, Brodine, Ito, & Le, 1999). No investigations have identified risk factors for back or upper extremity problems among Marines.

In an epidemiological study that utilized administrative medical surveillance databases (i.e., the Defense Medical Surveillance System and the Defense Medical Epidemiological Database), Huang, Feuerstein, and Arroyo (in press) determined that back- and upper extremity-related disorders were among the chief contributors to ambulatory visits, duty limitations, and lost time among enlisted Marine Corps personnel. The ICD-9 categories, 724 – Other and unspecified disorders of back and 726 – Peripheral enthesopathies and allied syndromes were the second and third greatest sources of ambulatory visits. Additionally, ICD-9 categories that contain musculoskeletal-related disorders related to the back and upper extremities were the first, second, third, and seventh greatest sources of work duty limitation. Specifically, these categories (and rank) were: 726 – Peripheral enthesopathies and allied syndromes (1); 724 – Other and unspecified disorders of back (2); 719 – Other and unspecified disorders of joint (3); and 729 – Other disorders of soft tissue (7). The only musculoskeletal-related condition among the top ten categories associated with lost days (i.e., release with sick at home) was 724 – Other and unspecified disorders of back. This diagnosis category was the fifth most common cause of lost time among all ICD-9 diagnoses.

Given that musculoskeletal disorders were major sources of ambulatory visits, duty limitations, and lost days within the Marine Corps, the top 15 low back and upper extremity-related diagnoses for ambulatory visits were then identified. Results indicated that the back diagnosis, lumbago, had the highest rate among these musculoskeletal (i.e., low back and upper extremity) diagnoses with 27.5 cases per 1000 person-years. The diagnosis, unspecified enthesopathies, was associated with the highest ambulatory visit rate (10.5 cases/1000 person-years) among upper extremity diagnoses and had the third highest rate among the 15 musculoskeletal diagnoses.

Mantel-Haenszel chi-square tests for linear association indicated that rates for ambulatory visits associated with these diagnoses tended to increase with age according to gender and race. Age-specific rate ratios also found that females had higher risks for most back and UE disorders (i.e., lumbago, sciatica, lumbar sprain/strain, carpal tunnel syndrome, cervicalgia, unspecified enthesopathies, myalgia & myositis (unspecified), neck sprain/strain), while lower enlisted Marines (i.e., E1 - E4) had higher risks but for fewer diagnoses (i.e., lumbar sprain/strain, unspecified enthesopathies, neck sprain/strain).

These efforts have established back and upper extremity disorders as prevalent problems in the Marine Corps. However, additional research is needed that builds off this work. More specifically, investigations should be conducted to determine the occupations associated with higher rates of musculoskeletal disorders and to identify modifiable risk factors for these problems and how they interact with each other to influence work and health outcomes. Past studies (Feuerstein, Berkowitz, Haufler, Lopez, & Huang, under review; Feuerstein, Berkowitz, & Huang, 1999; Huang, Feuerstein, Berkowitz, & Peck, 1998) have highlighted that job stress is one factor that deserves particular attention. Subsequent findings can then be used to help develop secondary prevention programs aimed at key work- and non-work-related risk factors for back and upper extremity disorders within this population.

Risk Factors for Work-related Musculoskeletal Disorders

Research on military and general populations has indicated that work-related musculoskeletal outcomes (i.e., symptoms, disorder, or disability) of the back and upper extremities are multidimensional in nature. Although no direct cause-effect relationship has been established, there is evidence to support the notion that several factors are associated with and/or predictive of each of these outcomes. Classification of these factors has often placed them into individual, ergonomic/biomechanical, or occupational psychosocial categories. The present discussion will focus on the epidemiological literature as they relate to individual, ergonomic, and occupational psychosocial factors.

Individual Factors

Risk factors associated with individual characteristics can be either non-modifiable or modifiable in nature (e.g., Burdorf & Sorock, 1997; Dempsey, Burdorf, & Webster, 1997; Hales & Bernard, 1996; Shelerud, 1998). Non-modifiable variables that have been investigated in work-related musculoskeletal symptoms/disorders studies include: age, gender, medical history/status, height, and weight. However, based on a review of epidemiological studies on work-related low back disorders, Burdorf and Sorock (1997) argued that little emphasis should be placed on variables such as height, weight, and marital status because of the limited evidence supporting their association. Modifiable risk factors attributed to the individual such as smoking, physical fitness/exercise, and individual psychosocial factors may be of more interest because of their value in developing specifically tailored individual behavioral modification/stress reduction programs.

Although little can be done to address the demographic and anthropometric factors, they can provide an indication of the type of person who may have an increased likelihood for a back or upper extremity outcome. Perhaps more importantly, however, is that epidemiological research that focuses identifying workplace stressors must consider (i.e., control for) all of these individual factors, whether modifiable in nature or not.

<u>Non-modifiable individual risk factors</u>

Age

Frequency of low back pain symptoms tend to peak between the ages of 30 to 55 (Shelerud, 1998). A review of epidemiological studies by Burdorf and Sorock (1997) reported on the associations among physical, psychological, and individual risk factors for back disorders. With regard to age, findings indicated that older age either placed a person at greater risk or had no association with a back disorder in a majority of the studies. It was also noted that the prevalence of back disorders tended to increase with age to about 45 to 50 years of age. In a population of active duty enlisted Marines, rates for back-related ambulatory clinic visits tended to increase with age group as well (Huang, 2000). Furthermore, older workers have also been observed to experience symptoms of low back pain over a longer period of time and are more likely to have more time lost from work (Goertz, 1990; Shelerud, 1998).

In upper extremity-related studies, older age has been associated with a greater risk for a self-reported upper extremity disorder among visual display terminal workers (Bergqvist, Wolgast, Nilsson, & Voss, 1995). The likelihood of having reported medically-diagnosed carpal tunnel syndrome has been reported to increase with age among persons who had "ever worked" (i.e., greater than 18 years of age) according to the 1988 National Health Interview Survey (Tanaka et al., 1994).

Gender

Gender generally does not appear to have a significant effect for work-related low back disorders (Burdorf & Sorock, 1997). Additionally, the prevalence and incidence of low back pain appears to be equal for men and women (Garg, 1992; Shelerud, 1998). Some studies have indicated that females may have a slightly increased risk for low back problems. One population-based study of Dutch workers found that women were more likely to report back complaints (Houtman, Bongers, Smulders, & Kompier, 1994), while a separate population-based study in Belgium also found that a self-reported history of low back pain and daily low back pain was predicted by female gender (Skovron, Szpalski, Nordin, Melot, & Cukier, 1994). However, after adjusting for work-related and/or physical load factors, other studies have determined that there were no statistically significant increases in risk for women with medically examined back disorders (Heliovaara, Makela, Knekt, Impivaara, & Aromaa, 1991) or self-reported "long-term" back pain (Liira, Shannon, Chambers, & Haines, 1996).

In contrast to work-related low back disorders, Cherniak (1996) in a review of work-related upper extremity disorders, notes that women are more likely to have work-related upper extremity disorders. Data from the Bureau of Labor Statistics (1999) indicated that females comprised a much larger proportion of cases who had CTS (70.4%) or tendonitis (61.5%) that involved days away from work in 1997. Furthermore, it should be noted that female U.S. federal employees, were more likely to have been diagnosed with CTS as well as receive a non-specific UE diagnosis than male employees (Feuerstein et al., 1998). Results from a study of newspaper employees have also shown that women were at greater risk for having a self-reported work-related disorder in the neck, shoulder, and hand or wrist regions (Bernard et al., 1994).

Medical history / status

It has been suggested that obtaining a comprehensive history that includes occupation, job task description, and potential mechanisms for injury are crucial (Johanning, 2000; Peate, 1994). Items related to medical history such as length of time since last low back episode and frequency of episodes have been associated with future reports of low back pain (Dempsey, Burdorf, & Webster, 1997). A three-year prospective study on commonly used physical examination and history data for employees has found that a history of treatment for pain problems placed a man working in the aircraft industry at a slightly greater risk (risk ratio (RR) = 1.3) for a future acute back injury as determined by a report to the company medical department, filing of an incidence report, or from an industrial insurance report (Bigos et al., 1992). It has also been suggested that sciatica can provide a good indication of the significance of a clinically important lumbar disc herniation (Deyo, Rainville, & Kent, 1992). Prior history of disability has also been shown to predict cases with medically diagnosed occupational low back injuries (Zwerling, Ryan, & Schootman, 1993). In workers with a recently diagnosed upper extremity disorder (i.e., within six weeks), poorer clinical outcome (i.e., composite of symptoms, function, lost workdays, and mental health) at one-month post baseline has been predicted by the number of past upper extremity diagnoses and pain severity (Feuerstein, Huang, Haufler, & Miller, 2000). At 12 months, the number of prior treatments/providers and past recommendation for surgery for a work-related upper extremity problem contributed in predicting who would have poorer outcomes.

Modifiable individual risk factors

Physical fitness / strength

Findings on physical fitness and strength in work-related musculoskeletal disorders have mainly been reported in the occupational low back pain/disorders literature. One classic study on the relationship between aerobic fitness, strength, flexibility and back injuries was conducted in a sample of firefighters by Cady and colleagues (1979). Using a composite fitness index comprised of aerobic fitness, strength, and flexibility, findings indicated that injury incidence over a four-year period was significantly lower among the more fit individuals. However, in a separate study by Battie and colleagues (1989), cardiovascular fitness, as measured by VO_2 max, was not found to predict future reports of back injury. Physical fitness (defined by isometric strength, muscular endurance, and flexibility) was also not found to predict future back injury cases in a sample of nurses (Ready, Boreskie, Law, & Russell, 1993). Dempsey and colleagues (1997) have suggested that while increased physical fitness and strength (i.e., trunk strength) be considered as beneficial factors that may protect against low back pain and disorders and are important from a physiological and ergonomic perspective, it is unlikely that they contribute significantly to the prediction of such outcomes. However, they also note that "physical fitness" in relation to the work-related low back pain/disorder literature is a term that could refer to several items such as muscle strength and physical work capacity. The ambiguity regarding what aspect of physical fitness, if any, is associated with work-related musculoskeletal disorder in general requires that discussion of this variable should make efforts to be as specific as possible.

Smoking

In investigating work-related low back disorders, several authors have suggested that smoking be taken into consideration (Dempsey et al., 1997; Johanning, 2000; Pope et al., 1991). A recent study of employees with work-related low back disorders at a metal stamping plant found that a greater number of cigarettes smoked per day was associated with a greater low back pain intensity as well as lower level of functioning (Oleske, Andersson, Lavendar, & Hahn, 2000). A prospective study comparing workers who smoked to those who did not smoke found that smokers who had a job that required heavy lifting and standing were had 5.5-fold greater likelihood to have low back pain (Eriksen, Natvig, & Bruusgaard, 1999). One mechanism by which smoking may contribute to a low back disorder was proposed by Frymoyer and colleagues (1983) and suggests that nicotine may impact discal metabolism by reducing blood flow.

Findings reporting a link between smoking and upper extremity symptoms or disorders have been less consistent than in the back-related literature. One prospective study of white and blue collar employees in the metal industry found that while there was a three-fold greater likelihood for future shoulder symptoms in smokers compared to non-smokers, there was no significant finding associated for the prediction of other upper limb symptoms (Leino-Arjas, 1998). Smokers with neck and upper extremity symptoms have also been reported to miss work more than non-smokers (Dimberg et al., 1989). However, in this study, smokers were also found to have higher absenteeism for all reasons when compared to non-smokers.

Individual psychosocial

Stress coping style & personality-related factors.

Considering that the experience of stress and how one copes with it may be associated with physical and mental health outcomes (e.g., King, Taylor, Albright, & Haskell, 1990; Kvam & Lyons, 1991; Mason, 1975; Selye, 1956; Sherbourne, Hays, & Wells, 1995), it is important to address the role of stress coping styles. It has been suggested that coping with job stress can involve a focus on the problem/task or emotions/reactions (Latack & Havlovic, 1992). One study of workers who were on sick leave and had low-back pain for at least ten days reported that an avoidant coping style (measured by the Utrecht coping list) predicted functional disability (based on the Roland Disability Questionnaire) after three months (van der Weide, Verbeek, Salle, & van Dijk, 1999). However, the original instrument used to measure coping was not written in English nor were the items specified in the paper. Therefore, it is difficult to determine whether the avoidant coping style involved coping with job stress, pain, or other factors.

In another study of U.S. Army soldiers who had self-reported low back pain within the past 12 months and given the Social Problem Solving Inventory (D'Zurilla, Nezu, & Maydeu-Olivares, 1997), an avoidant approach to problems, a decreased tendency to problem solve, and greater impulsivity/carelessness, were associated with greater physical limitations (Shaw, Feuerstein, Haufler, Berkowitz, & Lopez, under review).

Peate (1994) notes that 55% of patients with acute low back pain believe that it will be a chronic and disabling condition. Therefore, distress associated with and an individual's ability to cope with pain may also be important factors in work-related musculoskeletal disorders and associated outcomes. One such method of coping is "catastrophizing" and refers to "negative self-statements and overly negative thoughts and ideas about the future" (Weisenberg, 1994). Examining low back pain patients, Rosenstiel and Keefe (1983) found that a catastrophizing coping style related to how one adjusted to chronic pain. Catastrophizing was also found to predict poorer clinical outcome in patients with recently diagnosed work-related upper extremity disorders at one and three months post baseline questionnaire (Feuerstein et al., 2000). It also appears that pain coping style plays a role in determining disability as an outcome for both back and upper extremity disorders. Results from a prospective study of low back pain patients indicated that catastrophizing was positively associated with subsequent disability (Burton, Tillotson, Main, & Hollis, 1995). Patients disabled from a work-related upper extremity disorder could also be distinguished from non-disabled patients on the basis of catastrophizing in relation to the pain (Himmelstein et al., 1995). Additionally, catastrophizing also distinguished those patients in this sample with longer durations of disability.

Other personality-related factors in musculoskeletal-related outcomes have been more prominent in literature on upper extremity symptoms/disorders. In a sample of acute carpal tunnel syndrome patients seeking treatment from an orthopedic hand surgeon, 21% were reported to have met the DSM-IIIR diagnostic criteria for at least one personality disorder (Mathis, Gatchel, Polatin, Boulas, & Kinney, 1994). Of these diagnoses, obsessive-compulsive (9%) and paranoid (9%) personality disorders were the most common. Vogelsang and colleagues (1994) reported that CTS patients and non-CTS patients could also be distinguished by performance focus and efficiency, goal directedness, timeliness of task accomplishment, and organization of physical space as assessed by the Lifestyle Approaches Scale (Williams, Moore, Pettitbone, & Thomas, 1992). Among Danish salespersons, an interaction between low control and high levels of perceived competition from other salespeople placed an individual at a greater risk for having self-report symptoms in the neck region (Skov, Borg, & Orhede, 1996).

Family, home, & life.

Recognition should also be given to non-work related stressors that can figure prominently in a worker's life such as family/home and life satisfaction. While little emphasis has been placed on matters associated with a worker's family and life in general in relation to work-related musculoskeletal disorders, they cannot be ignored when considering the daily experiences of a worker (e.g., Ferber, O'Farrell, & Allen, 1991). Based on Frankenhaeuser's (1991) concept of total workload, Melin & Lundberg (1997) have suggested that work and home-related workloads may contribute to musculoskeletal disorders. Ong and colleagues (1995) have also suggested that family burden in particular is related to musculoskeletal disorders and note that working mothers have more health problems and health-related complaints in general than working women without children.

Some research has suggested that these home-related factors may play a role in musculoskeletal morbidity. Compared to healthy controls, a group of ambulatory chronic low back pain individuals were found to have greater levels of family conflict and general stress and lower levels of family control (Feuerstein, Sult, & Houle, 1985). For work-related musculoskeletal disorders in the upper body and arms among dental hygienists, risks have been reported to increase with family overload (Ylipaa, Arnetz, & Preber, 1999). Research on a sample of VDT workers has also found that being a woman with children at home is a risk factor for an upper extremity disorder (Bergqvist et al., 1995). Among patients with compensable work-related upper extremity disorders, a better ability to cope with stress at home has been correlated with working status (Chen, Novak, Mackinnon, & Weisenborn, 1998).

As for general life-related stress, significantly more chronic low back pain patients who reported having at least one stressful life event (assessed by the Inventory of Life Changing Events (Siegrist & Dittmann, 1983) prior to their last substantial aggravation of pain were found to have an uncertain etiology for the pain rather than a known etiology (e.g., herniated nucleus pulposus, spinal stenosis, degenerative spondylolisthesis) (Lampe et al., 1998). U.S. Army soldiers who reported having worries that interfered with life "sometimes" were found to be 2.2-times more likely to be disabled with a back-related diagnosis (Feuerstein et al., 1999). In a sample of metal working employees who had a documented work-related low back disorder, "personal stress" was correlated with general physical health and function (Oleske et al., 2000). A prospective study of low back pain patients receiving workers' compensation reported that living arrangement, family relocation, and financial difficulty were predictive of failure to return to work for patients who were off for less than six months for the claim (Lancourt & Kettelhut, 1992). For patients who were off work for more than six months, failure to return to work was predicted by financial difficulty as well as living arrangement and the length of this arrangement. These studies suggest that in addition to the potential increased risk associated with family/home and life factors for work-related musculoskeletal disorders, these stressors may also play a role in the prognosis with regard to recovery and function.

Ergonomic/Biomechanical Factors

Ergonomics refers to the study of how a worker interacts with his/her work environment and how to best fit the work environment to the worker in order to improve productivity and comfort (Helander, 1997; Kaplansky, Wei, & Reecer, 1998; Stobbe, 1996). Ergonomic risk factors for work-related musculoskeletal disorders include: awkward and/or static postures, repetitive motions, twisting, extended work without rest/breaks, forceful exertions, mechanical stress, vibration, and extreme temperatures (Kaplansky et al., 1998; Stetson, Keyserling, Silverstein, Armstrong, & Leonard, 1991; Tittiranonda, Burastero, & Rempel, 1999).

Biomechanical models (e.g., Armstrong et al., 1993; Garg, 1992) have suggested that excessive physical forces, stress, and strain placed on muscles and tissues can lead to internal physiological changes that subsequently present as musculoskeletal symptoms. One example of how physical/ergonomic stressors can have a physiological impact is when low muscle contraction levels maintained for a long duration result in localized fatigue (NRC, 1999; Rodgers, 1997). Repetitive movements have also been associated with inflammatory responses by the muscles and tendons (Putz-Anderson, 1992). In addition to producing fatigue, vibration can negatively impact internal disc pressure in the back region and microcirculation and nerve conduction in the upper extremities (e.g., Nilsson, Hagberg, Burstrom, & Kihlberg, 1994; Wilder, 1993). While research is continuing to determine whether a causal mechanism or dose-response relationship can be established between exposure to ergonomic risks and musculoskeletal problems, numerous studies have determined that a relationship does exist.

Assessing exposure to ergonomic risk factors may include direct observation, utilizing checklists, or self-report (e.g., Punnett, 1998; Stetson et al., 1991). One method for examining ergonomic risks is the Ovako Working Posture Analysing System (OWAS) (Karhu, Kansi, & Kuorinka, 1977). This observational method was initially developed for workers in the steel industry and involves the rating of back, upper limb, and lower limb postures. Based on these ratings, action categories can be determined that provide an indication of the immediacy for corrective/intervening actions. Another technique for job analysis is that by Rodgers (1992). This method evaluates effort level, duration, and the frequency of activation in specified muscle groups. The Rapid Upper Limb Assessment (RULA) (McAtamney & Corlett, 1993), as the name implies, is specific to analyses of upper limb postures. Ratings are made in accordance to upper arms (i.e., shoulder), lower arm (i.e., elbow, forearm) and wrist postures. Muscle use and force-related scores are also included in the calculation of a grand score that indicates the action level that should be taken for intervention purposes. Keyserling, Stetson, Silverstein, and Brouwer (1993) have also developed a checklist for evaluating upper extremity-related ergonomic risk factors. In this checklist, repetitiveness, mechanical stress, force, posture, and tolls/equipment factors are simply checked off as either occurring or not (i.e., yes/no categories). A self-report measure for ergonomic risk exposure is that used primarily in military settings is the Job Factors subscale of the Job Requirements and Physical Demands Survey (JRPDS) (Marcotte et al., 1997). This survey asks questions about the frequency of certain job-related movements and postures for both the back and upper extremities.

Ergonomic risk factors for work-related low back pain / disorders

Based on various job analysis techniques and assessment methods, studies of work-related low back pain and disorders have found that primary ergonomic/physical risk factors are heavy physical work, static work postures, lifting, twisting and bending, and whole body vibration (NIOSH, 1997; Shelerud, 1998). The following sections describe related findings according to these risk factor categories.

Heavy physical work

Heavy physical work has been defined in different ways. One definition is work that requires high energy demands and/or some measure of physical strength (NIOSH, 1997). Marras et al. (1995) describes heavy physical work as that which imposes large compressive forces on the spine. Swedish residents who reported having moderate or heavy physical demands on the job have been found to have a significantly greater amount of self-reported back pain than those who had light physical demands (Bergenudd & Nilsson, 1988). Also, in a study of oil company employees ($\underline{n} = 10{,}350$), having a job with greater physical demands placed a worker at a moderately increased risk (RR = 1.6) for being a low back injury case (Tsai, Gilstrap, Cowles, Waddell, & Ross, 1992). Although some significant associations for "heavy physical work" and work-related low back pain/disorders have been reported, findings have generally not provided strong support (NIOSH, 1997; Shelerud, 1998). Of the studies finding heavy physical work to place a worker at a greater likelihood for a back-related problem, few of the odds ratios were within a statistically significant range (i.e., greater than 1.0) (e.g., Burdorf & Zondervan, 1990; Johansson & Rubenowitz, 1994; Videman, Nurminen, & Troup, 1990).

Static work postures

Static work postures can cause loads that contribute to the development of fatigue and residual deformation of tissues of the spine (NIOSH, 1997; Shelerud, 1998).

Exposure definitions for static work postures differ in the literature on low back pain and disorders (NIOSH, 1997). However, static postures are common to work that is sedentary and/or involves much sitting or standing. Sedentary work, defined by sitting more than half the time at work, has been identified as a risk factor for disc herniation in persons older than 35 years (Kelsey, 1975). One investigation by Skov and colleagues (1996) involved administering a questionnaire on musculoskeletal symptoms and work-related factors in a sample of salespeople. The results indicated that having sedentary work "all of the time" was associated with a 2.5-fold greater likelihood for the self-report of low back symptoms. Another study that examined spinal pathologies in Finnish males who had died, found that sedentary work was associated with very high risk (OR = 24.6) for symmetric disc degeneration (Videman et al., 1990). A recent review of work-related low back pain studies in the People's Republic of China determined that prevalence ratios ranged from 1.5 to 14.3 for static posture (Jin et al., 2000).

Lifting

Lifting of heavy objects has been fairly well established as a risk factor for work-related low back pain and disorders (Shelerud, 1998). In fact, NIOSH has developed a lifting equation to provide recommendations for appropriate weights that should be lifted based on distance, height, weight, and frequency of the lifting task (Waters, Putz-Anderson, Garg, & Fine, 1993). Studies such as those by Liles and colleagues (1984) have found that the highest level of lifting exposures as determined by the Job Severity Index is associated with a greater incidence of back injury (RR = 4.5). In a study that provided a quantitative level for what constitutes a high risk weight, Punnett, Fine, Keyserling, Herrin, and Chaffin (1991) found that automobile assembly plant workers were more than twice as likely to be a case with a medically diagnosed back disorder if they lifted at least 44.5 Newtons (10 pounds).

Twisting / bending

Twisting and bending can also place a significant amount of force on the lower back that can contribute to work-related low back pain or disorders. Research that compared a healthy low back group to an intermittent low back pain and a chronic low back pain group found that non-neutral working postures were reported more frequently in the intermittent and chronic low back pain groups (Hultman, Nordin, & Saraste, 1995). Stooping has also been associated with a higher prevalence rate ratio of self-reported severe low back pain in construction workers regardless of the duration that the person works in this posture (Holmstrom, Lindell, & Moritz, 1992). In the Punnett et al. (1991) study of automobile assembly plant workers, flexion was associated with odds ratios in the five to six range for a medically diagnosed back disorder depending on the extent of the flexion (i.e., mild or severe). In the same study, twisting or lateral bending had an odds ratio of 5.9 for a back disorder.

Vibration

Back-related problems associated with whole body vibration (WBV) include increases in internal disc pressure, increases in shear flexibility, decreased disc resistance to buckling instability, and paraspinal muscle fatigue (Wilder, 1993). The body's natural frequency is about 4.5 Hz (Pope et al., 1998). It is estimated that approximately 4% to

7% of American, Canadian, and European workers are potentially exposed to high-risk frequencies (Shelerud, 1998). Occupations frequently exposed to WBV are those that involve transportation or operating a motorized vehicle. A review of various vehicle operators has found odds ratios for low back pain to range from 1.6 (fork-lift trucks) to 3.7 (wheel-loaders) (Shelerud, 1998). Bovenzi and colleagues (1992, 1994) have found an odds ratio of 2.8 for male bus drivers, while male tractor drivers had an odds ratio of 3.2 for lifetime prevalence of low back pain.

Ergonomic risk factors for work-related upper extremity symptoms / disorders

Ergonomic risk factors for upper extremity symptoms and disorders include repetition, excessive force, awkward postures, and vibration (Gerr et al., 1991; NIOSH, 1997; Williams & Westmorland, 1993). Studies such as that by Punnett (1998) have found that several observed and/or self-reported risk factors such as non-neutral postures, manual forces in handling tools and parts, mechanical pressures in tool use, and vibration to be associated with an increasing prevalence of upper extremity disorders. The following sections discuss empirical findings for a particular ergonomic exposure and for symptoms/disorders in any/all upper extremity anatomical regions.

Repetition

Numerous studies have indicated that repetitive tasks are associated with upper extremity symptoms/disorders in all UE regions. Using videotaping, observational, and postural analysis methods, Ohlsson and colleagues (1995) examined the relationship between repetitive tasks at an assembly line and neck/shoulder disorders in females as determined by physical examination. Results indicated that exposure to a repetitive task with cycles of less than 30 seconds placed a worker at a 3.6-fold greater likelihood for tension neck syndrome. Another study found case status, based in part on having a shoulder diagnoses, could be predicted by repetitive shoulder rotation with arm elevation at work (OR = 2.3) (English et al., 1995). By using self-reported amount of time spent typing as a measure of repetition, typing 80% to 100% of the working day was reported as having an odds ratio of 2.8 for elbow/forearm symptoms among computer users at a newspaper (Burt, Hornung, & Fine, 1990). Analyses of data obtained from the 1988 National Health Interview Survey have also indicated that self-reported repetitive bending/twisting of the hands/wrists placed a worker at a greater risk for carpal tunnel syndrome (Tanaka et al., 1995).

Force

Unlike the exposure in occupational low back disorders which usually involves lifting or carrying a heavy load, force in relation to upper extremity problems typically involves exertions made in performing a given job task (e.g., Chiang et al., 1993; Osorio et al., 1994). One study did examine letter carriers who carried the weight from mail bags with shoulder straps and found that they reported a significantly greater amount of neck pain than postal clerks (Wells, Zipp, Schuette, & McEleney, 1983). Based on electromyographic recordings in the forearm flexor muscles, Chiang and colleagues (1993) found that high force exertions predicted shoulder girdle pain for men and women (OR = 1.8) and carpal tunnel syndrome in women (OR = 1.6) who worked in a fish-processing factory. The combination of repetition and force also predicted shoulder girdle pain in this sample. Similarly, an investigation of supermarket workers found that high levels of exposure to repetitive and forceful wrist motions had a much greater risk (OR = 8.3) for CTS symptoms compared to workers with low exposure levels (Osorio et al., 1994). Female cases meeting a NIOSH definition for work-related upper extremity symptoms and who normally perform visual display terminal-based word processing for a minimum of three to four hours a day have been observed to apply a greater amount of force in a keyboard task than non-cases (Feuerstein, Armstrong, Hickey, & Lincoln, 1997). In this study, cases also reported experiencing a greater impact of pain on function and higher levels of pain at work.

Awkward / static postures

Risks associated with awkward and/or static postures can come from performing job tasks and conditions of the workstation (NIOSH, 1997). Studies reporting significant findings for neck disorders include those by Hales et al. (1994) that found the use of bifocals in VDT users increased the likelihood of reporting a disorder. It should be noted that "use of bifocals" may involve awkward postures because of the requirement of the worker to extend or flex the neck in order to properly read. Factors associated with sitting such as uncomfortable positions and non-optimally adjusted seats have also been indicated to place workers at greater risks for neck, shoulder, elbow symptoms/disorders (Ekberg et al. 1994; Hoekstra, Hurrell, & Swanson, 1994). Odds ratios of four to five for neck and shoulder disorders in women who performed assembly work have been found for jobs that involve static loads on the shoulders (Ohlsson et al., 1995). With regard to CTS though, a review conducted by NIOSH (1997) suggested that there is insufficient evidence that awkward postures alone are associated with carpal tunnel syndrome. However, in a study of newspaper employees, Faucett and Rempel (1994) reported that decision latitude and supervisor conflict interacted with keyboard height to predict severity of upper extremity numbness.

Vibration

Research on the relationship between vibration and upper extremity symptoms/disorders have primarily focused on occupations that require the use of heavy vibrating machinery. Among a sample of bricklayers, rockblasters, and construction foremen, vibration predicted signs of clinically examined shoulder tendonitis for both sides (OR = 1.7 for right; OR = 1.8 for left) in the rockblasters only (Stenlund, Goldie, Hagberg, & Hogstedt, 1993). Compared to maintenance workers who perform manual tasks, forestry operators who used chain saws were found to be 21-times more likely to have CTS based on symptoms and physical examination (Bovenzi, Zadini, Franzinello, & Borgogni, 1991). Another study of forestry operators who used chain saws also indicated that the odds ratio for vibration white finger was 11.8 when using shipyard workers as a referent group (Bovenzi et al., 1995). A lower odds ratio (6.2) was associated with vibration white finger if only a saw with an anti-vibration mechanism was used.

Suggestions based on the literature

Presently, there is strong evidence implicating that ergonomic factors are associated with work-related musculoskeletal symptoms and disorders. As research continues to investigate the identified risk factors (e.g., repetition, force, awkward postures, duration) and attempts to establish and validate potential mechanisms by which these stressors impact the worker, efforts also are being made to develop ergonomic assessment tools. While several assessment tools are available (e.g., OWAS, RULA, ergonomic checklists), one tool that may be particularly useful is the JRPDS. As a self-report instrument, the JRPDS may help reduce the effort, time, and resources required in conducting ergonomic job analyses. The JRPDS has already been used in research involving military populations (e.g., Feuerstein et al., under review; Marcotte et al., 1997; Smart, Feuerstein, & Haufler, 1998). Therefore, studies should continue to determine its applicability among uniformed personnel. Furthermore, a preliminary investigation has shown that self-report measures including the JRPDS and Borg (1998) Perceived Exertion Scale are correlated with observable ergonomic measures such as the OWAS and Rodgers' method for back-related exposures (Smart et al., 1998). Research that uses the JRPDS can assist with determining its predictive validity in musculoskeletal symptoms and disorders.

Although ergonomic risk factors are an important consideration in addressing work-related musculoskeletal disorders given the current state of the literature, there are studies to suggest that a multidimensional approach to worker health be adopted. In addition to ergonomic stressors, occupational psychosocial factors should also be examined concurrently in related research. For example, a retrospective nested case-control study of workers from the general population indicated that in women, heavy physical workload, sedentary work, and a combination of whole-body vibrations and low influence over work conditions were associated with self-reported low back pain (Thorbjornsson et al., 2000). For men, a greater risk for low back pain was associated with heavy physical workload, sedentary work, high perceived load outside of work, and a combination of poor social relations and overtime. Faucett and Rempel (1994) have found that relative keyboard and seat back heights in conjunction with psychological workload, decision latitude, and employee relationship with the supervisor contributed to the self-report of shoulder/neck/upper back and hand/arm symptoms in VDT operators. Another study of newspaper employees reported that frequent deadlines, high psychological demands (i.e., work pace and conflicting demands), low skill discretion and social support, and more time spent keyboarding, and having a computer screen that was in a non-optimal position all placed one at a greater risk for self-reported upper limb symptoms (Polyani et al., 1997). In addition to upper extremity comorbidity, baseline pain severity, and pain coping style, exposure to ergonomic risk factors and low job support predicted a composite clinical outcome of symptoms, function, lost workdays, and mental health one month later in persons with a recently diagnosed upper extremity disorder (Feuerstein, Huang, Haufler, & Miller, 2000). Since ergonomic factors have not fully explained why a worker may experience a given musculoskeletal outcome (e.g., Werner, Franzblau, Albers, & Armstrong, 1998), research should investigate how both physical and psychosocial workplace stressors are involved in work-related musculoskeletal outcomes.

Occupational Psychosocial Factors

Definitions & concepts

Occupational psychosocial factors have often been discussed in relation to characteristics of work and how it is organized. A term more commonly used to describe these items is "work organization". Yet, despite the increasing attention given to these factors and their impact on the worker and work environment, it is difficult to find a precise or common definition for "work organization". As a result, challenges arise to having a unified approach to understanding and discussing research on work organization and its relation to work-related musculoskeletal disorders and symptoms. More broadly, work organization has been described as "the way work processes are structured and managed" (Amick, Swanson, & Chang, 1999; NIOSH, 1996; Rosenstock, 1997). Hagberg et al. (1995) defines work organization as the manner work is organized, supervised, and carried out. Sauter and colleagues (1999) include management and supervisory practices, production practices, and their influence on work performance in their description of work organization. From these descriptions, the more salient aspects of work organization include work processes and practices, production, performance, and related components such as people, job tasks, and their interaction. Yet, even these areas can encompass a wide range of variables and constructs.

Work organization variables

Generally, work organization factors in the context of worker health connote stressors that are experienced by the worker or refer to an individual's perceptions of his/her work (Lindstrom, 1994). Quick and colleagues (1997) have suggested that work organizational stressors be grouped into one of four types of demands: physical, task, role, and interpersonal. In the National Occupational Research Agenda (NORA), NIOSH (1996) describes work organization as being comprised of six major components. These components are: scheduling, job design, interpersonal, career concerns, management style, and organizational characteristics. These categories closely resemble those proposed in an earlier model by Cooper and Marshall (1976) on the dynamics of work stress. In this model, the sources of stress or exposures are classified as those intrinsic to the job, role in the organization, relationships at work, career development, organizational structure and climate, and the home-work interface.

While these categorizations assist with broadly conceptualizing work organization, the actual variables to which they refer are not always readily apparent. It was reasoned that a systematic search of the scientific literature in the area of work organization might provide a more detailed breakdown of the components of work organization. The search involved obtaining English language abstracts from the MEDLINE (Knowledge Finder, Version 4.22, Aries Systems Corp., North Andover, MA) and PsycLIT databases (American Psychological Association, SilverPlatter Information, Ltd., Norwood, MA) between 1970-1999 and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) database from 1982-1999 (years for which abstracts were available). The keywords that were specified were "work", "organization", "variables", and "factors", in addition to the six terms used to categorize work organization in the National Occupational Research Agenda (NIOSH, 1996) as discussed above. This latter search parameter was incorporated in order to be consistent with earlier efforts to describe the concept of work organization (NIOSH, 1996).

Selection of work organization terms was based on the following criteria: 1) those examined as either dependent or independent variables in their respective study; and 2) those in which a specific operational definition was provided. These terms were further specified as belonging to one of the six NORA work organization categories.

This process was conducted as follows: variables involving temporal qualities of work were placed in the scheduling category; constructs related to operational and/or task characteristics were considered as job design factors; interpersonal and/or relationship aspects of work (i.e., with supervisors and/or co-workers) were included under interpersonal factors; terms related to evaluative aspects of the job or one's career/job future were labeled as career concerns; managerial and/or supervisory characteristics of the job were categorized as management style; and, variables associated with organizational climate and culture of the worker and/or organization were placed in the organizational characteristics category.

All variables/constructs identified in the literature search, in addition to those already given by NIOSH, are listed in Table 2 according to their respective NORA work organization category. Table 2 also gives the number of terms associated with each NORA category from the literature search. A total of 103 work organization terms were obtained from the literature, with those relating to job design as the most common. The present effort was an attempt to methodically organize the literature and suggests that the occupational stress/work organization variables that have been examined, described, and/or discussed can be considered within the context of one of the six NORA work organization categories.

Insert Table 2 here

Review of the literature on work organization and work-related musculoskeletal disorders

In studies involving Huang and colleagues, job stress was consistently observed to be associated with some type of upper extremity-related outcome. As noted previously, one case-control investigation of U.S. Army soldiers found that the self-report of experiencing a high level of job stress significantly predicted disability status related to an upper extremity disorder (Huang, Feuerstein, Berkowitz, & Peck, 1998). In a prospective study of individuals with a recently diagnosed work-related upper extremity disorder, job stress as measured by the Work Stress Subscale from the Life Stressors and Social Resources Inventory (Moos & Moos, 1994) was found to predict a composite outcome of lost workdays, symptoms, function, and mental health at 3-months (Feuerstein, Huang, Haufler, & Miller, 2000). Heightened job stress as determined by the Work Stress Subscale was also found to predict intensity of upper extremity-related pain at work and decreased function in a cross-sectional study of female office workers (Haufler, Feuerstein, & Huang, 2000). It should be noted that the Work Stress Subscale assesses work-related conflicts, perceptions of work pressure, and physical environment.

The pattern of results related to job stress in the aforementioned studies subsequently led the present author to conduct a systematic literature review on job stress (i.e., work organization) and work-related back and upper extremity symptoms and disorders. The intent of the review was to determine the specific aspects of job stress reported to be associated with and/or predictive of such symptoms and disorders. Keywords for the literature search on occupational low back problems were the work organization terms given in Table 2 and "occupational low back", "work-related low back", "pain", "symptoms", "disorders", and "sciatica". For the upper extremity review, search terms were: "upper extremity disorders", "upper limb disorders", "hand/wrist/elbow/shoulder/neck disorders", "symptoms", "pain", "tingling", "numbness", "fatigue", "complaints", and "problems". Additionally, the literature search was limited to English language articles in the MedLine and PsycLit databases from 1970-1999 and in the CINAHL database from 1982-1999. Letters to editors, reviews, and non-peer reviewed papers were excluded. Papers were immediately excluded on the basis of its abstract if they were not specific to work or work organization, reported on back/upper extremity problems that clearly were not associated with work (e.g., sports injury, traumatic event), or was not an empirical study (e.g., case study). Original empirical studies were then obtained if the following selection criteria were met: occupation/job task of the study participants was listed; definition/description of the work organization variable(s) provided; description of assessment methods for both work organization and back/upper extremity outcomes given; and, the relationship between the work organization variable(s) and back or upper extremity outcome was specifically examined/stated.

Work organization measures used in studies of WMSDs

Questionnaires and structured interviews were the most utilized method of assessing the independent variables of interest. These independent variables primarily dealt with decision latitude, workload, and job control. Additionally, it should be noted that social support at work was a commonly investigated area and that job satisfaction was frequently investigated in the back-related studies. While the majority of studies did not indicate the specific questions that were used, several papers did note the references from which items were obtained and/or adapted. Of the questions used to measure occupational psychosocial/work organization factors, those by Karasek (1979, 1985), Karasek and Theorell (1990), and Rubenowitz (1984, 1997) were the most frequently referenced. Other measurement tools included: the Occupational Stress Questionnaire (Elo, Leppanen, Lindstrom, Ropponen, 1992); the NIOSH General Job Stress Questionnaire (Hurrell & McLaney, 1988); the Job Characteristics Inventory (Sims, Szilaqyi, & Keller, 1976); the Job Diagnostic Survey (Hackman & Oldham, 1974); and the Work Environment Scale (Insel & Moos, 1974). Bergenudd and Nilsson (1988), Bigos et al. (1991), Kamwendo, Linton, & Moritz, (1991), Leino and Hanninen (1995), Papgeorgiou et al. (1997), and van Poppel et al., (1998) also provided the actual questions given to study participants in their investigations.

Work organization and work-related low back pain/disorders

After examining the abstracts related to occupational low back pain/disorders, some additional studies were excluded because the outcome of interest was not specifically low back pain or disorders (e.g., return to work, sick leave related to back pain, disability). In some studies, it was not clear that the back problem was of an occupational nature. That is, while work-related variables were examined, the study sample was one with reports of back pain obtained from the general population. From these additional criteria, 26 articles were selected for review. Table 3 summarizes these studies by listing the work organization variables examined, measures used to assess these variables, and study findings. The following sections discuss the work organization measures that were used and findings as they relate to symptoms/disorders in the low back region.

Insert Table 3 here

A majority of the studies selected for review used a cross-sectional design. Specifically, 19 (73.1%) investigations utilized questionnaires to cross-sectionally examine the association between work organization variables on work-related low back pain/disorders. Of these studies, job control/discretion (job strain) and/or job demands were among the most commonly observed work organization factors found to be significantly associated with back pain/disorders. Myers and colleagues (1999) reported that "medium" (OR = 1.7) and "high" (OR = 2.1) levels of job strain as measured by the Job Content Questionnaire (Karasek & Theorell, 1990) were associated the medical documentation of low back pain in Baltimore city workers. In a sample of manual workers, delivery drivers, computer operators, and general office staff, an occupational psychosocial index consisting of high mental demands and low job control was found to place both men and women at a 2.4-fold greater likelihood for having reported self-reported low back pain within the past seven days (Devereux, Buckle, Vlanchonikolis, 1999). Hagen, Magnus, and Vetlesen (1998) also reported that high psychological demands assessed by items from Karasek (1979) to be associated with low back symptoms in the past 12 months. Men employed at a supermarket or municipal power distributor who had self-reported low back pain were found to report lower levels of job discretion, higher job demands, lower recognition at work, higher subject workloads, perceive higher levels of competition, be less satisfied with their jobs (Foppa & Noack, 1996).

Social relations at work were also indicated as a risk factor for work-related back outcomes. While there were no significant findings for work organization variables among carpenters or machine operators, among male office workers, "problems with workmates or supervisor" (RR = 1.9) was associated with a three-year cumulative incidence of self-reported sciatic pain (Riihimaki et al., 1994). A similar risk ratio (1.9) for self-reported back pain in the previous month was found for "difficult human relations at work" in nursery school cooks (Ono, Shimaoka, Hiruta, & Takeuchi, 1997). In examining another aspect of relations with others at work, Skov and colleagues (1996) found that having the "least" amount of contact with colleagues placed salespersons at a 1.8-fold greater likelihood for self-reported low back pain within the past month.

It should be noted that some studies did not find any relationship between work organization and low back pain/disorders. Engstrom, Hanse, and Kadefors (1999) reported that neither decision latitude, social support at work, or psychological workload were correlated with self-reported back symptoms. However, decision latitude was significantly correlated with upper extremity symptoms, while workload was correlated with neck/shoulder symptoms. In a sample of bus drivers, truck drivers, and sedentary workers, relationships with co-workers/supervisor and job satisfaction were not found to be associated with self-reported low back pain in the study by Magnusson, Pope, Wilder, and Areskoug (1996). Although the items assessing relationships at work in this study were more specific to social support rather than the nature of interactions with co-workers/supervisors as in the other studies that reported significant findings.

In the prospective investigations, work organization variables found to predict low back pain/disorders were similar to those in the cross-sectional studies. In a study that specifically examined psychosocial work factors and musculoskeletal morbidity in blue- and white-collar employees, work content and social relations at work were associated with a ten-year change in physically examined low back symptoms in only the blue-collar workers (for both men and women) (Leino & Hanninen, 1995). Krause, Ragland, Fisher, and Syme (1998) found that high psychological demands (OR = 1.5) and high job satisfaction (OR = 1.6) predicted the incidence of a back sprain, strain, contusion, or pain among transit operators. High job demands (PRR = 2.0) were also predictive of self-reported back pain in civil service workers (Verbeek & van der Beek, 1999).

Work organization and work-related upper extremity symptoms / disorders

Upon examining the abstracts relevant to work organization and work-related upper extremity problems, 37 met the selection criteria. The literature on work organization and work-related upper extremity symptoms and disorders was found to include a variety of occupations, work organization variables, and measures. Summaries of the reviewed studies are presented in Table 4. Specifically, the work organization variables examined, measures used to assess these variables, and study findings are listed.

Insert Table 4 here

Work organization and shoulder / neck symptoms and disorders.

Of the studies that distinguished findings by anatomical region, 25 (64.1%) reported significant relationships between work organization and symptoms and/or disorders in the neck and/or shoulder. Furthermore, these studies were predominantly cross-sectional in design. It should be noted that findings for both the shoulder and neck regions were often grouped together and, therefore, are discussed accordingly in the following section. However, results are specifically described as being related to shoulder or to the neck whenever possible.

Although different work organization variables were examined in the cross-sectional studies, decision latitude and/or work demands were among the most common ones observed to have an effect on neck and/or shoulder symptoms and disorders. Studies that reported effect sizes for these items as odds ratios include Bernard and colleagues' (1994) research on newspaper employees that found modest effects for low decision latitude (OR = 1.6) and perceived increased pressure (OR = 1.5) on shoulder symptoms. In telecommunication employees, the lack of decision-making opportunities has been reported to place an individual at a 4.2-fold greater likelihood for having a NIOSH case definition for a neck disorder (Hales et al., 1994). A 4.5-fold greater risk for shoulder symptoms occurring more than once per month or having lasted more than one week in the previous year was indicated for low decision latitude (based on Karasek's (1979) Job Stress Questionnaire) in aluminum smelter workers (Hughes, Silverstein, & Evanoff, 1997). Another aspect of job control, influence on work schedule was also a moderate risk factor (OR = 1.9) for shoulder disorders in the Lemasters et al. (1998) study on carpenters. Skov et al. (1996) found that low control over time predicted neck symptoms (OR =1.4), while high work demands (OR = 1.5) was a risk factor for shoulder symptoms in the past 12 months. Low work control (OR = 1.7) and high work demands (OR =1.8) were also found to be associated with self-reported shoulder symptoms in another study of female nursing personnel (Lagerstrom, Wenemark, Hagberg, & Hjelm, 1995).

Only one prospective study (Lindstrom, Leino, Seitsamo, & Torstila, 1997) reported significant findings for neck/shoulder problems in a sample of visual display terminal (VDT) users. Neck- and shoulder-related complaints as determined by the self-report of pain and ache were initially (i.e., at baseline) found to be related to high physical workload (i.e., monotonous and repetitive work movements, "unpleasant" work positions, factors in physical environment, and boundness to work). Eight years later, VDT breakdowns, amount of use, high physical workload, and lack of job content variety and control predicted neck and upper limb complaints. Analyses were not conducted separately for the neck and the upper limb regions.

Work organization and hand / wrist / arm / elbow symptoms and disorders.

While fewer studies found a relationship between work organization and symptoms/disorders specifically in the arms, elbows, wrists, and/or hands, some work organization risk factors were similar to those for neck/shoulder outcomes. Hales and colleagues (1994) reported that lack of decision-making opportunities (OR = 2.8) and surges in workload (OR = 2.4) were associated with self-reported elbow disorders, while high information processing demands (OR = 2.3) were related to hand/wrist disorders. Lack of work stimulation (OR = 1.6) was also found to be a risk factor for self-reported hand symptoms among female nursing personnel (Lagerstrom, Wenemark, Hagberg, & Hjelm, 1995). However, Hughes, Silverstein, and Evanoff (1997) indicated that work organization variables alone were not related to upper extremity outcomes in the hand/wrist/arm/elbow locations.

In addition to these individual risk factors, an interesting pattern was noted in these papers. In the investigations by Faucett and Rempel (1994) and Bergqvist, Wolgast, Nilsson, & Voss (1995), a combination of work organization ergonomic exposure was significantly associated with self-reported hand/wrist/shoulder and arm/hand symptoms, respectively. Furthermore, Silverstein and Hughes (1996) reported that high decision latitude (as opposed to low decision latitude for shoulder/neck outcomes) was associated with abnormal median and ulnar nerve tests.

Among the studies included in the present review, none examined work organization in relation to the hand/wrist/elbow/arm regions specifically. Two prospective studies (Leino & Hanninen, 1995; Lindstrom, Leino, Seitsamo, & Torstila, 1997) did look at "upper limb" problems, but did not report findings based on the upper extremity regions of interest.

Suggestions based on the literature

The review of the literature found that while "job stress" was a risk factor (e.g., Marcus & Gerr, 1996), a number of specific work organization stressors could be identified and were correlated with or predictive of work-related musculoskeletal symptoms and disorders. Of these variables, job demands, workload, and decision latitude/job control were among those that were more consistently found as risk factors.

It appears that there is a greater degree of association between these job design variables and symptoms/disorders in the upper extremities than for problems in the low back region. Nevertheless, efforts that examine job design and low back disorders/pain should still be continued since relatively few studies have been conducted in this area. Perhaps more importantly though, is that there is a need for research that investigates other types of work organization variables. As noted, descriptions/discussions of work organization have typically involved other psychosocial aspects of work such as interpersonal factors, supervision, practices, and organizational characteristics (Hagberg et al., 1995; NIOSH, 1996; Sauter et al., 1999). In the available literature, it is unclear how work organization factors other than job design are associated with work-related musculoskeletal outcomes.

Models of Job Stress/Work Organization and Health

While it is important to know what job stress/work organization involves and those variables that have been identified as risk factors for WMSDs, such knowledge is limited unless placed within the context of hypothesized relationships (i.e., models) between exposure and health. Earlier works by Cannon (1932), Selye (1956), Lazarus (1966), and Levi (1972), among others, have given rise to a number of general theories and models of stress. These theories and models range from an exclusive focus on individual factors such as age, gender, coping and problem solving abilities, and emotional predisposition (e.g., negative affectivity) (e.g., Lazarus, 1966, Levi, 1972, Cox, 1978) to those that emphasize environmental factors such as demands, interpersonal relations, technology, and physical exposures (e.g., French, Caplan & van Harrison, 1982; Karasek & Theorell, 1990; Smith & Carayon-Sainfort, 1989). Furthermore, models of psychosocial stress and illness suggest that a stimulus (i.e., stressor) or set of stimuli trigger an acute stress response that typically includes a cascade of physiological changes that if persistent or recurrent, can lead to the onset of symptoms and subsequent illness. Accordingly, psychosocial stressors under study in a given research or clinical investigation can vary significantly depending on the model that is used.

General models of job stress and health originate from the basic theories of stress. As with the general stress models, job stress models can be categorized based upon their relative emphasis on either individual or environmental factors. The Siegrist (1998) effort-reward imbalance model places a greater emphasis on the individual while models such as Karasek's (1979) psychological demand/decision latitude model is one example of an environmentally focused model. The Hurrell and McLaney (1988) model of job stress represents a hybrid model that incorporates both environmental and individual factors. Each of these models is discussed in the following section.

Siegrist (1998) model of effort-reward imbalance at work

The model of effort-reward imbalance (Siegrist, 1998) centers around the assumption that for adults, work role (i.e., occupation) is key to providing a person with opportunities to perform, make contributions, be rewarded or valued, and/or have a sense of belonging to a particular group. Within a social context, efforts are made with the expectation that there will be reciprocity. At work, such reciprocity involves rewards such as money, esteem, or status control (e.g., social role, interpersonal rewards). According to the model, when costs outweigh gains and an imbalance between efforts and rewards exists, a state of emotional distress arises and there is a likelihood for autonomic arousal and physiological strain reactions (Siegrist, 1996).

As part of the efforts portion of the model, Siegrist (1998) describes two sources from which high efforts at work may come. One source is labeled "extrinsic" and involves the demands and obligations of the job. The other source is called "intrinsic" and comes from the motivations of an individual worker in a given work situation (see Figure 1). This intrinsic source can be a pattern of coping and has been referred primarily in terms of a "need for control" (Siegrist, 1998). By having a coping style that is rooted in a need for control, a worker may exert much energy and/or immerse himself/herself a great deal in his/her work although there is little to be gained. While it may seem that maintaining such a coping style for extended periods of time would be difficult, Siegrist (1998) argues that at work, other possible costs from abandoning this input of effort (e.g., being laid off, downward mobility) must be taken into account to explain the high efforts on the part of the worker.

Insert Figure 1 here

The concentration placed on one's coping pattern is the reason this model is considered as more of an individual-centered than environment-centered conceptualization of job stress. By addressing characteristics of the worker, the model suggests that approaches targeting a worker's coping style, need for control, social skills, and/or beliefs/cognitions on what constitutes a reward may reduce the experience of job stress. Furthermore, stress management techniques that have shown some potential in assisting workers with stress-related health problems such as exercise, muscle and relaxation training (DeFrank & Cooper, 1987; Hurrell & Murphy, 1996; van der Hek & Plomp, 1997) may prove beneficial to this subgroup of individuals. However, as a model that focuses on individual coping style, it was not designed to address work organization factors. As such, the model does not explain what may be expected if interventions were targeted at work organization variables. Additionally, the effort-reward imbalance model does not discuss how physical stressors play a role in health outcomes such as WMSDs.

Demand / decision latitude model (Karasek, 1979)

A classic model of work organization and health is the psychological demand/decision latitude model (Karasek, 1979) shown in Figure 2. According to this model, the interaction between the levels of psychological demands and the workers' level of decision latitude, or control, can contribute to a variety of health outcomes. From these two components, four types of interactions are possible. The "passive" situation involves low levels of demands with low decision latitude (control). While there are few adverse affects on health, it is proposed that this situation results in a loss of skill and eventual atrophy of one's ability to cope (Theorell, 1998). Conversely, high levels of psychological demands coupled with high levels of control results in psychological growth and the development of new coping patterns. The ideal situation is called the "low-strain" situation and involves the combination of low demands and high levels of decision latitude. In the fourth combination, a high-strain situation, a worker has high levels of psychological demands but low levels of control. It is hypothesized that this high strain situation places the individual at the greatest risk for psychological strain and physical illness.

Insert Figure 2 here

The utility of this model comes from the fact that it specifically hypothesizes how decision latitude and job control interact to contribute to a given health outcome. However, the model is somewhat narrow in scope in relation to the broad array of work organization/job stress variables that make up the possible universe of stressors. Also, similar to the effort-reward imbalance model, the demand/decision latitude model was not directly developed for consideration of work-related musculoskeletal disorders and therefore does not address other potential risk factors such as ergonomic exposures.

<u>Model of job stress and health</u> (Hurrell & McLaney, 1988)

In a model that proposes a relationship between workplace stress and health, Hurrell and McLaney (1988) primarily utilize work organization variables as their sources of job stress (see Figure 3). In this model, "job stressors" are listed as: physical environment; role conflict; role ambiguity; job control; interpersonal conflict; work load; responsibility for people; underutilization of abilities; cognitive demands; and shift work. It is suggested that these variables contribute to acute psychological, physiological, and/or behavioral reactions that subsequently can produce outcomes such as a medical diagnosis (e.g., disorder) and disability. Individual factors such as age, gender, and job title, as well as non-work factors (e.g., domestic/family demands) and "buffer" factors (e.g., work and non-work-related social support) are integrated into the model as moderators of the mechanism by which work organization factors lead to the acute reactions.

Insert Figure 3 here

In illustrating the role of work-related stress in both physical and mental health, this model highlights several specific variables. It also brings particular attention to the role of occupational psychosocial variables. However, in its description of job stressors, physical and psychological stressors all are placed into a single category. From this categorization, there seems to be an underlying assumption that there is little or no difference between these two types of stressors in terms of how they may contribute to health outcomes. If so, it follows that the mechanisms by which these stressors act are similar. Although there may be a common mechanism by which physical and psychological factors act, research is needed to determine whether such a possibility exists. Additionally, since there are a variety of work organization and physical stressors to which one can be exposed, a broad view of job stress makes it difficult to distinguish if one, some, or all variables should be targeted in treatment/intervention/prevention efforts. Therefore, it is important that this model be considered as a general model that provides an overarching framework for understanding how adverse health outcomes may be tied to work-related factors.

Multivariable Models of Work-related Musculoskeletal Symptoms / Disorders

Generic models of job stress are helpful in providing an overall conceptualization of how occupational psychosocial factors may influence health in general. However, these models were not intended to specifically address the relationship between occupational stress and WMSDs. In accordance with the different types of risk factors reported in the literature, models addressing work-related musculoskeletal disorders tend to be multidimensional in nature. Some of the more prominent models, which will be discussed, incorporate principles from physiology, human factors engineering/ergonomics, biomechanics, and psychology. From such frameworks, theoretical contexts are provided for guiding future research and prevention efforts.

<u>Dose-response model for work-related neck and upper-limb musculoskeletal disorders</u> (Armstrong et al., 1993)

A dose-response model developed by Armstrong and colleagues (1993) highlights the importance of mechanical and physiological factors in work-related musculoskeletal disorders. A schematic conceptualization of this model is shown in Figure 4. In this model, external exposure to work requirements can cause internal doses such as tissue loads and metabolic demands. Mechanical, physiological, or psychological changes, called internal "disturbances", are believed to result from the internal doses. Such internal disturbances may involve changes in tissue shape, ion concentrations, or cellular processes in the body. When repeated or sustained doses and responses occur, a worker's ability to adapt to the internal changes may be improved or compromised. If the capability for adapting to the changes is compromised, then muscle, tendon, or nerve-related disorders result.

Insert Figure 4 here

One strength of this model is the use of the dose-response relationship concept between exposure to biomechanical factors and a musculoskeletal outcome. This concept is viewed as a necessary prerequisite for determining the plausibility of an exposure – outcome relationship and can help guide research on the biological plausibility of such a relationship (Wells, 1997). However, the lack of attention given to psychological factors limits its ability to provide a more comprehensive perspective on how both physical and psychological factors might interact. While the involvement of psychological factors is acknowledged, the model is unclear on how these factors influence the biomechanical dose-response relationship. Furthermore, the model does not consider how biomechanical, physiological, and psychosocial factors all combine to produce a musculoskeletal outcome.

<u>Epidemiological model of musculoskeletal disorders</u> (Bongers et al., 1993)

The model described by Bongers and colleagues (1993) was developed in light of the epidemiological evidence for musculoskeletal disorders. Their model, illustrated in Figure 5, combines concepts utilized in research on stress and health, the personalities of chronic pain (i.e., back pain) patients, and the epidemiology of musculoskeletal disorders.

It is hypothesized that work-related psychosocial factors, in conjunction with one's ability to cope, can lead to increases in work-related stress. This stress subsequently results in increased muscle tone and/or a moderation of mechanical loads. In the case of increased muscle tone, musculoskeletal symptoms may arise via a specific physiological mechanism such as a neuroendocrine pathway. With regard to the association between work-related stress and mechanical loads, musculoskeletal symptoms may be produced as a result of an enhanced perception of symptoms and/or a reduced ability to cope with these symptoms. Regardless of the pathway by which musculoskeletal symptoms occur, it is further hypothesized that these symptoms can in turn become chronic and lead to disability and/or increased health care utilization.

Insert Figure 5 here

One difference between the epidemiological model by Bongers and associates and other musculoskeletal models is its presentation in the context of a comprehensive, systematic evidenced-based literature review. Based on the results of the review, specific variables (i.e., monotonous work, time pressure, and perceived high work load) were found to have a positive association with musculoskeletal problems. It was further concluded that low control and poor social support at work were likely to be positively associated with musculoskeletal problems independent of increased mechanical loads. The hypothesis that perceived stress or stress symptoms play an intermediate role between occupational psychosocial factors and the onset of musculoskeletal symptoms was also supported by some studies that measured stress symptoms before the development of musculoskeletal symptoms. While Bongers and colleagues did not intend for the model to be explanatory, but rather a framework for understanding the literature, the criteria used the literature review helped to provide empirically supported arguments for their proposed associations/mechanisms. However, there are limitations in the literature that must be taken into account and suggest that one exercise caution in making conclusions about such associations/mechanisms. Specifically, as noted by Bongers and her colleagues, more longitudinal studies should be conducted to further elaborate the proposed associations according to the models. The model was primarily based on literature related to back and neck pain or disorders and did not directly address the range of upper extremity disorders observed in the workplace. Also, there is very little information provided on potential underlying biological processes. It should be emphasized however that this was not the major purpose of the model.

Ecological model of musculoskeletal disorders (Sauter & Swanson, 1996)

Sauter and Swanson's (1996) ecological model incorporates psychosocial, biomechanical, and cognitive factors in explaining musculoskeletal outcomes as illustrated in Figure 6. The model also is specific to those persons whose work involves visual display terminals/office technology and was designed to explain the etiology of work-related upper extremity symptoms/disorders. The model has been recently tested through path analyses (Amick, Swanson, & Chang, 1999).

Insert Figure 6 here

According to the ecological model, a biomechanical component that involves physical demands and biomechanical strain is proposed to be the primary mechanism by which musculoskeletal symptoms occur. However, the psychosocial/stress component and cognitive component (i.e., somatic interpretation) of this model play moderating roles. The psychosocial/stress component, which involves work organization factors, along with individual factors are primary influences on psychological strain. This psychological strain, can subsequently impact the biomechanical strain that a worker experiences, ultimately leading to an adverse musculoskeletal-related outcome such as increased symptom reporting, increased health care utilization, performance problems, and disability. Although the manner in which psychological strain mediates biomechanical strain has yet to be determined, based on past studies, Sauter and Swanson (1996) suggest that mood disturbances, increased worries, fatigue, and sleep problems may have an intermediary effect. Work organization can also influence the physical demands that a worker experiences by influencing how a job task is performed (e.g., typing). Therefore, work organization is proposed to play an indirect role in the causal mechanism for a musculoskeletal outcome.

The cognitive component of this model is an interesting aspect that should be noted. Bodily sensations that are detected by the individual may be attributed to a number of factors and may partially account for some of the variance in work-related musculoskeletal disorders. Attribution theory states that individuals are psychologically uncomfortable when they cannot explain bodily symptoms (Cioffi, 1996). Therefore, to understand why one is experiencing symptoms such as fatigue or pain, he/she may attribute these sensations to the workplace although another cause may also be feasible (e.g., home-related duties, hobbies). However, this model does not rule out a worker's ability to accurately attribute the cause for their distress and/or symptoms to work-related factors (either psychosocial or physical). Schaubroeck and colleagues (1998) found that negative affective traits (i.e., trait anxiety) did not explain correlations between job stressors or work attitudes across jobs among individuals who worked part-time in a military reserve unit and who also had a full-time job in a separate organization. This finding suggests that among workers who might be predisposed to viewing their world in a negative way, their view does not necessarily bias their reporting of their experience of workplace stressors. While this model is comprehensive, it needs to explicate the temporal relationship among its various components in more detail. Additionally, although a very complicated goal, it would be helpful for validation purposes if future versions elaborate on the specific pathways linking exposures and cognitive processes to outcomes and their biological substrates.

Biopsychosocial model of job stress (Melin & Lundberg, 1997)

According to a biopsychosocial stress model developed by Frankenhaeuser (1991), psychological stress could stem from excessively high demands that can exceed an individual's ability to deal with them or from demands that are too low (e.g., monotonous work situations) that do not challenge the individual enough. Melin and

Lundberg (1997) applied this model to explain the relationship between mental and physical stressors and how they may affect hormonal stress responses and muscle tension (see Figure 7). The Melin and Lundberg model proposed that mental and physical stressors from one's workload produce physiological responses while at work. Although delineating the array of specific stressors was not a primary objective in the model description, stressors such as monotonous and repetitive work tasks, high workpace, and low job satisfaction are cited. These mental or physical demands could each separately result in increased muscle tension as well as increased cortisol and catecholamines activity. However, the combination of both types of demands would produce an even greater increase of these items (Melin & Lundberg, 1997). The model also addresses post-work activity (i.e., when a worker returns home) when it is generally assumed that the stress response associated with exposure to work tasks and/or the work environment subsides or recovers. Specifically, this model proposes a contrary notion that a full recovery to levels prior to exposure to the work stressor(s) may not occur. That is, after work, the stress response may continue in the form of sustained muscle tension and/or secretion of adrenaline and cortisol. Furthermore, should the individual be exposed to other workloads such as household work or child-care, the recovery may be to a lesser degree. As the physiological stress response persists over time, a worker may be placed at greater risk for a musculoskeletal disorder.

Insert Figure 7 here

By suggesting that the concept of "total workload" (i.e., work and home factors) (Melin & Lundberg, 1997) be adopted, it is important to distinguish the influence of job stressors on WMSDs from home-related stressors. Such information should prove potentially useful when developing innovative methods for treatment and/or prevention/intervention that may have a spread effect on both sources of stress.

This model represents a very important addition to the emerging models used to help explain the link between job stress and WMSDs. Yet, the model, at present, tends to focus more on the potential physiological processes in response to stress than on identification of specific dimensions of the workplace or the worker that might contribute to excessive levels of stress or the lack of physiological recovery following work.

Balance theory of job design and stress (Carayon, Smith, & Haims, 1999)

Based on a model that originally described the potential relationship between job stress and health in general (Smith-Carayon-Sainfort, 1989), Carayon, Smith, and Haims (1999) described a model specific to work-related musculoskeletal disorders (see Figure 8). In this model, the work system, short-term stress responses, and long-term stress outcomes are hypothesized to work in a "feedback loop" manner. In addition, individual characteristics of the worker such as personality, perceptions, experience, health status, and knowledge/skills can concurrently influence each of these items. The feedback loop characteristic of the model suggests that once a long-term outcome results, it can also impact the individual by subsequently influencing how the work system and/or short-term stress responses maintain and/or exacerbate a negative outcome. For example, a short-term stress reaction such as increased muscle tension can result in a WMSD (long-term outcome), which can then affect the individual's perception of work organization (Carayon et al., 1999).

Since work organization can play a key role in defining the nature and parameters of the job task, it also influences perceived levels of occupational stress that can stem from technology, the organization (e.g., career considerations, job security, climate), the task (e.g., workload, repetition), and the environment (e.g., physical, social). Figure 9 illustrates how these factors comprise the work system and are proposed to impact the worker. As a whole, work-related stressors (e.g., work organization, technology, work environment) can lead to short-term stress responses on emotional, physiological, and/or behavioral levels. Using a psychobiological mechanism, Smith and Carayon (1996) give an example of how this model operates with regard to "cumulative trauma disorders". Job stress associated with increased work pressure could result in increased corticosteroid levels. Fluid retention that results from the increased corticosteroid levels can in turn produce a nerve compression that causes pain and/or parethesia. They also argue that work organization can moderate the role of ergonomic risk factors. More precisely, Carayon et al. (1999) suggest that work organization can influence on the degree of repetitiveness, the strength of the ergonomic factors (e.g., static jobs, machine pacing), exposure to ergonomic factors, and exposure to poor physical environment.

Insert Figures 8 & 9 here

The balance model highlights the need to consider the potential interaction among workplace stressors. Additionally, by taking into account how a change in one area of the work system may cause a change in another, the model adds another important consideration for developing strategies targeted at helping the worker. It is recommended that in order to reduce any detriment to the worker, any negative impact associated with one element should be compensated for or balanced out by the other elements. This suggestion is specific to this model and may be further benefited by delineating the biological pathway(s) that explain the process by which WMSDs occur. The model also does not clearly describe or define what an optimal balance is or how it can be measured. It is possible, therefore, that this balance may vary for each individual worker and would need to be determined on a case-by-case basis. This possibility may prove to be a significant challenge for an organization-wide implementation of interventions. As a systems-based model though, organizational intervention may be feasible but just has not been specified. In addition, given that a temporal description (i.e., short-term, long-term) is used when discussing outcomes, addressing what these time frames actually are and how they relate to the recurrent or episodic nature of both the stressors and the symptoms should help clarify how stress results in the experience of upper extremity symptoms/disorders/disability.

Workstyle model (Feuerstein, 1996; Feuerstein, Huang, & Pransky, 1999)

The workstyle construct (Feuerstein, 1996; Feuerstein, Huang, & Pransky, 1999) has been defined as an individual pattern of cognitions, behaviors, and physiological reactivity involved in performing a job task. It has been proposed that a certain workstyle response to increased work demands can result in a cascade of physiological changes that if repeatedly evoked can contribute to the development, exacerbation, and/or maintenance of work-related upper extremity symptoms. This high-risk workstyle can be triggered by an increase in actual work demands or perceived increase in demands that are self-imposed by the worker. Based on this construct, a multidimensional model has been developed that incorporates psychosocial (individual and occupational), ergonomic, and medical factors (Figure 10). In this model, workplace psychosocial stressors in combination with work demands and ergonomic stressors can trigger a response to work that, in turn, leads to the musculoskeletal hazard chain (i.e., symptoms, disorders, disability). These symptoms, disorders, and/or disability, which can be intense and prolonged, can further moderate the workplace stressors that are experienced and continue to elicit an adverse workstyle.

Insert Figure 10 here

The workstyle model provides an integrating framework to help explain how job stress and ergonomic exposures might interact to contribute to UE symptoms, disorders and disability. Consequently, potential avenues are given for decreasing ergonomic and work organization risks on both individual and organizational levels. However, the workstyle construct requires validation as independent from job stress in general and the various components of the model remain to be tested. That is, there is a particular need to develop a measure of the construct that has acceptable psychometric properties.

Additionally, the model proposes that workplace psychosocial stressors and work demands impact behavioral, cognitive, and physiological responses by the worker, but it does not specifically detail the exact dimensions of these components of the stress response. While work organization factors may be possibilities for what these workplace psychosocial stressors and work demands refer to, further work is required to delineate these components as well. Lastly, underlying biological processes need to be specified in greater detail and specific biologically plausible pathways delineated.

Proposed model for the combined effect of work organization and ergonomic factors in work-related musculoskeletal disorders

It is suggested that of the multivariable models given, the Workstyle model (Feuerstein, 1996; Feuerstein, Huang, & Pransky, 1999) has particular promise for understanding the occurrence of work-related musculoskeletal outcomes. The reason for its utility is because of its incorporation of workplace physical and psychosocial stressors, description of their interaction, and provision of a potential mechanism for musculoskeletal symptoms, disorders, and disability. Although the model is not specific in its description of work organization, it does provide a framework for including particular work organization variables. Therefore, this model can guide research that extends what has been reported in the literature with regard to ergonomic and work organization stressors.

Figure 11 illustrates an extended version of the Workstyle model in predicting work-related musculoskeletal symptoms and subsequent health care visits. This model indicates the dimensions of work organization that are potentially involved and also includes the role of modifiable and non-modifiable individual characteristics. The proposed model separates the six NIOSH work organization categories into the workplace psychosocial stressors and work demands categories of the original Workstyle model. Work organization categories that are included in workplace psychosocial stressors are Interpersonal, Career Concerns, and Organizational Characteristics. Job Design, Management Style, and Scheduling are the three work organization categories considered as work demands in the model.

In addition, decreased job satisfaction has been included among the cognitive responses to workplace physical and psychosocial stressors in the modified model. While job satisfaction is believed to involve both cognitive and affective influences, studies on job satisfaction measures suggest that cognitive considerations (e.g., appraisal of job, evaluation of conditions, perceived opportunities) play a more important role (e.g., Moorman, 1993; Organ & Near, 1985; Williams, 1988).

Insert Figure 11 here

According to the model, the hypothesized mechanism by which work organization and ergonomic stressors lead to musculoskeletal symptoms involves behavioral, cognitive, and/or physiological reactivity of the worker to work demands. Support for each of these aspects come from observational and laboratory-based studies. A laboratory study of sign language interpreters by Feuerstein and Fitzgerald (1992) compared those who were working with pain to those who were not. All study participants were given a standardized interpreting task and videotaped to assess the repetition of hand/wrist motions, work-rest cycles, postural stress, and fluidity of movements. The results showed that increased pain was associated with increases in hand/wrist deviations and that increased fatigue was associated with fewer rest breaks. The group working with pain also had significantly less rest breaks, higher hand/wrist deviations, work envelope excursions, and pace of hand/finger movements. In another investigation that utilized videotape assessment methods, Pascarelli and Kella (1993) observed that some (26%) disabled keyboard operators with upper extremity (i.e., hand, wrist, forearm, elbow, shoulder) pain tended to use the keyboard with greater "vigor and rapidity". Feuerstein and colleagues (1997) also found that persons with a NIOSH case definition for work-related upper extremity symptoms tended to use more force on a keyboard than controls. Based on measures of work demands and job stress, cases in this study also were found to have greater workload variance pressure and lower social support from co-workers, supervisors, and family. Although not specifically examined in these studies, there exists the possibility that these persons approach a work task in their respective manner because of increased work demands and/or workplace psychosocial stressors as well as physical requirements resulting from non-optimal ergonomic conditions (e.g., Faucett & Rempel, 1994). While further research is required to test this possibility, these findings suggest that a combination of job stressors and ergonomic stressors may contribute to the evocation of an adverse workstyle that, in turn, sets the stage for musculoskeletal disorders.

With regard to the cognitive reactivity component of the Workstyle model, it has been noted that some epidemiological investigations have identified both work demands and job satisfaction as risk factors (e.g., Bergenudd & Nilsson, 1988; Dehlin & Berg, 1977; Hughes et al., 1997; Tola et al., 1988). Multiple regression analyses have indicated subjective perceptions of work monotony predicted job satisfaction and psychological distress in a sample of blue-collar workers (Melamed, Ben-Avi, Luz, & Green, 1995). Among civil servants in the United Kingdom, job dissatisfaction was predicted by organizational climate, organizational influence, job constraints, organizational pressure, factors intrinsic to the job, and the management's role as assessed by the Occupational Stress Indicator (Bogg & Cooper, 1995). In the same study, organizational climate was also associated with a general measure of physical health. Although only one component of job stress predicted the physical health outcome, there appears to be a link between job stress, job satisfaction, and physical health outcomes. Moreover, it may be argued that the use of a broad measure of health probably was not adequate for capturing any relationships between work demands, workplace psychosocial stressors, cognitive reactivity (e.g., job satisfaction), and musculoskeletal symptoms/disorders. As for ergonomic factors, high levels of ergonomic job design (indicating high levels of self-reported physical comfort) have been positively correlated with job satisfaction in government office employees with both high and low levels of self-efficacy (May, Schwoerer, Reed, & Potter, 1997). Hierarchical regression analyses also found that ergonomic job design significantly predicted job satisfaction levels, persistent overall job-related bodily pain, somatic complaints, and turnover intentions. Therefore, the proposed model hypothesizes that both occupational psychosocial stress and ergonomic stressors can influence job satisfaction and cognitions related to performing a job task. For example, in addition to psychosocial stressors that result in job dissatisfaction and/or negative cognitions/perceptions on the job, a task involving a heavy physical workload or high repetition may give the worker more reason to be dissatisfied at work or frustrated from an inability to control or change these stressors. In turn, these things can contribute to the onset and/or maintenance of symptoms/disorders.

Physiologically, muscle-related fatigue, pain, and muscle failure have been associated with repetitive loading cycles, heavy lifting, and repetitive tasks (Pope et al., 1991; Westgaard, 1999). Lundberg and colleagues (1999) have suggested that psychological stress may also produce the sustained activation of small, low-threshold motor units that, in turn, cause degenerative processes and damage in the muscles. In a laboratory-based study, motor units in the trapezius muscle have been demonstrated to actively fire (as measured by surface EMG recordings) through the duration of a cognitively demanding complex two-choice reaction-time task (Waersted, Eken, & Westgaard, 1996). Psychological work demands have also been correlated with self-reported muscle tension (Theorell, Harms-Ringdahl, Ahlberg-Hulten, & Westin, 1991). Additionally, the introduction of psychosocial stressors, in the form of visual feedback suggesting inadequate performance and criticism were found to be associated with significant increases in spinal loadings, muscle responses, and kinetic responses from a lifting task (Marras, Davis, Heaney, Maronitis, & Allread, in press). Therefore, it is possible that work demands that are psychological in nature can further contribute to increases in muscle tension that stem from physical stressors. Subsequently, this combination effect can then lead to the onset of symptoms.

There is support for the idea that individual work organization variables and exposure to ergonomic risk factors may produce a response or set of responses while performing a work task. Based on the proposed model though, it is conceivable that a combination of work demands, workplace psychosocial stressors, and ergonomic factors, may produce a pattern of behavioral, cognitive, and physiological reactivity that is greater than that from a single stressor. Such an increased level of reactivity may in turn contribute to a greater likelihood for a work-related musculoskeletal outcome. It is suggested that research that uses the proposed model to examine this potential interaction between workplace physical and psychosocial stressors may help with understanding why a worker may experience musculoskeletal pain, fatigue, and/or other symptoms.

Limitations of the Literature

The recent increase in investigations of the combined role of medical/physical, ergonomic, and psychosocial risk factors has led to greater recognition of the multidimensional nature of work-related musculosketal problems. Adverse ergonomic exposures have been established as placing workers at higher risks for musculoskeletal symptoms/disorders. Compared to ergonomic factors, significantly less research has been conducted on occupational psychosocial factors. Additionally, occupational psychosocial factors in studies of work-related musculoskeletal disorders are often grouped together as one construct. As noted, occupational psychosocial stressors have been conceptualized within the context of work organization. While some dimensions of work organization have been identified as risk factors, no studies have specifically delineated the different sources of job stress involved in low back an upper extremity problems. Subsequently, it is unclear whether certain categories of work organization play a more salient role in WMSDs and where prevention/intervention efforts should be focused. Therefore, research is needed that utilizes a systematic approach to examining the different components of work organization (e.g., NIOSH, 1996) in relation to musculoskeletal symptoms/disorders.

While it is important to investigate these physical and occupational psychosocial stressors independently, particular consideration should also be given to any combined effect that they might have. Some models of work-related musculoskeletal health have proposed that ergonomic factors interact with each other (e.g., force x repetition x posture) to contribute to musculoskeletal outcomes. Additionally, a few studies have found that a combination of ergonomic and occupational psychosocial variables is associated with symptoms, particularly in the upper extremities (Bergqvist, Wolgast, Nilsson, & Voss, 1995; Faucett & Rempel, 1994). However, no research has explicitly set forth to test specific types of combinations and whether such combinations are better predictors of musculoskeletal outcomes. Studies that show an effect and/or greater risk may provide additional insight on any potential mechanisms by which work organization and ergonomic stressors act.

Addressing these limitations can help provide a more comprehensive understanding of work-related stressors and their association with on back and upper extremity outcomes. Furthermore, such efforts can assist in guiding prevention programs that are tailored towards the needs of both the worker and organization. In turn, the subsequent costs and impact and be reduced and worker health and organizational productivity can be improved.

Study Description

The present study was intended to address the limitations of the existing literature on work organization and musculoskeletal outcomes. The three primary goals to this research were: 1) to identify high-risk jobs for low back and upper extremity disorders within a population (i.e., U.S. Marine Corps) for which musculoskeletal disorders are major sources of ambulatory visits and duty limitations; 2) to delineate specific work organization factors that are associated with musculoskeletal symptoms; and, 3) to determine the combined effect of work organization and ergonomic stressors on low back, upper extremity, and concurrent low back and upper extremity symptoms.

More specifically, medical administrative databases were first utilized to identify high-risk occupational categories for both low back and upper extremity disorders in the USMC. Subsequently, a cross-sectional study that included individuals from the identified high-risk jobs was conducted to assess work-related physical and psychosocial stressors and to examine whether specific ergonomic and work organization variables (individually and combined) place an individual at a higher risk for musculoskeletal symptoms. Work organization stressors were conceptualized within the context of the NORA categories used in the previously discussed literature review and referred to work demands and other workplace psychosocial stressors as described in the proposed model (see Figure 11). Additionally, cases were classified as having low back symptoms, upper extremity symptoms, or concurrent low back and upper extremity symptoms. These groups were defined in accordance with research suggesting that different sets of work organization stressors may be associated with symptoms in disparate anatomic locations and that ergonomic factors may also present differential loads on the tendons/ligaments and/or muscle groups (e.g., erector spinae, trapezius, flexor and extensor carpi radialis) in the low back and upper extremities (e.g., Marras, 1997; NRC, 2001). Given that the low back and upper extremities may differ with regard to work task exposures, it is possible that the biobehavioral pathways by which work-related stressors (i.e., ergonomic and psychosocial) operate may also differ, thereby suggesting the need to delineate these areas in research.

It should be noted that while the Workstyle model was used as a framework for examining work organization and hypothesizing its interaction with ergonomic risk factors, it was not the intent of this study to validate the mechanism proposed by the model. According to the Workstyle model, work organization and ergonomic factors are believed to interact and elicit a set of behavioral, cognitive, and physiological responses to the work task. The present study did not set forth to determine whether or how these responses occur but rather if a combination of workplace stressors were associated with musculoskeletal outcomes in a manner that is consistent with that proposed by the model.

Study Hypotheses

The specific hypotheses for the present study were:

H1a: Adjusting for age, gender, and education level, specific dimensions of work organization (i.e., scheduling, job design, management style, interpersonal, career concerns, and organizational characteristics) will place an individual at a greater risk for self-reported low back symptoms.

H1b: Adjusting for age, gender, and education level, specific dimensions of work organization (i.e., scheduling, job design, management style, interpersonal, career concerns, and organizational characteristics) will place an individual at a greater risk for self-reported upper extremity (i.e., neck, shoulder, arm/elbow, hand/wrist) symptoms.

H1c: Adjusting for age, gender, and education level, specific dimensions of work organization (i.e., scheduling, job design, management style, interpersonal, career concerns, and organizational characteristics) will place an individual at a greater risk for both self-reported low back and upper extremity symptoms.

H2a: Adjusting for demographic, health behaviors, physical demands, and individual psychosocial variables, a combination of work organization (i.e., scheduling, job design, interpersonal, career concerns, management style, and organizational characteristics) and ergonomic stressors will place an individual at a greater risk for self-reported low back symptoms.

H2b: Adjusting for demographic, health behaviors, physical demands, and individual psychosocial variables, a combination of work organization (i.e., scheduling, job design, interpersonal, career concerns, management style, and organizational characteristics) and ergonomic stressors will place an individual at a greater risk for self-reported upper extremity symptoms.

H2c: Adjusting for demographic, health behaviors, physical demands, and individual psychosocial variables, a combination of work organization (i.e., scheduling, job design, interpersonal, career concerns, management style, and organizational characteristics) and ergonomic stressors will place an individual at a greater risk for self-reported low back and upper extremity symptoms.

METHODS

Identification of High Risk Occupations in the U.S. Marine Corps

As previously noted, musculoskeletal disorders are major sources of health- and work-related outcomes in the U.S. Marine Corps (Huang, Feuerstein, & Arroyo, in press). Therefore, it was reasoned that identifying high-risk occupations for these problems would allow for a more focused investigation of potential work-related factors for these problems within this work group. To identify the military occupational specialties (MOSs) in the Marine Corps that have higher rates of low back and upper extremity disorders, the Defense Medical Surveillance System (DMSS) and Defense Medical Epidemiology Database (DMED) were utilized. The DMSS is an information system that contains data on diseases and medical events such as hospitalizations, ambulatory visits, reportable diseases, and health risk appraisals for the U.S. military. The Army Medical Surveillance Activity (AMSA) operates DMSS for the purpose of maintaining longitudinal data on personnel and deployment experience for all active duty and reserve component service members (AMSA, 1999).

The Defense Medical Epidemiology Database (DMED v 2.0; Army Medical Surveillance Activity, March 1999) allows access to a subset of DMSS data on in-patient (hospitalizations), out-patient (ambulatory), and reportable events (i.e., diseases and related events required to be reported by the Department of Defense). Population data from DMED is based on information from DMSS and validated against data from the Defense Manpower Data Center. Ambulatory data in DMED is based on out-patient data from 1997 through 1998 contained in the Standard Ambulatory Data Record (SADR), which was extracted from the Ambulatory Data System (ADS) and the CHCS (AMSA, 1999).

Data queries in DMED can be made according to demographics (age group, gender, race, marital status, rank), branch of service (Army, Navy, Air Force, Marines, All), military occupational specialty, and specific ICD-9 diagnoses.

Using the top 15 back and upper extremity diagnoses for enlisted Marines identified by Huang (2000) (see Table 5), outpatient visit counts, person-years (based on the cumulative experiences during the calendar year of interest for all members in the population substrata selected), and rates for these 15 diagnoses were then obtained for all Department of Defense (DoD) Primary Occupational Codes (U.S. Department of Defense, 1997).

Insert Table 5 here

Study Participants

After the high-risk occupations for musculoskeletal disorders were determined, locations with relatively higher concentrations of these MOSs were identified. Data on these locations were made available with the assistance of U.S. Marine Corps Manpower and Reserve Affairs at Quantico, VA. Commanders and associated personnel at these locations were then contacted, provided with the details of the research study and supporting letters from Safety Division, Headquarters, U.S. Marine Corps, and asked for permission to carry out the investigation. Bases granting permission to recruit potential study subjects were: Camp Pendleton, CA; USMC Base Quantico, VA; and, Headquarters, Marine Corps, Washington, DC.

At the bases, potential study participants were invited through news bulletins, electronic mail, and section heads to attend an information session about the study. At these sessions, Marines were provided with further details about the purpose and components of the study.

Eligibility was restricted to Marines who were on active duty and in the enlisted ranks (i.e., E-1 to E-9). The investigation was restricted to these individuals since enlisted personnel comprise the majority of Marines in the USMC (89.7% of active duty personnel) (Division of Public Affairs, Headquarters Marine Corps, 1999). Furthermore, because officers and reserve component personnel may considerably differ from enlisted personnel on work-related and other (e.g., demographic) characteristics, these two groups were not included in the present study. All eligible individuals wishing to participate were then provided with informed consent forms (see Appendix A) and subsequently given a questionnaire that assessed potential risk factors, musculoskeletal symptoms, and functional limitations.

Questionnaire

The questionnaire that was administered is provided in Appendix B. The risk factors assessed were categorized according to the following dimensions: demographics; health behaviors; physical demands; individual psychosocial (i.e., family/home/life); ergonomic; and work organization (occupational psychosocial). In accordance with the proposed conceptualization of work organization, occupational psychosocial variables are described in the following sections as belonging to one of the six NORA work organization categories. However, in order to avoid influencing responses, these categories were not explicitly labeled as such in the questionnaire. Outcome measures included musculoskeletal symptoms, physical function, and mental health. The items that comprise this questionnaire are summarized in Table 6.

Insert Table 6 here

Demographics

Demographic information obtained included: age; gender; marital status; number of children supported; education level; rank; length of service; MOS; and length of time in MOS.

Health behaviors

Items from the U.S. Army Health Risk Appraisal were used to measure smoking status, frequency of smoking, number of cigarettes smoked, and the frequency of aerobic activity (exercise). For the aerobic activity item, responses were "rarely/never", "1 or 2 times per week", and "3 or more times per week". This latter measure was selected based on past findings indicating that they were associated with back-related disability in U.S. Army soldiers (Feuerstein et al., 1999).

Physical demands

Physical demands were measured using a modified Borg (1998) CR10 Scale that asked about the physical effort required from one's job during a "typical day". Responses for this item were based on a 12-point scale (0 = nothing at all to 10 = very, very hard).

Individual psychosocial

In addition to the item on the number of children supported described in the Demographics section, items from the U.S. Army's Health Risk Appraisal (HRA) and the Family Environment Scale (Moos & Moos, 1981) were used. Questions from the HRA address frequency of life-related worries and availability of social support and had categorical responses (i.e., "never", "seldom", "sometimes", and "often"). These items were selected based on past findings indicating an association with back- and upper extremity-related disability in U.S. Army soldiers (Feuerstein et al., 1999; Huang et al., 1998).

The Conflict Subscale of the Family Environment Scale (Moos & Moos, 1981) was used to determine the amount of expressed anger, aggression, and conflict among family members. This 9-item subscale has been reported to have an internal consistency of 0.75 and 2-month test-retest reliability of 0.85. The Conflict Subscale was selected based on its ability to measure one potential source of family/home-related stress. It should be noted that one question from the subscale, "Family members sometimes hit each other" was not included because responses to this question could potentially incriminate military personnel.

Ergonomic

To assess exposure to ergonomic risk factors, the Job Factors subscale of the U.S. Air Force Job Requirements and Physical Demands Survey (JRPDS) (Marcotte et al., 1997) was used. This JRPDS subscale is a self-report measure containing 38 items related to movements, postures, loads, and environmental factors while performing a work task. Reliability from a two-week test-retest was found to have a kappa of 0.68 (88% raw agreement) and adequate validity in relation to worksite assessments performed by an ergonomist (Marcotte et al., 1997).

Work organization (occupational psychosocial)

One general question on frequency of job stress was included from the U.S Army HRA was included because of previous reports of its association with musculoskeletal-related disability in U.S. Army soldiers (Feuerstein et al., 1999; Huang et al., 1998). Responses to this question were "never", "seldom", "sometimes", and "often".

Items specifically addressing work organization variables were selected on the basis of their association with work-related musculoskeletal symptoms/disorders in previous work (see Tables 3 and 4), use in previous studies, potential ability to be modified through intervention efforts (e.g., Landsbergis & Vivona-Vaughan, 1995; Quick, Quick, Nelson, & Hurrell, 1997), psychometric properties (e.g., internal consistency, discriminant validity), and ease of administration (i.e., relatively few items). They are presented in accordance with their potential representation of one of the six categories used to conceptualize work organization in the present study.

Scheduling

The Scheduling dimension of work organization was represented by items adapted from the Work Environment Scale (WES) (Moos, 1994) and used in NIOSH investigations (e.g., Hales et al., 1994). In particular, three questions about one's agreement with the ability to relax, perceptions of constant pressure to keep working, and sense of urgency were asked. Although, it may appear that these items reflect aspects of job design, their primary focus on ability to relax and flexibility of work suggested that they be used as measures of Scheduling.

Additionally, two questions on work breaks and shift work from the Multimethod Job Design Questionnaire (MJDQ) (Campion, 1988; Campion & Thayer, 1985) were included. These items are part of the original Biological scale of the MJDQ and asked whether there is adequate time for work breaks given the demands of the job and whether the job requires shift work or excessive overtime. While analyses for individual items are not available, psychometric testing of this instrument on 1024 workers in 92 different jobs found an internal consistency reliability of 0.86 for the Biological subscale. Correlations between the Biological subscale and a measure of physical comfort that included items on physical fatigue, frequency of backaches, and frequency of pain in general were reported to be about 0.50 (Campion, 1988). These items have been used in previous research in relation to somatic complaints and pain associated with the low back and upper extremity regions (May et al., 1997).

Job Design

Skill discretion is one subdimension of decision latitude and addresses skill and creativity on the job as well as the flexibility allowed in using skills (Karasek et al., 1998). Six items from the skill discretion subscale of the Job Content Questionnaire (e.g., Karasek et al., 1998) were included in the present investigation. Studies in Japan, the Netherlands, Canada and the U.S. have found Cronbach's alpha reliability values ranging from 0.59 to 0.80 for this scale (Karasek et al., 1998).

The other subdimension of decision latitude is decision authority and was also considered as a dimension of Job Design. In the Job Content Questionnaire, this scale includes three items on how much ability a worker has to make decisions on his/her own on the job. Cronbach's alphas have ranged from 0.61 to 0.71 for this scale (Karasek et al., 1998). Both skill discretion and decision latitude are common indices of occupational psychosocial stress and have been reported to be associated with and/or predictive of work-related musculoskeletal symptoms/disorders. Therefore, these items were chosen for inclusion in the present questionnaire.

Job Design-related items also included 13 questions that dealt with cognitive aspects of the job such as information processing, memory, and routine associated with one's job. These items were adapted from those used in prior NIOSH investigations (e.g., Hales et al., 1994) and chosen because several past studies have indicated that "psychological" or "mental" work demands are associated with and/or predictive of work-related back and upper extremity symptoms (see Tables 3 and 4).

Management Style

Management Style involved three items originally developed by Caplan (1971) and used in NIOSH studies on work-related musculoskeletal disorders (e.g., Hales et al., 1994). These three items determined the amount a worker participates with others in making decisions and/or setting the way things are performed at work. This measure was selected based on its face validity as a potential measure of participatory management style.

Interpersonal

The Interpersonal category of work organization was represented by the Dealing with Others subscale of the Job Diagnostic Survey (JDS) (Hackman & Oldham, 1974). This subscale has been used to determine the level of personal interaction required on the job and includes three items that have been reported to have an internal consistency reliability of 0.59 (Hackman & Oldham, 1974). Discriminant validity analyses have found that it was correlated at a low level (0.15) with other scales in the JDS.

Another JDS measure, the Feedback from Agents subscale, was also used to assess Interpersonal factors. Questions from this subscale ask about the extent of feedback one receives from supervisors and co-workers as well as the frequency of such feedback. Psychometric properties of this subscale include an internal consistency reliability value of 0.78 and median off-diagonal of 0.15 (Hackman & Oldham, 1974).

Career Concerns

Items addressing Career Concerns were taken from those used in previous NIOSH studies (e.g., Hales et al., 1994) on future career picture, opportunities for promotion, value of job skills in the future, future responsibilities, ability to support oneself if he/she lost his/her job, and likelihood that the job will be replaced by computers/machines. These six questions, originally developed by Caplan (1971), were rated on a five-point scale from "somewhat uncertain" to "very certain".

Organizational Characteristics

The Organizational Characteristics dimension of work organization assessed organizational climate with regard to perceptions of individual and work group responsibility for performing a job task and how it is completed. These perceptions were determined by using the four-item, Experienced Responsibility for the Work subscale of the JDS (Hackman & Oldham, 1974). Items asked about one's degree of personal responsibility for his/her work, beliefs on receiving credit/blame for the work, how much responsibility one has in getting the job done right, and ability to care about if a job is done right. This subscale has an internal consistency reliability of 0.72 and discriminant validity (i.e., median off-diagonal correlation) of 0.23 (Hackman & Oldham, 1974).

<u>Outcomes</u>

Symptoms

A modified NIOSH symptom survey (e.g., Hales et al., 1994) was used to assess symptoms in the lower back, neck, shoulders, elbows/forearms, and wrists/hands region.

Questions addressed type of symptoms, time of first onset, frequency, duration, intensity, work interference, and associated limited duty within the past 12 months. A visual analog scale (VAS) that measured pain intensity over the past week was also used.

Function

Functional limitation in work and daily activities was measured by the SF-12 (Ware, Kosinski, & Keller, 1996). These items were derived from the longer SF-36 (Ware & Sherbourne, 1992) which has been used in past research on work-related musculoskeletal disorder populations (Feuerstein et al., 2000). The SF-12 is a 12-item questionnaire containing two subscales: the Physical Component Summary (PCS) and Mental Component Summary (MCS). These relate to physical and mental health function, respectively. A multiple R-square score of 0.91 was found for the PCS in predicting the SF-36 Physical Component Summary. The SF-12 MCS had a multiple R-square score of 0.92 in predictive validity analyses of the SF-36 Mental Component Summary score. Two-week test-retest reliabilities were found to be 0.89 for the PCS and 0.76 for the MCS (Ware et al., 1996).

Power Analyses / Sample Size

Using nQuery Advisor (release 3.0) (Statistical Solutions, Saugus, MA), sample sizes required for necessary statistical power were obtained. Calculations were performed for the back and upper extremities independently. Each set of calculations was based on parameters applicable for univariable analyses of each of the six work organization categories. Based on reports that odds ratios for ergonomic risk factors have been commonly greater than those for work organization variables, it was assumed that using odds ratios related to work organization variables would be more appropriate for determining the sample size in which risks for both work organization and ergonomic variables could be obtained.

The specific parameters used for sample sizes estimations were: 1) test significance level (α) of 0.05; 2) two-sided test; and 3) power (β) of 80%. Expected odds ratios for each of the six work organization categories were based on those reported in the literature (see Tables 3 and 4).

Squared multiple correlations of potential risk factors with the covariates were based on Pearson correlation coefficients reported in Leino and Hanninen (1995). It was reasoned that since these Pearson correlation coefficients were obtained in a sample consisting of a broad range of workers with both self-reported back and upper extremity symptoms and involved work organization variables similar to those to be examined in the present study that they would be appropriate estimates of the parameters in the sample size calculations. While a range of coefficients were given, a squared multiple correlation coefficient of 0.20 was used. This value was chosen because the data from Leino and Hanninen (1995) tended to be near this number and because it was a more conservative statistical choice given the range available.

Approximate proportions of subjects who would report musculoskeletal (i.e., lower back, neck, shoulders, elbows/forearms, and wrists/hands) symptoms were also obtained from reported figures in the literature. Upper extremity (i.e., neck/shoulder and hand/wrist/arm/elbow) proportions were based on findings from Bernard et al. (1994). This investigation was specifically utilized because it involved a case definition for work-related upper extremity symptoms that are similar to the one to be used in the presently proposed study. For back-related symptoms, the figures obtained from an investigation of both men and women in a variety of occupations by Toomingas et al. (1997) were used. Since the distributions for work-related upper extremity symptoms in the Toomingas et al. (1997) paper were similar to those in Bernard et al. (1994), it was assumed that they reflect the proportions subjects with back symptoms that would have been obtained if data on low back symptoms were collected in the Bernard et al. (1994) study.

Calculations indicated that approximately 165 participants (i.e., cases and controls) would be required for the back-related portion of the study. Also, 227 study participants (i.e., cases and controls) would be needed to detect any hypothesized effects for the upper extremities. Therefore, it was estimated that a total of 392 Marines would be needed for the present investigation.

Case Definitions

Four separate groups were delineated based on responses to the following questions: 1) Do you experience physical problems with any of the following areas of your body (i.e., lower back, neck, shoulder, elbows/forearms, wrists/hands)?; 2) When did you first notice the problem?; and, 3) What do you think caused the problem (i.e., work tasks, physical fitness training, off-duty activities, traffic accident, other)? An asymptomatic control group was defined as those study participants who did not report having any musculoskeletal symptoms in any of the anatomic locations (i.e., low back, neck, shoulder, elbow/forearms, wrists/hands). Symptomatic cases were classified into those who had low back symptoms only, upper extremity symptoms only, or both low back and upper extremity symptoms simultaneously. Additionally, only those individuals who reported having symptoms since beginning work in their current military occupational specialty and who did not report having had a prior accident/trauma to the region were included as cases for any of the symptomatic groups.

Study Participants

While the exact number of Marines who attended the information sessions was not recorded, it was estimated that approximately 400 Marines were presented with the details of the study. Of this total, 307 (approximately 76.8%) individuals consented to participating in the investigation.

Based on the criteria used in determining cases and controls, there were 90 asymptomatic controls, 59 cases with low back symptoms, 57 cases with upper extremity symptoms, and 83 cases with concurrent low back and upper extremity symptoms.

Analyses

Prior to conducting any analyses on the questionnaire items, all missing data were replaced by the mode of that respective question. Less than 3% of the total sample had missing data for any given item. All analyses were performed using SPSS v.10.0 (SPSS, Chicago, IL).

Factor analyses & reliability analyses

Factor analyses of the work organization items were first conducted in order to determine whether specific categories of work organization could be delineated and to determine the items to be included in these categories. Using a varimax (i.e., orthogonal) rotation, a rotated component matrix with seven components was observed. This procedure was conducted in order to maximize the variances of factor loadings such that unique factors could be subsequently partitioned (Nunnally & Bernstein, 1994; Tabachnick & Fidell, 1983). Since a factor should account for at least as much variance as an individual variable, those factors with component variances (i.e., eigenvalues) above one were retained for further analyses (Nunnally & Bernstein, 1994; Tabachnick & Fidell, 1983). Reliability analyses were also conducted to determine the internal consistencies (i.e., Cronbach's alphas) of the items comprising each work organization factor. The work organization factors identified from the factor analyses and for which Cronbach alphas were obtained were examined as independent variables in subsequent analyses.

Correlation analyses

Associations among the identified work organization variables and the HRA question on frequency of job stress, family conflict, and life-related worries were determined by computing Pearson correlation coefficients. The correlations were computed in order to determine the extent of any potential overlap between each of these variables. Additionally, correlations were examined for all symptomatic cases, asymptomatic controls, and all study participants combined.

Comparisons on pain intensity, physical function, & mental health

One-way analyses of variance (ANOVA) were conducted to determine if differences existed between the four groups (i.e., asymptomatic controls, low back symptoms only, upper extremity symptoms only, both low back and upper extremity symptoms) on pain intensity over the past week, physical function (SF-12 PCS subscale), and mental health (SF-12 MCS subscale). Post hoc analyses comparing the different groups were performed using Scheffe tests (Keppel, Saufley, & Tokunaga, 1992). In instances where variances were not homogeneous, post hoc analyses using Tamhane's test were conducted. Additionally, trends across the groups on each of these outcomes were identified by polynomial linear contrasts. The assumption of a linear trend across the four groups on the three outcome measures is based upon the assumption that those with symptoms in multiple anatomic locations would experience greater pain and functional limitation, while those with back pain would be impacted to a greater extent in their mobility and everyday activities (e.g., Duquesnoy, Allaert, & Verdoncq, 1998) and those with upper extremity problems would have more difficulty with more hand/arm intensive tasks (e.g., Morse et al., 1998).

Correlates of pain intensity, physical function, & mental health

In addition to determining whether groups differed on pain intensity, physical function, and distress, variables associated with these different measures of severity were identified. More specifically, stepwise linear regressions involving all study participants were conducted in order to provide indications on which factors contributed to different levels of these outcomes. Dependent variables were pain intensity over the last week, physical function (SF-12 PCS subscale), and mental health (SF-12 MCS subscale). Independent variables examined in the regression model were: age; gender; education; frequency of exercise; life-related worries; family conflict; perceived exertion at work; ergonomic risk exposure; skill discretion; cognitive demands; management style; time pressure; organizational climate; cognitive processing; and, interpersonal demands at work. From these analyses, beta coefficients, ΔR^2 – values, and the percent variance accounted for by the models were obtained.

Logistic regression analyses

Examination of individual risk factors for the occurrence of musculoskeletal symptoms

To identify risk factors associated with the occurrence of low back, upper extremity, and concurrent low back and upper extremity symptoms, separate logistic regression analyses were conducted that involved the following groups: cases with only low back symptoms and asymptomatic controls; cases with only upper extremity symptoms and asymptomatic controls; and, cases with simultaneous back and upper extremity symptoms and asymptomatic controls. The variables examined were: age; gender; education level; frequency of exercise; life-related worries; family conflict; and, perceived exertion at work; ergonomic risk exposure (JRPDS); skill discretion; cognitive demands; management style; time pressure; organizational climate; cognitive uncertainty; and, interpersonal demands at work.

For each set of groups (i.e., low back symptoms only and controls, UE symptoms only and controls, low back & UE symptoms and controls), all variables were initially examined in univariable logistic regression analyses. Those variables with a significance level (p - value) equal to or less than 0.25 in the univariable logistic regression analyses were then further examined in final multivariable logistic regression models that also adjusted for age, gender, and education level (Hosmer & Lemeshow, 2000). From all logistic regression analyses, odds ratios, 95% confidence intervals (CI), parameter estimates (β coefficients), and significance levels were obtained.

Examination of ergonomic and work organization combinations

Before examining the combined effect of ergonomic and work organization factors on symptom status, a risk stratification procedure was performed in which study participants were categorized as having "high" or "low" levels of exposure on the JRPDS and each work organization variable. Except for management style and organizational climate, "high" levels of exposure indicated more adverse exposures. Exposure levels were determined by the individual's score relative to a median split for the particular variable. This method was used because no cut-off points for delineating risk levels have been established in prior research. Based on risk levels for ergonomic risk exposure and a given work organization variable, study participants were then classified as having low/low, high/low, low/high, or high/high levels of exposure.

Using logistic regression analyses with case status (i.e., back case/control; UE case/control; back & UE case/control) as the dependent variable, combined ergonomic-work organization exposure was entered into the model with the demographic, health behavior, individual psychosocial, and physical demand variables examined in the univariable logistic regression analyses. Using the low risk combination as the referent group, each ergonomic-work organization combination was examined separately from the other combinations. For the combinations involving management style and organizational climate, the low risk groups were those with lower ergonomic exposures and higher levels of participatory management or positive organizational climate. From all logistic regression analyses, odds ratios, 95% confidence intervals (CI), parameter estimates (β coefficients), and significance levels were obtained.

RESULTS

High Risk Occupations for Musculoskeletal–related Clinic Visits

Table 7 lists the high-risk occupational categories for all low back and upper extremity diagnoses examined. Tables 8 and 9 further break down this information by specific low back and upper extremity diagnoses, respectively. As shown, Image Interpretation and the office job categories, Auditing & Accounting and Disbursing were among the top 10 occupations with high clinic visit rates for both low back and upper extremity-related disorders with rates of 51/100 person-years (PYs), 44/100 PYs, and 42/100 PYs, respectively. Image Interpretation and Aircraft Launch Equipment were the top two occupational categories with Marines who had a low back disorder. While the "Unknown" occupational category had the highest rate for upper extremity-related visits, Marines in the Musician, Investigations, and Information and Education categories were among those most frequently seen for an upper extremity complaint.

Insert Tables 7 to 9 here

Cross Sectional Investigation

Demographics

A total of 307 active duty, enlisted Marines participated in the study and completed the questionnaire. Of this group, 18 Marines did not meet eligibility criteria for the study because they indicated having muscloskeletal symptoms as the result of a non-work-related accident/trauma (e.g., sports, traffic accident). Of the remaining 289 eligible participants, the demographic characteristics most commonly reported were: male (88.2%); "White" (51.6%); married (39.8%); some college/other post high school education (45.7%), and the rank of E-5 – Sergeant (26.6%). The sample also ranged in age from 19 to 49 years with a mean age of 28.0 years (SD = 7.2).

Distributions according to case status were as follows: 31.1% (n = 90) asymptomatic controls; 20.4% (n = 59) low back symptoms only cases; 19.7% (n = 57) upper extremity symptoms only cases; and, 28.7% (n = 83) cases with both low back and upper extremity symptoms. Table 10 specifically breaks down the demographic distribution of the sample according to these groups.

Insert Table 10 here

Using the Department of Defense (1997) Primary Occupational Codes it was determined that the majority of Marines were from the Functional Support and Administration category. Specifically, there were 184 (64.2%) participants in this occupational category which includes the following subcategories: Personnel; Administration; Clerical/Personnel; Data Processing; Accounting/Finance/Disbursing; Other Functional Support; and, Information & Education. Figure 12 illustrates the distribution of all study participants based on DoD Primary Occupational Code categories. If the Marine Corps MOS coding system is used, study participants are found to range in their military occupational specialties with several MOSs being represented by one Marine. Of the total sample, the majority (46.2%) came from the occupational field 01 – Personnel and Administration. Breakdowns by specific MOSs found that the top three MOSs in the study were: 0151 – Administrative Clerk (20.1% of the total sample); 0193 – Personnel Administrative Chief (14.9%); and, 0121 – Personnel clerk (10.0%). It should be noted that these three MOSs are all in the occupational field 01 – Personnel and Administration.

Insert Figure 12 here

Chi-square tests on gender, race, education level, marital status, rank, and military occupational specialty indicated no significant differences between controls and the groups with low back symptoms only, upper extremity symptoms only, and both low back and upper extremity symptoms. From t-tests, only the combined low back and upper extremity group was found to be significantly older in age than the control group ($t = -3.15$, $df = 171$, $p < 0.01$).

Factor analyses of work organization items

Factor analyses using a varimax rotation indicated that seven components could be delineated from the work organization items. These components were Job Design, Management Style, Time Pressure, Organizational Climate, Career Concerns, Cognitive Uncertainty, and Interpersonal Demands and each had initial eigenvalues above 1.6. The seven components, the specific questionnaire items that comprise each factor, factor loadings, initial eigenvalues, and percent variance are given in Table 11.

Insert Table 11 here

While one reason for conducting the factor analyses was to reduce the number of items to be included within a particular work organization category, the Job Design factor was found to contain the items from the skill discretion subscale of the Job Content Questionnaire (Karasek, 1998) and from the cognitive demands section of the NIOSH work survey. Therefore, these items were separated into their respective subscales to maintain the original integrity of these variables. Subsequent analyses examined skill discretion and cognitive demands as separate variables.

Reliability analyses

Cronbach's alphas were obtained for each of the identified work organization factors and are given in Table 12. As indicated, most work organization factors had modest to adequate reliabilities with Cronbach's coefficient alphas ranging from 0.71 to 0.83 (Nunnally & Bernstein, 1994). The cognitive uncertainty factor had a Cronbach's coefficient alpha of 0.60.

Insert Table 12 here

Correlation analyses

Table 13 lists the correlation coefficients computed for the work organization factors, HRA item relating to the frequency of job stress experienced, and the individual psychosocial variables on family conflict and life-related worries for all study participants. Examination of the correlations by asymptomatic controls and all symptomatic cases indicated similar patterns in the correlation coefficients for all work organization variables. Table 13 shows that aside from the correlation between skill discretion and cognitive demands, statistically significant correlations between work organization items were low to moderate (0.04 to 0.36). The skill discretion and cognitive demand variables that were initially grouped together as a single factor in the factor analyses had a relatively higher level of correlation (0.62). The HRA item on the frequency of job stress had the highest correlation with time pressure (Pearson correlation coefficient = 0.411, $p < 0.01$) and life-related worries (Pearson correlation coefficient = 0.486, $p < 0.01$).

Insert Table 13 here

Comparisons between groups on symptoms, physical function, & mental health

The ANOVAs comparing controls, low back symptoms only group, upper extremity symptoms only group, and the group with both low back and upper extremity symptoms indicated that the groups were significantly different on pain intensity over the last week ($F = 51.7$, $df = 3$, $p < 0.01$) and physical function ($F = 16.7$, $df = 3$, $p < 0.01$).

No significant differences were found for mental health. While the assumption of homogeneity of variances was not met in the ANOVAs for pain intensity and physical function (as indicated by Levene's test for homogeneity of variances), findings can still be accepted based on the level of significance and the nature (i.e., robustness) of the analyses (Keppel, Saufley, & Tokunaga, 1992). Post hoc analyses using Tamhane's test found that all three musculoskeletal symptom groups significantly differed from controls on pain intensity and physical function. The group with concurrent back and upper extremity symptoms was also significantly different from the upper extremity symptoms only group on pain intensity according to Tamhane's test.

Significant linear trends were also found for pain intensity over the last week and physical function. Cases with both low back and upper extremity symptoms had the highest level of pain intensity (mean = 4.41), followed by low back symptom only cases (mean = 3.66), upper extremity symptom only cases (mean = 3.09), and controls (mean = 0.34), respectively ($\underline{F} = 138.6$, $\underline{df} = 1$, $\underline{p}, < 0.001$). Physical function levels in descending order were: controls (mean = 57.56); upper extremity symptom only cases (mean = 53.07); low back symptom only cases (51.43); and, cases with both low back and upper extremity symptoms (mean = 50.18) ($\underline{F} = 46.2$, $\underline{df} = 1$, $\underline{p} < 0.01$). No significant differences were found between groups for mean on the SF-12 MCS subscale. Figures 13 to 15 graphically depict the group means for pain intensity, physical function, and mental health, respectively.

Insert Figures 13 to 15 here

Correlates of pain intensity, physical function, & mental health

Table 14 summarizes the pattern of correlates for pain intensity, physical function, and mental health among all study participants based on linear regression analyses. Included in this table are the respective beta coefficients and ΔR^2 values for each of the significant variables in addition to the variance accounted for by the models.

Age, life-related worries, and exposure to ergonomic stressors, and organizational climate accounted for 13% of the variance for musculoskeletal pain intensity over the past week. Physical function as measured by the SF-12 PCS subscale was associated with age, exercise, perceived exertion at work, exposure to ergonomic stressors, and organizational climate. These variables accounted for 13% of the overall variance for this outcome. Correlates of mental included age, family conflict, life-related worries, and career concerns. These variables accounted for 36% of the total variance.

Insert Table 14 here

Risk factors for musculoskeletal symptoms

Odds ratios, 95% confidence intervals, parameter estimates, and levels of statistical significance for all control variables in the univariable logistic regression analyses are provided in Table 15. In Table 16, odds ratios, 95% confidence intervals, and levels of statistical significance obtained from the univariable logistic regression analyses are provided for each of the work-related stressors examined. Since all models adjusted for age, gender, and education, these demographic variables were all included in the final multivariable logistic regression models. Based on a p – value of 0.25 or lower in the univariable logistic regression analyses, the variables selected for the final logistic regression analysis for the occurrence of back symptoms only were: life-related worries; family conflict; ergonomic risk exposure; time pressure; career concerns; and, interpersonal demands. To determine risk factors for upper extremity symptoms, the final model included: perceived physical exertion at work; family conflict; ergonomic risk exposure; and, time pressure. In the final model for determine the concurrent occurrence of low back and upper extremity symptoms, perceived physical exertion at work, family conflict, ergonomic risk exposure, skill discretion, cognitive demands, time pressure, cognitive uncertainty, and interpersonal demands were examined in the final multivariable model.

Risk factors for each of the three different case groups that were identified from the final multivariable logistic regression models and their associated odds ratios and 95% confidence intervals are summarized in Table 17. It should be noted that odds ratios for the ergonomic and work organization variables represent risks for each point increase on the respective scales. Unless otherwise indicated, all significant risk factors were significant at the $p \leq 0.05$ level (i.e., had a 95% CI with a lower limit greater than or equal to 1.00). Hosmer-Lemeshow goodness-of-fit tests (e.g., Hosmer & Lemeshow, 2000) for all final multivariable models were non-significant indicating that the models effectively described the outcome variables of interest (i.e., musculoskeletal case status).

Insert Tables 15 to 17 here

Risk factors for the occurrence of low back symptoms

Demographic.

Each year increase in age was found to be associated with a 1.09-fold risk for the self-report of low back symptoms within the time one started his/her job. The 95% confidence interval was 1.02 to 1.16.

Health behaviors.

No health behavior variables were included in the final logistic regression model.

Physical demands.

Perceived exertion at work was not included in the final logistic regression model.

Individual psychosocial.

Life-related worries were not found to be significantly associated with cases status for low back symptoms. Greater family conflict as measured by the Family Environment Scale – Family Conflict subscale placed an individual at higher risk for low back symptoms. An odds ratio of 1.30 (95 % CI: 1.03 – 1.64) for each point increase was found for this variable.

Ergonomic.

Increased exposures to ergonomic stressors as reported on the JRPDS Job Factors subscale were associated with the presence of low back symptoms (OR = 1.03; 95% CI: 1.00 –1.05).

Work organization.

Two work organization variables were found to place individuals at a greater risk for low back symptoms. Greater time pressure had an odds ratio of 1.18 (95% CI: 1.00 – 1.38), while greater interpersonal demands at work found to be a protective factor with an odds ratio of 0.73 (95% CI: 0.54 – 1.00).

The final multivariable logistic regression model correctly classified 68.7% of all subjects ($\chi^2 = 29.4$, $\underline{df} = 12$, $\underline{p} < 0.001$). Specifically, 79.6% of controls and 52.5% of cases were correctly classified by the model.

Since the odds ratios reported for the work-related stressors were in reference to single point increases on their respective scale, odds ratios based on the means of the high and low level risk groups were computed to provide another indication of the risks associated with each stressor. The odds ratios associated with the occurrence of low back symptoms only are depicted in Figure 16 and show that those in the group with greater exposures to ergonomic risk factors were about 2.33 times more likely to be a case. Compared to the lower level exposure group, those with higher levels of time pressure were 2.02 times more likely to be a low back symptomatic case, while the group with higher levels of interpersonal demands had on odds ratio of 0.55 for case status.

Insert Figure 16 here

Risk factors for the occurrence of upper extremity symptoms

Demographic.

No demographic variables were found to be significant risk factors for upper extremity symptoms.

Health behavior.

No health behavior variables were included in the final logistic regression model for upper extremity symptoms.

Physical demands.

Perceived physical exertion at work was not found to be a significant risk factor for upper extremity symptoms.

Individual psychosocial.

The Family Environment Scale – Family Conflict subscale was significantly associated with upper extremity symptom case status. An odds ratio of 1.27 (95% CI:

1.04 – 1.55) for each point increase on the scale (i.e., greater family conflict) was determined for this variable.

Ergonomic.

Exposure to ergonomic stressors was a significant risk factor for upper extremity symptoms. Each point increase on the JRPDS, indicating greater levels of exposure to ergonomic risk factors, was associated with a 1.02-fold risk (95% CI: 1.00 – 1.05) for upper extremity symptoms.

Work organization.

Greater time pressure was significantly associated with the occurrence of upper extremity symptoms. The odds ratio was 1.16 with a 95% CI of 1.00 to 1.34.

The final multivariable logistic regression model correctly classified 66.9% of all subjects ($\chi^2 = 21.3$, $df = 8$, $p < 0.01$). Specifically, 85.2% of controls and 37.0% of cases were correctly classified.

Figure 17 illustrates the odds ratios associated with the work-related stressors that were computed from the means of the high and low level risk groups. The groups with higher levels of ergonomic exposures and time pressure were found to have about a 2-fold greater likelihood (1.81 for ergonomic exposure, 1.93 for time pressure) for being symptomatic upper extremity cases than the lower exposure level groups.

Insert Figure 17 here

Risk factors for the occurrence of both low back and upper extremity symptoms

Demographic.

For low back and upper extremity case status, age was found to have an odds ratio of 1.13 (95% CI: 1.07 – 1.20) for each year increase. Neither gender nor education level were found to have statistically significant odds ratios.

Health behavior.

Health behavior was not included in the final model.

Physical demands.

Perceived exertion at work was not found to be a significant risk factor for concurrent low back and upper extremity symptoms.

Individual psychosocial.

Family conflict was not found to be a significant risk factor for concurrent low back and upper extremity symptoms.

Ergonomic.

Increased exposure to ergonomic risk as determined by the JRPDS was found to be a significant risk factor for a low back and UE case status. Each point increase on the JRPDS had a 1.04-fold (95% CI: 1.01 – 1.06) greater likelihood for case status.

Work organization.

Four work organization variables were associated with a greater risk for the occurrence of low back and upper extremity symptoms. These variables were: skill discretion (OR = 1.09; 95% CI: 1.02 – 1.15); cognitive demands (OR = 1.20; 95% CI: 1.04 – 1.39); cognitive uncertainty (OR = 1.22; 95% CI: 1.05 – 1.43); and, interpersonal demands (OR = 1.56; 95% CI: 1.05 – 2.33). For the skill discretion variable, higher scores indicated less skill discretion on one's job, while higher scores on the cognitive demands, cognitive uncertainty, and interpersonal demands variables represented greater demands.

The final mulitvariable logistic regression model correctly classified 71.2% of all subjects ($\chi^2 = 49.3$, $\underline{df} = 12$, $\underline{p} < 0.001$). Specifically, 73.9% of controls and 68.3% of cases were correctly classified.

Odds ratios computed from the means of the high and low exposure groups for the significant work-related risk factors are shown in Figure 18. Compared to the group with lower levels of a given stressor, the odds ratios for the higher level exposure group were:

2.91 for JRPDS; 2.65 for skill discretion; 2.41 for cognitive demands; 2.28 for cognitive uncertainty; and, 2.09 for interpersonal demands.

Insert Figure 18 here

Association between combined ergonomic and work organization exposures and musculoskeletal symptoms

In order to compute the odds ratios associated with various ergonomic-work organization combinations and musculoskeletal case status, risk stratification (i.e., determination of high and low risk levels) was first conducted using the following median split values: 33.00 for ergonomic risk exposure; 24.00 for skill discretion; 19.00 for cognitive demands; 13.67 for management style; 10.00 for time pressure; 5.83 for organizational climate; 18.00 for career concerns; 12.00 for cognitive uncertainty; and, 6.50 for interpersonal demands. Table 18 provides the distribution of subjects within each comparison group (i.e., controls and back; controls and UE; controls and back and UE) based on this risk stratification procedure.

Insert Table 18 here

Tables 19 to 26 provide the full logistic regression models and the results of their analyses for all ergonomic-work organization risk level combinations. Table 27 summarizes the statistically significant ergonomic-work organization combinations and gives their associated odds ratios, 95% confidence intervals, and p -values. Figure 19 illustrates these odds ratios for a case status of low back symptoms only or UE symptoms only. Figure 20 graphically depicts the odds ratios for the ergonomic-work organization combinations obtained from the analyses on cases with both low back and upper extremity symptoms.

Insert Tables 19 to 27 here

Insert Figures 19 & 20 here

Compared to persons with low levels of ergonomic risk exposure and low levels of time pressure, persons who had both high levels of ergonomic risk exposures and high levels of time pressure were found to have greater risks for being a case with low back symptoms only or a case with upper extremity symptoms only. Specifically, a 2.61-fold greater likelihood (95% CI: 1.39 - 4.91) was found for low back symptom cases. For upper extremity symptom cases, an odds ratio of 2.90 (95% CI: 1.49 – 5.66) was indicated.

Individuals with high levels of ergonomic risk exposure and high levels of either time pressure, interpersonal demands, cognitive demands, or cognitive processing were at greater risk for having both low back and upper extremity symptoms when compared to individuals with low levels of these work-related stressors. A 2.21 odds ratio (95% CI: 1.19 - 4.10) was associated with both high levels of ergonomic exposures and time pressure. The odds ratio for high levels of ergonomic exposure and high interpersonal demands was 2.44 (95% CI: 1.35 - 4.41). High levels of ergonomic risk exposure and high levels of cognitive demands placed an individual at a 2.25-fold greater likelihood (95% CI: 1.23 - 4.09) for being a case. A 2.08 odds ratio (95% CI: 1.16 - 3.75) was associated for high levels of ergonomic exposure and high levels of cognitive processing.

Compared to group with lower ergonomic exposures and higher participatory management, those with higher levels of ergonomic risk exposure and lower levels of involvement in a participatory management style were 2.50 times more likely (95% CI: 1.30 – 4.81) to be a case with both low back and upper extremity symptoms. Persons with higher exposures to ergonomic stressors and positive organizational climate (reflecting greater perceived responsibility and commitment by oneself and the group) were found to have a 2.15-fold greater likelihood (95% CI: 1.14 – 4.06) than those with lower levels of ergonomic risk exposure and negative organizational climate (i.e., less perceived responsibility).

DISCUSSION

A cross-sectional investigation was conducted to determine whether suspected ergonomic and specific work organization variables were associated with the presence of low back and/or upper extremity symptoms in workers engaged in jobs identified as having higher risks for musculoskeletal disorders. The work organization variables investigated measured potential stress related to scheduling, job design, management style, organizational characteristics, career concerns, and interpersonal factors. These components of work organization were ones that have been proposed represent the multiple dimensions of occupational stress.

Compared to asymptomatic controls, all three symptomatic groups had significantly greater pain intensity and lower levels of physical function. The symptomatic groups did not differ from the healthy control group on a global measure of mental health suggesting that differential levels of distress cannot account for the observed findings regarding the risks of ergonomic and/or work organization on the symptoms in the various anatomic locations studied. While exposure to ergonomic stressors was consistently found as a risk factor for each musculoskeletal symptom group, risks associated with work organization stressors were dependent on the musculoskeletal symptom group (i.e., low back, upper extremity, or both low back and upper extremity). These results support the hypothesis that certain dimensions of work organization are associated with low back and/or upper extremity symptoms. Specifically, greater time pressure was a risk factor for the occurrence of either low back symptoms or upper extremity symptoms. In addition, greater interpersonal demands at work placed one at a lower risk for low back symptoms that occurred during one's present job. Greater interpersonal demands, cognitive demands, and cognitive uncertainty and less skill discretion were related to increased risks for having concurrent low back and upper extremity symptoms.

When looking at the combination of physical and psychosocial work stressors, individuals with higher exposures to ergonomic stressors and higher levels of time pressure had a greater risk for low back or upper extremity symptoms when compared to persons with lower levels of exposure. Higher levels of ergonomic exposures and cognitive demands, cognitive uncertainty, or interpersonal demands placed one at a higher likelihood for both low back and upper extremity symptoms. These findings supported the hypothesized importance of the combined effect of ergonomic and work demand factors and musculoskeletal symptoms. Additionally, higher levels of ergonomic exposure and positive organizational climate (i.e., greater perceived responsibility) or lower levels of involvement in participatory management were significant risks for combined low back and upper extremity symptom case status.

High-risk Jobs for Musculoskeletal Disorders in the U.S. Marine Corps

It is noteworthy that of the identified high-risk occupational categories, a majority of them are not commonly associated with high physically demanding jobs as might be initially assumed for a military population. In particular, jobs in the administration (i.e., Auditing and Accounting, Disbursing), intelligence (i.e., Image Interpretation and Surveillance/Target Acquisition), legal, and education fields were among the top 10 occupational categories associated with relatively higher rates of musculoskeletal-related outpatient visits. While the exact nature of the biomechanical stressors in these jobs is currently unknown, it is generally assumed that extreme exposures such as heavy lifting or excessive metabolic demands are not typically involved. However, these high-risk jobs may include risk factors for WMSDs such as repetitive motion and/or sustained awkward postures.

It is also interesting that the office-based categories, Auditing and Accounting, and Disbursing were among the top three occupations associated with the highest outpatient visit rates for both low back and upper extremity-related problems. According to equivalent Dictionary of Occupational Title (U.S. Department of Labor, 1991) codes obtained from the U.S. Marine Corps Military Occupational Specialties Manual (Headquarters, U.S. Marine Corps, 1999), these occupational groups were found to have job tasks related to: compiling and maintaining records; typing; data entry; computation of wages/payments; and, preparation of receipts, bills, invoices, and statements. Accordingly, there appears to be little difference between military and civilian workers in these jobs. These findings are consistent with reports from civilian populations that musculoskeletal disorders are problematic among individuals working in these types of jobs (e.g., Bergqvist et al., 1995; Kamwendo et al., 1991; Marcus & Gerr, 1996; Punnett & Bergqvist, 1997).

Past studies of office workers have indicated that ergonomic and occupational psychosocial stressors are key risk factors for low back and UE disorders (Bergqvist et al., 1995; Kamwendo, Linton, & Moritz, 1991; Riihimaki et al., 1994). Therefore, it is essential that identification of risk factors within high-risk occupations address both work-related physical and psychosocial factors (e.g., Carayon, Smith, & Haims, 1999; Feuerstein, 1996; Sauter & Swanson, 1996). There is also a need to move the knowledge further in terms of the independent role of specific occupational psychosocial stressors and their interactive effect with ergonomic stressors in the occurrence of musculoskeletal symptoms. Such information can be useful for tailoring focused prevention/intervention efforts to those performing high-risk jobs.

Delineation of Specific Work Organization Factors

Past discussions of occupational psychosocial stress (i.e., job stress) and WMSDs have rarely made distinctions on the dimensions of such stress. Furthermore, in clinical and empirical efforts outside the behavioral and social sciences, job stress has been considered as a broad and vague construct that is difficult to assess and/or to be controlled for in a given investigation (e.g., Hurrell, Nelson, & Simmons, 1998; Kasl, 1998; Landsbergis & Theorell, 2000). The lack of a common definition for discussing and examining these factors have limited efforts in understanding its role in worker health and health outcomes, including those associated with musculoskeletal disorders.

As evidenced in the introduction, a number of varying constructs have been used to reflect the different aspects of psychosocial stress in the work environment. The present study supported previous discussions and models (e.g., Cooper & Marshall, 1976; NIOSH, 1996) that have conceptualized work organization as consisting of six components related to: Scheduling, Job Design, Management Style, Organizational Characteristics, Career Concerns, and Interpersonal factors. Specifically, the factor analyses of the work organization items indicated that Scheduling was related to work break opportunities, perceptions of pressure to keep working, and urgency on the job. Items related to skill discretion, cognitive demands, and cognitive uncertainty in work tasks were also identified and can be considered within the context the Job Design factor. Items that loaded on a Management Style factor were empirically defined in this study as particular to one's involvement/participation in making decisions that affect the individual worker as well as the group and feedback, while Organizational Characteristics referred to perceptions of an individual's and others' responsibility for the work and how it is completed. Concerns related to future job advancement, stability, and responsibilities were grouped together as Career Concerns. Finally, items loading on the Interpersonal factor involved the requirement of working with others on the job and not conflict with co-workers or supervisors. Although it may appear that some similarities among these work organization stressors exist, correlation analyses indicated that any overlap was not strong. Furthermore, the work organization variables were found to have low, if any, correlation with the individual psychosocial items of family conflict and life-related worries suggesting that the work-related stressors were specific to work environment conditions and related to general life and/or individual conditions to a lesser degree.

Based on the present results related to the dimensions of occupational stress, it is suggested that future conceptualizations and research on occupational psychosocial stressors differentiate between Scheduling, Job Design, Management Style, Organizational Characteristics, Career Concerns, and Interpersonal factors. Future work that validates models of occupational psychosocial stress and their proposed pathways for musculoskeletal outcomes should use these work organization factors (Huang, Feuerstein, & Sauter, in press). For example, research may examine the cognitive, behavioral, and physiological reactions that have a high probability of occurring in response to each of the exposures and subsequent musculoskeletal morbidity (Feuerstein, 1996; Feuerstein, Huang, & Pransky, 1999). By looking at work organization in more precise terms, work and health outcomes related to WMSDs might be better understood.

Risk Factors Associated with the Occurrence of Musculoskeletal Symptoms

The present study indicated that risk factors for the occurrence of low back, upper extremity, or both low back and upper extremity symptoms were associated with certain aspects of demographics, individual psychosocial, ergonomic, and work organization factors. Age, family conflict, ergonomic stressors, time pressure, skill discretion, cognitive demands, cognitive uncertainty, organizational climate, and interpersonal demands were found to have statistically significant odds ratios for musculoskeletal symptoms. In contrast, results suggested that gender, education level, exercise, perceived exertion at work, and career concerns play less of a role in the occurrence of symptoms in healthy workers. However, these variables may be important in influencing other outcomes such as lost time and/or disability in workers with a longer history of WMSDs and should not necessarily be excluded from future investigations.

As noted, a key component of the present study was the identification of specific work organization variables that may be involved with musculoskeletal symptoms in different anatomic locations. The following sections first discuss age, family conflict, and ergonomics in the scope of musculoskeletal disorders in general. Afterwards, a more focused discussion on the findings for the work organization variables in relation the type(s) of musculoskeletal symptoms (i.e., low back, upper extremity, low back and upper extremity) is given.

Age

The present findings that increasing age is associated with increasing risks for low back and upper extremity symptoms are consistent with those in past research. Burdorf and Sorock (1997) reviewed epidemiological investigations that examined physical, psychological, and individual risk factors for back disorders and found that most of the studies reported a positive (i.e., greater risk) or no association for age. Older age was also found to be a risk factor for self-reported upper extremity disorders in visual display terminal workers (Bergqvist et al., 1995). Among a sample of workers with unspecified types of jobs who participated in the 1988 National Health Interview Survey, increasing age placed one at a greater likelihood for the self-report of having had medically-diagnosed carpal tunnel syndrome (Tanaka, Wild, Seligman, Cameron & Freund, 1997).

While increasing age has been associated with either back or upper extremity disorders, the present study also found that it is a risk factor for Marines with concurrent low back and upper extremity symptoms that occurred since the start of their current job. However, since age is unmodifiable from a prevention/intervention perspective, it mainly gives an indication of those who may require a greater need for accommodative solutions in order to reduce the probability of musculoskeletal symptoms in general. It also may be related to degenerative processes, particularly in the spine (Frymoyer & Andersson, 1991). In the Marine Corps, such attention may be particularly important given that the rates for 12 of the top 15 low back- and upper extremity-related sources of outpatient clinic visits were found to significantly increase across age groups in enlisted personnel (Huang, 2000).

Family conflict

The present study indicated that family conflict is also a risk factor for low back and upper extremity symptoms relatively health young workers. Dimensions of this family conflict included whether family members became angry, fought, lost their tempers, and criticized each other. Relatively few studies have examined the association between family stressors and work-related musculoskeletal disorders. When compared to healthy controls, Feuerstein, Sult, and Houle (1985) found that persons with recurrent mechanical low back pain had higher levels of family conflict. Altogether, these findings suggest that the presence of family stressors should be assessed when determining risk for low back or upper extremity symptoms.

The role of family conflict in musculoskeletal disorders may relate to the additional stress on the worker that stems from this conflict and its potential reflection of the lack of family support. Melin and Lundberg (1997) primarily address workloads from work and the lack of recovery at home in proposing a biopsychosocial pathway for musculoskeletal disorders. It is possible that stress associated with conflicts at home contribute in this failure to recover as well. That is, acute elicitation of stress responses such as increased muscle tension/activity and elevated cortisol and catecholamine levels may be triggered when a family/home conflict occurs. When adverse family/home conditions are present over an extended period of time, these stress responses may add to the stress at work and create a condition of persistent physiological arousal that places a person at greater risk for a musculoskeletal disorder. It should be noted that the items used to assess family conflict deal with the family/home environment in general, rather than isolated occurrences of conflict. Therefore, it is likely that the family conflict measured has existed for longer periods of time, thereby potentially setting the stage for musculoskeletal symptoms. The potential contribution of family conflict to musculoskeletal symptoms needs to be explored further in order to understand its specific role.

The possible relationship of family conflict to reduced social support is important to understand given that social support has been noted to have positive associations with physical and psychological health (House, Landis, & Umberson, 1988). Several studies have observed that lower levels of social support at work are associated with low back and upper extremity disorders (e.g., Devereux, Buckle, & Vlachonikolis, 1999; Faucett & Rempel, 1994; Kamwendo, Linton, & Moritz, 1991; Lagerstrom, Wenemark, Hagberg, & Hjelm, 1995). It is still unclear whether lower levels of family support are associated with work-related musculoskeletal disorders. However, it is possible that a home environment characterized by conflicts would be an indication that there is little or no family support available. In addition to the resulting stress and stress responses, the lack of a supporting home environment to buffer the stress from work may contribute to the experience of low back and/or upper extremity symptoms (Feuerstein, Berkowitz, & Huang, 1999).

Ergonomic stressors

Exposures to adverse ergonomic conditions such as high repetition, sustained awkward postures, excessive force placed on tendons, joints, and muscles, and inadequate recovery of musculoskeletal structures have been widely established in the literature as risk factors for both back and upper extremity symptoms and disorders

(Holmstrom, Lindell, & Moritz, 1992; NIOSH, 1997; Ohlsson et al., 1995; Punnett et al., 1991). Similarly, the present study found that self-reported exposures to ergonomic risk factors were associated with an increased likelihood for the occurrence of low back and/or upper extremity symptoms. Although the odds ratios may appear modest, one should bear in mind that these figures were for each point increase on the JRPDS. In comparing the high level and low level exposure groups, it was determined that these odds ratios could translate into a 1.8 to 2.9-times greater likelihood for being a symptomatic case (see Figures 15 to 17). Such risks suggest that ergonomic factors are important risk factors within this population and their assessment is essential with regard to musculoskeletal disorders.

Work Organization Factors: A Comprehensive Examination of Job Stress and Work-related Musculoskeletal Symptoms

Examination of the specific work organization variables that were significantly associated with musculoskeletal symptoms indicated that time pressure as a stressor was more prominent among those with only low back or UE symptoms while a different set of stressors (i.e., skill discretion, cognitive demands, cognitive uncertainty, and interpersonal demands) were involved with persons with both low back and UE symptoms. While it is possible that a lack of study power may have contributed to an inability to obtain significant associations for the other work organization variables, the p-values for these statistically non-significant variables did not suggest any trends towards significance. In turn, the patterns that were indicated highlight the need for making distinctions among particular work organization factors in discussions of occupational psychosocial risk factors for musculoskeletal disorders and related research.

Risk factors for either low back or upper extremity symptoms

Some studies have reported that perceived time and/or work pressure place workers at greater risk for musculoskeletal problems. A cross-sectional study of nurses found that the belief that one "ought to slow down at work" had a prevalence odds ratio (POR) of 1.94 for self-reported back complaints, while a difficult work rate (POR = 1.68) and the belief that one ought to slow down at work (POR = 2.71) were associated with arm or neck complaints (Engels, van der Gulden, Senden, & van't Hof, 1996). Increased time pressure at work (defined by reduced time to complete job-related goals) and work/rest schedule were also found to be associated with a greater incidence of upper extremity disorders among customer service representatives at a bank (Ferreira, Conceicao, & Saldiva, 1997). The present study indicated that similar aspects of time pressure involving perceptions that one must continuously work and that things must be completed in an urgent manner are particularly relevant in determining the occurrence of low back or upper extremity symptoms. One possibility for why time pressure is associated with musculoskeletal symptoms is its effects on muscle activity. A recent investigation found that higher time pressure in completing a standardized computer task produced greater EMG activity in the trapezius, deltoid, infraspinatus, and extensor digitorum muscle groups in female computer aided design operators (Birch, Juul-Kristensen, Jensen, Finsen, & Christensen, 2000). Feuerstein and Fitzgerald (1992) have also reported that fewer opportunities to rest was associated with higher levels of fatigue in a sample of sign language interpreters with upper extremity symptoms in comparison to matched asymptomatic controls. Therefore, perceptions of the need to keep working and to work at a faster pace may be especially problematic since they could lead to overexertion and prevent one from taking breaks that assist with recovery processes (e.g., Rodgers, 1997).

It is interesting that greater interpersonal demands (e.g., requirement of a lot of cooperative work with others) were found to be a protective factor for low back symptom status. Although past studies have indicated that poorer social relations at work were correlated with and/or predictive of low back pain/disorders (e.g., Dehlin & Berg, 1977; Leino & Hanninen, 1995; Riihimaaki, et al., 1994), Ylipaa and colleagues (1997) found that solitary work was associated with neck, shoulder, and/or upper back pain in dental hygienists. Therefore, it appears that whereas adverse interpersonal relationships at work may be a potential stressor, they should be regarded separately from job requirements that involve social contact with other workers. The questionnaire items used in the present study asked whether the job required one to work with others and not about the quality of such interactions. The protective nature of these requirements may stem from increased opportunities for mobility at work. Since sedentary work (e.g., seated work) and static work postures can produce loads that lead to the development of fatigue and residual deformation of tissues, particularly on the spine (Bendix, 1994; NIOSH, 1997; Shelerud, 1998), work that involves more movement to interact with others may help reduce the probability of back pain. Future research should quantitatively assess physical movement activity levels (e.g., standing, walking) associated with cooperative work before further conclusions can be made. Nevertheless, the finding related to greater interpersonal demands and the occurrence of low back symptoms demonstrates that certain work organization factors may have protective features in worker health.

Risk factors for concurrent low back & upper extremity symptoms

Contrary to the results from the analyses of cases with low back symptoms only, greater interpersonal demands in addition to lower skill discretion and greater cognitive demands and uncertainty placed one at an increased risk for having both low back and upper extremity symptoms. First, it is important to emphasize that the group with symptoms in multiple anatomic locations had higher levels of pain and decreased physical function, thereby indicating that these individuals were more severe cases. Also, the finding that a greater number of work organization stressors were significant in the final analyses while family/home/life factors (i.e., family conflict and life-related worries) were not, suggested that perhaps work-related stressors play a more prominent role in more severe instances of musculoskeletal symptoms (i.e., having both low back and UE symptoms). Altogether, one can infer from these results that there is a potential dose-response relationship between the number of work-related stressors and musculoskeletal symptoms in both the low back and upper extremity. That is, having symptoms in both the low back and upper extremity regions, greater levels of pain, and lower levels of physical function may be related to the experience of a greater number of work organization stressors. It should also be noted that three of the four significant risk factors involve some type of demand placed on the worker. A recent review of the epidemiological evidence for work-related musculoskeletal disorders indicated that more studies reported positive associations for high job demands than no associations (National Research Council, 2001).

The present study found that lower skill discretion alone placed individuals at higher risks for both back and UE symptoms. One should bear in mind that skill discretion is one subcomponent of the decision latitude construct as proposed by Karasek and colleagues (1998). The other subcomponent is decision authority. While some studies on back disorders have indicated associations with lower levels of skill discretion or utilization (e.g., Ahlberg-Hulten, Theorell, & Sigala, 1995; Foppa & Noack, 1996), upper extremity disorder studies that have examined skill discretion have done so primarily in the context of both skill discretion and decision authority (e.g., Bernard et al., 1994; Faucett & Rempel, 1994; Hughes, Silverstein, & Evanoff, 1997). Additionally, decision latitude has been reported to have more positive associations with back disorders but more null associations in upper extremity disorders (National Research Council, 2001). Given the present findings, it may be worthwhile to examine how skill discretion by itself is associated with specific musculoskeletal disorders.

Studies such as those conducted by Engstrom, Hanse, and Kadefors (1999), Hagen, Magnus, and Vetlesen (1998), Krause and colleagues (1998), and Polyani and colleagues (1997) (see Tables 3 & 4) have indicated that high levels of "psychological demands" are associated with work-related musculoskeletal disorders. Additionally, Melin and Lundberg (1997) have suggested that mental stressors are associated with increased muscle activity. However, by specifying what these mental/cognitive stressors refer to (e.g., cognitive uncertainty, memory requirements, information processing), discussions of their link to musculoskeletal problems may be better understood.

Waersted and colleagues (1996) have demonstrated through EMG-recordings that trapezius muscle motor units actively fire when performing a cognitively demanding choice-reaction time task. The present study suggests that additional laboratory investigations on how cognitive/psychological demands lead to physiological changes and associated reports of pain and other symptoms should utilize conditions/tasks related to decision-making, memorization of pertinent information for performing a job task, and information processing.

Ergonomic & Work Organization Combinations Associated with the Occurrence of Musculoskeletal Symptoms

Few studies have examined how combinations of ergonomic factors and specific work organization variables are related to musculoskeletal symptoms. Bergqvist and colleagues (1995) found the interaction between working on a visual display terminal and having limited opportunities for rest breaks had an odds ratio of 4.8 for reporting neck/shoulder discomfort in office workers. In the same study, arm/hand diagnoses as determined by a physiotherapist were associated with limited rest break opportunities and lower arm support in persons who worked more than 20 hours a week. Faucett and Rempel (1994) also found that decision latitude, job insecurity, supervisor support, and supervisor conflict all independently interacted with relative keyboard height in determining severity of upper extremity numbness in newspaper employees. While these findings suggest that physical and psychosocial work stressors have a joint association in upper extremity symptoms/disorders, the conclusions that can be made are limited because these analyses only examined the product of the ergonomic and work organization variables in either logistic regression or multiple linear regression analyses. In other words, such analyses are unclear as to how such interactions should be interpreted in determining risks and what levels of these combinations give one a greater likelihood for upper extremity problems (Rothman, 1986). Furthermore, since no studies have looked at the interaction between ergonomic and work organization factors in low back disorders, inferences cannot be made with regard to how such interactions are involved in low back disorders.

Combinations associated with either low back or upper extremity symptoms

The finding that high levels of both exposures to ergonomic stressors and time pressure significantly placed one at greater risks for either low back or upper extremity symptoms suggest that there is an additive effect for these two factors. It has been observed that increased time pressure at a computer-based task produced increased EMG activity in various upper extremity muscle groups (Birch et al., 2000). Research has yet to examine if time pressure is associated with muscle tension and/or greater loads in the trunk musculature or spine. Nevertheless, it is possible that when workers are in an adverse ergonomic environment, any resulting musculoskeletal fatigue and discomfort may be further exacerbated by increased muscle activity stemming from greater time pressure. Mention has already been given to potential mechanisms by which time pressure influences either low back or upper extremity symptoms. The present findings suggest that particular attention be given to time pressure when also in the presence of ergonomic risks because of its association to symptoms in multiple anatomic regions.

Combinations associated with concurrent low back & upper extremity symptoms

Even though several combinations of ergonomic and work organization factors were associated with risks for concurrent low back and upper extremity symptoms, patterns were noted among these combinations. In particular, combinations that involve both ergonomic stress and job demands (i.e., cognitive and interpersonal) or ergonomic stress and personal involvement factors (i.e., management style and job responsibility) could be distinguished. The following sections address the findings according to these patterns.

Ergonomic exposure & work demands

Epidemiological investigations have linked greater work demands to WMSDs (Bergenudd & Nilsson, 1988; deZwart, Broersen, Frings-Dresen, & van Dijk, 1997; Foppa & Noack, 1006; Holmstrom, Lindell, & Moritz, 1992; Polyani et al., 1997). However, the wide range of potential demands makes it unclear as to what may be involved and whether they contribute to musculoskeletal pathology above and beyond physical factors. It is suggested that levels of ergonomic stressors be more closely examined in conjunction with levels of work demands that are cognitive as well as social in nature.

Mechanisms explaining how work demands and ergonomic factors mutually act in musculoskeletal disorders may involve physiological and biochemical responses to such stressors. Potential mechanisms involving exposures to ergonomic risks and time pressure have already been discussed in the preceding section. It has also been hypothesized that "psychological stress" can lead to sustained activity levels in small, low-threshold motor units that result in muscle damage and/or degenerative processes (Lundberg et al., 1999). This hypothesis has been supported by Waersted and colleagues' (1996) findings that trapezius motor units actively fire over the course of performing choice-reaction tasks. Furthermore, this study and another by Waersted and Westgaard (1996) have reported that activity in the frontalis and upper trapezius muscles is prevalent when a person is engaged in tasks that require cognitive and perceptual attention. Past work in psychophysiology has linked social interaction to autonomic arousal as indicated by heart rate acceleration, increased skin conductance, and increased facial EMG activity (Cacioppo, Rourke, Marshall-Goodell, Tassinary, & Baron, 1990; Gardner, Gariel, & Diekman, 2000; Vrana & Rollock, 1998; Waldstein, Neumann, Burns, & Maier, 1998). On a biochemical level, it has been indicated that epinephrine is correlated with mental stress tasks (Lundberg & Johansson, in press). Additionally, anticipation of negative events/outcomes may lead to increases in cortisol (Kirschbaum & Hellhammer, 1989). Such activity may be particularly relevant in job tasks in which there is uncertainty on how to proceed (i.e., cognitive uncertainty). Taken together, work demands may trigger certain physiological responses that intensify pathological processes that were initiated by non-optimal ergonomic work environments. Future research should utilize physiological and biochemical indices of the stress response in order to establish any potential pathway by which work demands and ergonomic factors interact.

Ergonomic exposure & job involvement

In addition to the risks from ergonomic and work demand combinations, the other set of combinations identified were those involving ergonomic exposure and job involvement (i.e., in a participatory management style and perceived responsibility at work). In a sample of U.S. Army soldiers, greater involvement at work (as measured by the Work Environment Scale (Insel & Moos, 1974)) was found to be protective against having lost time associated with occupational low back pain (Feuerstein et al., under review). The management style variable in the present study was comprised of items related to an individual's participation in decision-making processes and may reflect perceived control at work, which should be distinguished from actual control (Spector, 1998). Perceived control has been related to several different work and health outcomes including job satisfaction, performance, role ambiguity, role conflict, physical symptoms, emotional distress, and lost time (Elloy, Everett, & Flynn, 1995; Karasek, 1979; Spector, 1986; Terry & Jimmieson, 1999). Extensive discussion has been given to the role of control (perceived or actual) in general physical and psychological health (e.g., Spector, 1998), although relatively little of this discussion has focused specifically on musculoskeletal health among workers.

It has been proposed that a lack of perceived control at work has a moderating effect on the experience of other job stressors and may potentially lead to subsequent distress (Spector, 1998). Specifically, when a worker perceives his/her level of control to be low, an emotional reaction may take place that involves elevations in epinephrine, norepinephrine, and cortisol (Frankenhaeuser, 1979; Frankenhaeuser & Lundberg, 1982). When coupled with tissue degeneration and/or increased muscle fatigue associated with ergonomic exposure, these stress hormones may facilitate the onset of pain and increased fatigue in the low back and upper extremities. Such a possibility may explain how those with high ergonomic exposures to risk factors and low involvement in management/decision-making were at a 2.5-fold greater risk for having both low back and upper extremity symptoms.

Interestingly, greater perceptions of personal and group responsibility for the job and how it is performed (i.e., organizational climate) were found in conjunction with high ergonomic exposures to place persons at a higher risk for low back and upper extremity symptoms. Spector (1998) has suggested that responsibility is linked with control, which as discussed, was potentially why lower involvement in a participatory management style was a risk factor. Additionally, while increased responsibility and/or perceptions of such are commonly viewed as positive qualities to have at the workplace, they may be associated with a set of behaviors that place workers at increased risk for the occurrence of WMSDs. Having a greater sense of responsibility for work can lead to taking greater initiative and exerting more effort to ensuring that a particular task is completed and completed well (e.g., Fay, Sonnentag, & Frese, 1998). With such effort, there may be greater physiological arousal that can induce catecholamine secretion (Frankenhaeuser & Lundberg, 1982; Schonpflug, 1986) which, in turn, can lead to the onset of symptoms. Furthermore, being in an environment that fosters and encourages greater responsibility can contribute to an individual's sense of responsibility and subsequent physical exertion for an extended period of time. Not only can these conditions set the stage for fatigue and pain, but also detriments in physical function as suggested by the present finding that greater perceived responsibility and JRPDS score related to lower levels of physical function, even after controlling for physical exertion.

Implications of the combined ergonomic-work organization findings

Based on the set of combinations identified as risk factors in the present study, musculoskeletal symptoms appear to be associated with an additive effect from ergonomic and work organization factors. The observation that neither of the mixed high-low or low-high combinations of ergonomic exposures and work organization had significant odds ratios for either low back or upper extremity symptoms suggest that it is not sufficient to address ergonomic or time pressure factors independently. Physical or occupational psychosocial stressors by themselves may produce a set of similar physiological responses involving muscle activity and/or the release of catecholamines and cortisol. However, when both exposures are present, the sum of the subsequent responses may be one that places an individual above a threshold for the onset of fatigue and pain. The exact mechanism by which this event may occur is currently unclear.

In addition to the insights into potential mechanisms, the present results also have implications for conceptualizing musculoskeletal outcomes according to the initially proposed model (i.e., modified Workstyle model – see Figure 11) and for prevention and intervention strategies. These implications are discussed in sequence in the following sections.

Relation of Findings to Proposed Model

The patterns of combinations observed to be risk factors suggest that they can be conceptualized to represent work demands or workplace psychosocial stressors in accordance with the Workstyle model. Specific demands that contributed with ergonomic factors were those related to scheduling (i.e., time pressure) and job design (i.e., cognitive demands, cognitive uncertainty). However, interpersonal demands were another type workplace variable that should be included in this group of work demands. Also, since items related to management style were more pertinent to one's participation in decision-making processes rather than demands placed upon the worker from management as initially hypothesized, this factor should be re-categorized as a workplace psychosocial stressor. While this restructuring does not preclude utilizing the model as initially proposed, the present findings provide direction for how the more prominent work organization factors should be viewed in context of the Workstyle model.

Discussion of the proposed mechanisms by which ergonomic and work organization factors jointly impact low back and/or upper extremity disorders primarily focused on physiological responses. Yet, behavioral and cognitive reactivity in response to work-related stressors also deserve consideration. For example, when one is under greater time pressure, he/she may work in a manner that contributes to pain and symptoms. In computer-based tasks such as keying and mouse use, increased time pressure may cause individuals to exact more force than necessary that, in turn, is associated with higher levels of symptoms (e.g., Feuerstein et al., 1997). Time pressure may also produce greater increases in cognitive activity since greater attention may be required to complete a job accurately (e.g., Birch et al., 2000). Similar scenarios may be described with regard to skill discretion, cognitive demands/uncertainty, and interpersonal demands. While no work organization variables were found to be associated with increased pain intensity, based on the current findings, these work organization factors were associated with the occurrence of musculoskeletal symptoms but not severity. Furthermore, it is also important to note the role of workstyle in functional limitations. As noted, the present study's finding that physical function was correlated with greater perceived responsibility suggests that, in addition to ergonomic factors, how a person carries out his/her work in response to such perceptions could influence levels of physical function. Future research that attempts to validate the Workstyle model should utilize the identified work-organization variables as sources of stress while concurrently assessing exposure to ergonomic risk factors in determining the pathways for particular musculoskeletal-related outcomes (i.e., symptoms, severity, function).

Implications for Prevention and Intervention

Besides elucidating potential mechanisms for WMSDs, the identification of workplace risk factors can direct evaluation, prevention, and/or intervention efforts. Such efforts can help to reduce or eliminate potential stressors before workers are exposed (i.e., primary prevention), modify or control the impact that a stressor may have (i.e., secondary intervention), or enable workers to more effectively manage or cope with subsequent reactions to a stressful condition (i.e., tertiary intervention) (Hurrell & Murphy, 1996). Furthermore, interventions can occur at the level of the individual, individual/organizational interface, or organization (van der Hek & Plomp, 1997).

Scheer and Mital (1997) note that ergonomic interventions can be described in terms of worker training, worker selection, and job redesign. Even though all three methods can potentially assist with reducing the impact of musculoskeletal disorders, job redesign has been a more prominent approach to low back and upper extremity problems (e.g., Chaffin, 1997; Smith & Cohen, 1997). Since high levels of physical stressors that included repetitive movements, frequent bending/twisting, sustained awkward postures, and/or inadequate rest/recovery posed significant risks to Marines for musculoskeletal symptoms, job redesign that decreases such exposures represents a logical component of prevention/intervention.

With regard to work organization factors, the number of risk factors identified in the present study suggests that multiple approaches may be beneficial. However, before any type of intervention is implemented, particular aspects of the job that contribute to the perceived demands should be determined. One option for obtaining this information may be to conduct focus groups (e.g., Templeton, 1994). In the present study, discussions with study participants anecdotally suggested that insufficient manpower and increased work demands stemming from misunderstood job roles/responsibilities by other divisions were among sources of "job stress". By systematically collecting similar types of qualitative data on sources of cognitive demands, cognitive uncertainty, or interpersonal demands, direction can be provided for where prevention/intervention efforts should be focused.

Once specific sources of job stress are identified, various stress management techniques can be integrated on both individual and organizational levels. Instruction on problem solving methods may be one useful way to assist with reducing the impact of and distress from workplace stressors (e.g., D'Zurilla & Chang, 1995; D'Zurilla & Sheedy, 1991). By improving one's ability to problem solve, subsequent identification and corrective actions that are taken may assist with reducing or eliminating the elements that cause greater cognitive demands, cognitive uncertainty, or interpersonal demands (Xerox, 1986). Other courses of action such as exercise and muscle and relaxation training also deserve consideration (e.g., Hurrell & Murphy, 1996; van der Hek & Plomp, 1997). Given the possible biobehavioral mechanisms related to WMSDs previously described, especially in relation to the combination of positive organizational climate (i.e., greater perceived responsibility) and ergonomic stressors, techniques that can decrease adrenergic responsivity and facilitate muscle tension release may hold promise for improving worker health (Everly, 1989).

The recent recognition by the Marine Corps for the need to reduce non-fatal injuries may also help with the adoption of organization-level policies that support group- and individual-level interventions (Assistant Commandant of the Marine Corps, 2000). From an organizational standpoint, operational efforts should consider facilitating participation in both ergonomic redesign and decision-making processes (e.g., Noro, 1999; Nytro, Saksvik, Mikkelsen, Bohle, & Quinlan, 2000). Although the hierarchical organization of the Marine Corps requires that lower ranked individuals follow orders from superiors and/or officers, higher ranked individuals may still take into account suggestions from those under their command. This suggestion could present wider possibilities for enhancing operations as well as increase the level of involvement in a participatory management style, which should decrease the risk for musculoskeletal symptoms based on the present findings. Information sessions (i.e., safety briefs) that are periodically conducted can also begin to incorporate aforementioned problem solving strategies and techniques with the purpose of helping Marines to recognize physical and occupational psychosocial stressors and what can be done to reduce their impact. Not only would such an approach be more logistically plausible than case-by-case or individual interventions, but encouragement from higher level authorities would demonstrate a needed emphasis and commitment in efforts aimed at reducing the occurrence of work-related musculoskeletal disorders (NRC, 2001).

With any implementation of prevention/intervention efforts, it is essential that risks be continuously monitored. The findings related to ergonomic risk exposure suggest that the Job Factors subscale of the JRPDS, which takes a only few minutes to complete, may prove useful in a comprehensive ergonomic assessment strategy for the Marine Corps. In conjunction with MCO P5100.8f, the Marine Corps directive on occupational safety and health that provides ergonomic guidelines (Commandant of the Marine Corps, 1998) and the Navy's Corporate Ergonomic Plan (Chief of Naval Operations, 1999), the JRPDS as a self-report measure may assist with determining ergonomic risk exposure. As a result, fewer resources, such as time and manpower, would be required than if observational job analyses were conducted throughout the service. In a study of U.S. Army soldiers, this same measure has also been found to significantly predict individuals who had occupational low back pain and lost time within the past 12 months (Feuerstein et al., under review). Therefore, in addition to determining those workers at risk for the occurrence of musculoskeletal symptoms, the JRPDS may also help to enhance readiness by identifying persons who are at risk for having lost time associated with a WMSD. However, as noted, any potential benefit from using the JRPDS is limited unless scheduling, job design, organizational characteristics, and interpersonal factors are also assessed.

Evidence exists to suggest that workstation redesign, exercise, employee involvement, and management support have positive impacts on back and upper extremity outcomes (NRC, 2001). However, reviews of individual or organizational-level stress management programs have produced mixed results on their efficacy (e.g., Hurrell & Murphy, 1996; Kirstensen, 2000; Reynolds, 2000; van der Hek & Plomp, 1997). Therefore, after the initiation of a particular prevention and/or intervention strategy, outcome data on symptom reports, clinic visits, lost time, and costs related to WMSDs should be regularly examined in order to provide a basis for evaluating their effectiveness and to determine whether any modifications need to be made (Pransky & Himmelstein, 1996).

Limitations

While the present investigation advanced knowledge on specific dimensions of work organization and identified combinations of ergonomic and job stressors associated with the occurrence of musculoskeletal symptoms, notice should be given to its limitations because they provide a context for interpreting the results and future directions for research.

The cross-sectional methodology utilized can only give indications of the associations between risk factors and musculoskeletal outcomes and not cause-effect relationships (Kleinbaum, Kupper, & Morgenstern, 1982). However, findings from such studies can help support past links and/or establish a basis for prospective research that examines identified associations over time. Additionally, they can help generate hypotheses on potential mechanisms for how a given outcome occurs. The present study delineated work organization factors involved in low back, upper extremity, and concurrent low back and upper extremity symptoms in a manner that had not been previously performed. However, before conclusions can be made on the directionality of these factors, prospective investigations should be conducted to examine how these specific variables influence musculoskeletal morbidity. Currently, efforts are underway to examine whether the identified risk factors (individual and combined) predict future clinic visits for a musculoskeletal disorder.

In the present study, ergonomic and work organization exposures were determined through self-report. Wiktorin and colleagues (1993) have found that self-reported exposures to various work postures including having one's head bent in a forward position, sitting, and lifting had moderate correlations (Spearman correlation coefficients = 0.41 to 0.85) and "acceptable" accuracy (kappa values = 0.32 – 0.52 for a three-point self-report scale) with objective measurements from a posimeter, inclinometer, and observation by an ergonomist. However, they argue that if more precise detail on level of exposure is required that a self-report measure may not be sufficient. Kasl (1998) also notes that although subjective measurement tools that enable the assessment of perceptions of environmental conditions are important in empirical investigations of job stress, objective measurement may provide a clearer picture of potential etiological processes and helps reduce potential confounding from influences that may influence subjective reports. Even though the present study helps to narrow the scope of workplace stressors to be examined, future investigations should also include objective measures of ergonomic risk exposure and work organization stressors (e.g., time pressure, interpersonal demands). External (objective) assessment methods of ergonomic exposures include the OWAS (Karhu, Kansi, & Kuorinka, 1977) and Rodgers' (1992) job analysis technique, while methods for examining job stress may include reports from supervisor or co-workers or observations by outside individuals

(Landsbergis & Theorell, 2000). The use of these assessment techniques may subsequently enable a standardized method (as opposed to the use of self-report) for determining risks from both physical and work organization factors. While resource restrictions limited the ability to carry out such observations in the present study, self-report ergonomic and work organization measures were selected based on their psychometric properties and use in prior investigations of workplace stress and/or WMSDs. These items, in turn, enabled the identification of job features that placed individuals at increased risk for musculoskeletal symptoms.

As with the assessment of potential risk factors, musculoskeletal case status was also based on self-report. Though medical records could have served as an alternate source for confirming the existence of symptoms (Silverstein et al., 1997), symptomatic individuals within this relatively healthy, young population may not have necessarily gone to see a health care provider at this point in their natural history. Other objective methods such as physical examination by a medical professional could have also been utilized. However, the time and resource requirements for implementing such an approach was not feasible. Toomingas, Nemeth, and Alfredsson (1995) suggest that while epidemiological investigations of musculoskeletal symptoms/disorders should use medical examinations, self-administered upper extremity examinations had acceptable validity for determining tenderness in the neck and shoulder regions (kappa = 0.27 – 0.38). In an attempt to establish some consistency with prior research (e.g., Bernard et al., 1994; Feuerstein et al., 2000; Hales et al., 1994), the present study used a modified NIOSH case definition that included the report of symptoms since starting one's current job. In comparison to other available case definitions based on self-report (e.g., Hunting et al., 1994; Kuorinka et al., 1984), Beaton and colleagues (2000) have noted that the NIOSH definition is more "stringent" because of its requirements on frequency and severity of symptoms. Nevertheless, until a consensus definition on work-related musculoskeletal symptoms and disorders is reached, studies must clearly define how cases are determined.

The use of a military sample could also lead to questions about the ability to generalize the results to a civilian population. One should bear in mind that one aim of the present study was to identify risk factors within a population known to have significant burdens associated with musculoskeletal disorders. Consequently, assessing potential risk factors in this particular group was necessary to build off previous knowledge. Yet, the fact that a majority of study participants had job tasks with generic job descriptions that were similar to their civilian counterparts provides support that findings are applicable to both military and civilian workers. Furthermore, comparisons on the SF-12 physical function and mental health subscales indicated that the sample was similar to age- and gender-matched norms obtained from the general U.S. population (Ware, Kosinski, & Keller, 1998). One should be aware, however, that the present study sample was relatively young (mean age = 28.0 years) and was 88.2% male, reflecting the predominance of males among the enlisted ranks in the Marine Corps (94.2%) (Division of Public Affairs, Headquarters Marine Corps, 1999). The overrepresentation of young males would suggest that additional studies in both military and civilian populations be conducted with a particular emphasis on incorporating females to determine whether gender should be considered more strongly in determining risk and developing workplace interventions. However, the ethnic and racial diversity of the sample is a particularly unique characteristic of this study since studies on ergonomic and/or work organization factors in work-related musculoskeletal disorders often do not typically include groups with a wide range of cultural, ethnic, and/or racial backgrounds. In turn, the diversity of the sample suggests that findings may be generalized to persons of different ethnicities and races.

Study participants were also obtained from a convenience sample rather than a random sampling selection process. Subsequently, it is difficult to determine how representative the Marines were to the entire population of Marines in high-risk jobs. Additionally, in cross-sectional studies of work-related musculoskeletal outcomes, the possibility that workers choose less stressful or physically demanding jobs should be considered (Davis & Heaney, in press). However, should such a possibility exist, any significant findings would be underestimations of actual effects. Methodological issues related to the "healthy worker effect" (i.e., selection of only those who are able to work) are also important to address (Arrighi & Hertz-Picciotto, 1994). In the present study though, this concept is less applicable given its focus on determining risk factors for musculoskeletal symptoms in workers who are currently working.

Given the present study's limitations, future research should attempt to address these areas in order to extend conclusions that can be made on the role of work-related stressors in work-related musculoskeletal symptoms and disorders.

Conclusion

Work-related musculoskeletal outcomes (i.e., symptoms, disorders, disability) can have a widespread impact on workers and their organization. As epidemiological research continues to provide support for the multidimensional nature of these problems, it is becoming increasingly apparent that physical and occupational psychosocial factors play an important role. In addition to indications that exposures to physical stressors place individuals at greater risks for low back and/or upper extremity symptoms, the present investigation highlighted the need for efforts to further define occupational psychosocial risk factors in terms of the different dimensions of work organization. Specific combinations of ergonomic and work organization factors must also be considered in comprehensive approaches towards reducing the impact from WMSDs. As previously noted, the current findings suggest that there are several avenues for future research with regard to establishing cause-effect relationships and potential mechanisms. Several prevention/intervention strategies were also put forth based on the identified risk factors. Altogether, the present efforts help to extend existing knowledge on low back and upper extremity problems so that worker health and productivity as well as organizational operations can be enhanced.

TABLES

TABLE 1
Low Back & Upper Extremity-Related ICD-9 Diagnoses

LOW BACK		UPPER EXTREMITY	
Code	**Description**	**Code**	**Description**
720.0	Ankylosing spondylitis	353.0	Brachial plexus lesions
721.3	Lumbosacral spondylosis without myelopathy	354.0	Carpal tunnel syndrome
		354.1	Other lesion of median nerve
721.42	Spondylosis with myelopathy, lumbar region	354.2	Lesion of ulnar nerve
		354.3	Lesion of radial nerve
722.10	Intervertebral disc displacement w/out myelopathy - lumbar	354.8	Mononeuritis – arm, multiplex neck
		354.9	Mononeuritis - arm, multiplex (unspecified)
722.52	Degeneration of lumbar or lumbosacral intervertebral disc	443.0	Raynaud's syndrome
		721.1	Cervical spondylosis with myelopathy
722.73	Intervertebral disc disorder with myelopathy, lumbar region	723.1	Cervicalgia
		723.3	Cervicobrachial syndrome
722.83	Postlaminectomy syndrome of lumbar region	726.0	Adhesive capsulities of shoulder
		726.10	Disorders – bursae & tendons in shoulder region
722.93	Other and unspecified disc disorder of lumbar region	726.12	Bicipital tenosynovitis
		726.3	Enthesopathy of elbow region
724.02	Spinal stenosis - lumbar stenosis	726.30	Enthesopathy of elbow, unspecified
724.2	Lumbago	726.31	Medial epicondylitis
724.3	Sciatica	726.32	Lateral epicondylitis
724.5	Backache, unspecified	726.4	Enthesopathy of wrist and carpus
724.6	Disorders of sacrum	726.9	Unspecified enthesopathies
738.4	Acquired spondylolisthesis	727.00	Synovitis and tenosynovitis, unspecified
739.3	Nonallopathic lesions - lumbar region	727.03	Trigger finger (acquired)
		727.04	Radial styloid tenosynovitis
739.4	Nonallopathic lesions - sacral region	727.05	Other tenosynovitis of hand and wrist
		727.2	Specified bursitides - occupational origin
756.11	Congenital spondylolysis - lumbosacral region	727.9	Disorders of synovium, tendon & bursa (unspecified)
		728.4	Laxity of ligament
756.12	Spondylolisthesis, congenital	728.8	Other specified disorders of muscle, ligament, and fascia
846.0	Sprain/strain of lumbosacral		
846.1	Sprain/strain of sacroiliac	728.9	Disorders of muscle, ligament and fascia nonspecific
846.2	Sprain/strain of sacrospinatus	729.1	Myalgia and myositis, nonspecific
846.3	Sprain/strain of sacrobuberous	729.9	Disorders of soft tissue, neck and nonspecific
846.8	Sprain/strain of sacroiliac region neck	840.3	Sprain/strain of shoulder & upper arm – infraspinatus
		840.5	Sprain/strain of shoulder & upper arm – subscapularis
846.9	Sprain/strain of sacroiliac region nonspecific	840.6	Sprain/strain of shoulder & upper arm – supraspinatus
		840.8	Sprain/strain of shoulder & upper arm – other specified sites
847.2	Sprain/strain of back - lumbar		
847.3	Sprain/strain of back - sacrum	840.9	Sprain/strain of shoulder & upper arm – unspecified
		841.0	Sprain/strain of elbow & forearm – radial collateral ligament
		841.1	Sprain/strain of elbow & forearm – ulnar collateral ligament
		841.8	Sprain/strain of elbow & forearm – other specified site
		841.9	Sprain/strain of elbow & forearm – unspecified site
		847.0	Sprain/strain - Other unspecified part of back – neck

TABLE 2
Job Stress Items by NORA (NIOSH, 1996) Work Organization Categories

NORA Category	scheduling	job design	interpersonal	career concerns	management style	organizational characteristics
NORA terms	• work-rest schedules • hours • shift work	• complexity • skill/effort • control / decision latitude	• relationships with supervisors/ co-workers	• job security • growth opportunities	• participatory management style • teamwork	• climate • culture • communications
Literature search terms	• cycle • flexibility • piece work • rest/breaks	• activity • autonomy • constraints • content / task • cycle regulation • demands / loads • division of labor • expectations • job strain • job stress • monotonous • nature • pace • policies / procedures / rules • practices • pressure • process • production standards • role ambiguity • role conflict • rotation • structure • technology / mechanization / automation • variation • work distribution	• conflict • groups • openness • resources • socialization • support • teams • units	• achievement • advancement • challenge • change • competence • downsizing • effectiveness • engagement • enrichment • future • meaningfulness • performance • rewards • satisfaction • skill level • stage • status • stimulation • success • training / education • wages / salary	• administration • authority • bureaucratization • discrimination • hierarchy • institutionalization • planning • process • skill • subordination • superior • supervisory • treatment	• attitudes • commitment • confidence • environment • esteem • goals • identification • morale • size • strategy
# of terms	7	34	9	25	15	13

TABLE 3
Summary of Studies Examining Work Organization and Low Back Symptoms/Disorders

Author(s) & Year	Subjects	Study Design	Work Organization Variable(s)	Measure / Method of Assessment	Findings
Ahlberg-Hulten et al. (1995)	90 female nurses	cross-sectional	• social support at work • conflicts • stress • decision latitude • psychological demands • skill utilization • job strain	questionnaire; some items from Karasek (1979)	**psychological demands, decision latitude, skill utilization, job strain** univariately predicted self-reported low back pain; **job strain** predicted self-reported low back pain in multivariate model
Bergenudd & Nilsson (1988)	575 Swedish residents	longitudinal cohort	• job satisfaction • psychological work demands	questionnaire – items specified	Subjects with self-reported low back pain had less **job satisfaction** and more **mentally demanding jobs**
Bigos et al. (1991)	approximately 2265 factory workers	prospective	• co-worker support • job satisfaction • relations with supervisor	questionnaire – items specified	**job satisfaction** (RR = 1.5) predicted report of back injury (report to medical dept, filing of incident report, insurance claim) 4-years post
Dehlin & Berg (1977)	233 nursing aides	cross-sectional	• relation with supervisors & workmates • perceived need for info • job satisfaction • perceived need for education • perceived need for physical & psychic strength • perceived strain • adjustment to geriatric work	questionnaire – some items from Rubenowitz (1975)	persons with self-reported back pain/ache and that had low back symptoms starting after starting work had **poorer relations with supervisors/workmates, higher demands for physical & psychic strength, lower job satisfaction**;

Devereux et al. (1999)	638 manual workers, delivery drivers, technicians, customer service computer operators, general office staff	cross-sectional	• mental demands • job control • social support	questionnaire – items based on Karasek (1990) and given	men & women: **high physical, high psychosocial (i.e., high mental demands, low job control, low social support) demands (OR = 2.4)** associated with self-reported low back pain in past 7 days; **high physical, high psychosocial (OR = 3.0) & high physical, low psychosocial demands (OR = 2.4)** associated with self-reported recurrent back problems not before present job and in past 7 days; men: **high physical, high psychosocial demands (OR = 2.8)** associated with self-reported low back pain in past 7 days; **high physical, high psychosocial demands (OR = 2.8)** associated with recurrent back problems not before present job and in past 7 days.
Engstrom et al. (1999)	67 assembly operators	cross-sectional	• decision latitude • social support at work • psychological work load	questionnaire by Rubenowitz (1997)	**no workplace psychosocial factors** found to be correlated with self-reported low back symptoms
Feyer et al. (1992)	257 hospital staff; 256 postal workers	cross-sectional	• work environment • job satisfaction	Work Environment Scale (Moos, 1986);	nurses with self-reported low back pain in past 12-months significantly differed from nurse non-cases on **Task Orientation** subscale; no differences found on job satisfaction
Foppa & Noack (1996)	850 employed men & women	cross-sectional	• job discretion • work demands • control • time pressure • workload • recognition through work • competition	questionnaire – available from authors	compared to no back pain group - men: group with self-reported low back pain had **low job discretion, high job demands, low job discretion x high job demands, low recognition through work, high subjective workload, high competition, low job satisfaction** women: group with self-reported low back pain had **high job demands, lob job discretion x high job demands, time pressure, high subjective workload, dissatisfaction with salary**

Hagen et al. (1998)	645 manual workers; 66 machine operators; 124 administrative workers	cross-sectional	• psychological demands • intellectual discretion • authority over decisions	questionnaire – items from Karasek (1979)	**high psychological demands (OR = 2.0)** associated with self-reported low back symptoms over past 12 months
Holmstrom et al. (1992)	1773 construction workers	cross-sectional	• qualitative demands • quantitative demands • work support • understimulation • work anxiety • job satisfaction • job stress	items adapted from Swedish general health care questionnaire	**quantitative demands (PRR = 1.3), job stress (PRR = 1.6)** predicted self-reported low back pain; **quantitative demands (PRR = 2.0), solitary work (PRR = 1.5), understimulation (PRR = 2.2), job stress (PRR = 3.1)** predicted self-reported severe low back pain
Hughes et al. (1997)	121 aluminum smelter workers	cross-sectional	• job satisfaction • supervisor support • job demands • decision latitude	Karasek & Theorell (1979); Work Apgar (Bigos et al., 1991)	**low job satisfaction (OR = 0.2)** associated with physically diagnosed/self-reported low back pain; **low job satisfaction (OR = 0.2) low social support (OR = 5.3)** associated with self-reported low back pain
Johansson (1995)	999 municipal employees	cross-sectional	• influence on & control over work • supervisor climate • stimulus from work • relations with fellow workers • psychological workload	questionnaire – items from Rubenowitz (1984 & 1989)	**influence on and control over work (RR = 1.3), stimulus from work (RR = 1.4)** associated with self-reported work-related low back symptoms in past 12 months in home care workers
Kamwendo et al. (1991)	420 medical secretaries	cross-sectional	• work stimulation • work variation • superviser & co-worker support • job cooperation • job control • work demands • fear of re-organization	questionnaire – items specified	**work stimulation, work variation, social support, job control** predicted self-reported low back pain

Krause et al. (1998)	1449 transit operators	prospective	• shift • break time • frequency of job problems • decision latitude • psychological job demands • job strain • job satisfaction • co-worker support • supervisor support	questionnaire – items from Job Content Questionnaire (Karasek, 1985)	**High psychological job demands (OR = 1.5), high job dissatisfaction (OR = 1.6)** predicted incidence of spinal injury (i.e., sprain, strain, contusion, pain resulting in workers' compensation claim)
Leino & Hanninen (1995)	902 blue & white collar workers; 654 in 10-yr follow-up	prospective	• work content • work control • social relationships at work • overstrain (mental demands)	questionnaire – items specified	blue-collar men: **work content, social relations** correlated with low back physical findings 10 yrs post; **social relations** correlated with self-reported low back symptoms 10 yrs post; blue-collar women: **work content, work control, social relations, social strain** correlated with low back physical findings 10 yrs post; **work control** correlated with self-reported low back symptoms 10 yrs post white collar women: **social relations** correlated with low back physical findings 10 yrs post
Magnusson et al. (1996)	365 bus drivers, truck drivers, and sedentary workers	cross-sectional	• relationships with co-workers/supervisor • satisfaction with work tasks • job stress • job satisfaction	questions from Bigos et al. (1991)	no variables associated with self-reported low back pain

Myers et al. (1999)	600 workers; 200 back injured cases; 400 controls	cross-sectional	• job strain • job demands • work speed • pace • intensity • amount • flexibility • exercise of skill & creativity • opportunity to learn new things • decision latitude	Job Content Questionnaire (Karasek & Theorell, 1990); Work Control Scale; Psychological Job Demands	**"medium" (OR = 1.7) & "high" (OR = 2.1) job strain** associated with low back pain/strain as reported in medical records
Ono et al. (1997)	2799 nursery school cooks and teachers	cross-sectional	• workload • workload variance • responsibility • required concentration • time pressure • relations at work • staff shortages • inexperience • unplanned work • extra work due to poor physical condition of colleague • role ambiguity • decision latitude • discussion of work problems • work capacity	questionnaire – items specified	**"too much work" (RR = 2.2), "too many different tasks" (RR = 2.5), "too much responsibility" (RR = 2.3), "difficult human relations at work" (RR = 1.9), and "extra work due to poor physical condition of colleague" (RR = 2.1)** associated with self-reported low back pain in previous month

Papageorgiou et al. (1997)	1412 employed persons	prospective	• job satisfaction • social relations • sufficient money	questionnaire – items given	**"marked/severely" dissatisfied with work (RR = 1.4)** predicted low back pain in past month; **"slightly" (RR = 1.7) & "marked/severely" (RR = 2.0) dissatisfied with work** predicted report of low back pain with no medical consultation at 12 months; **"marked/severely" inadequate income (OR = 3.6)** predicted need for low back pain consult at 12 months
Riihimaki et al. (1994)	2222 working men in carpentry, machine operation, or office work	cross-sectional	• work pace • monotonous work • relations with workmates & supervisors	questionnaire from Riihimaki (1989)	**problems with workmates or supervisor (RR = 1.9)** predicted 3-year cumulative incidence of self-reported past sciatic pain among office workers; no significant findings for work organization variables found in machine operators or carpenters
Skov et al. (1996)	1306 salespeople	cross-sectional	• job demands • control • social support at work • sedentary work • perceived competition • role ambiguity • role conflict • uncertainty of employment prospects • work variation	Questionnaire based on Karasek (1979), Marmot et al. (1991), Fisher & Gitelson (1983), Nord-Larsen et al. (1992)	**"next to least" (OR = 1.5) & "least" social contact with colleagues (OR = 1.8), "next to most" (OR = 1.5) & "most" (OR = 2.0) tendency to feel overworked** associated with self-reported low back pain in past 12 months
Skovron et al. (1994)	Approximately 4000 Belgian adults (about 1800 working respondents)	cross-sectional	• job satisfaction	questionnaire – response categories given	**"Never"(OR = 2.49)** and **"Almost never" (OR = 3.45) being satisfied with job** predicted history of self-reported low back pain among working respondents; **"Never" (OR = 3.85) being satisfied with job** predicted self-reported daily low back pain

Toomingas et al. (1997)	358 workers in various jobs	cross-sectional	• psychological demands • decision latitude • social support • job strain (ratio = psychological demands/decision latitude)	questionnaire based on Karasek & Theorell (1990) and Theorell et al. (1990)	**high (PR = 1.6) & medium (PR = 1.5) levels social support** associated with self-reported lumbar back symptoms; no variables associated with self-report lumbar back tenderness
Van Poppel et al. (1998)	238 airline workers	prospective	• opinion of job • job satisfaction	questionnaire – items given	**job satisfaction (OR = 1.2)** predicted incidence of self-reported back pain within 12 months
Verbeek & van der Beek (1999)	189 civil service workers	prospective	• job demands • role ambiguity • responsibility • role conflict • confinement to workplace • decision latitude • social support at work	questionnaire – modified Dutch questionnaire on work stress (Marcelissen et al., 1988)	**job demands (PRR = 2.2, 2.0, 2.4), confinement to workplace (PRR = 1.6)** predicted self-reported back pain in the past year
Williams et al. (1998)	82 working aged men (18-50) with back pain	prospective	• job satisfaction	questionnaire – items from Job Descriptive Index (Balzer et al., 1990) and global assessment of job satisfaction	**job satisfaction** predicted self-reported back pain and disability at 6 months

TABLE 4
Summary of Studies Examining Work Organization and Upper Extremity Symptoms/Disorders

Author(s) & Year	Subjects	Study Design	Work Organization Variable(s)	Measure / Method of Assessment	Findings
Ahlberg-Hulten et al. (1995)	90 female nurses	cross-sectional	• social support at work • conflicts • stress • decision latitude • psychological demands • skill utilization • job strain	questionnaire; some questions from Karasek (1979)	**social support** predicted self-reported shoulder pain
Bergenudd et al. (1988)	61 Swedish workers	prospective	• job satisfaction	interview	**less job satisfaction** associated with history of shoulder pain
Bergqvist et al. (1995)	260 office workers (76% females)	cross-sectional	• peer contact • routine work • organizational influence • rest breaks • work task flexibility • overtime	questionnaire	**limited rest break opportunities (OR = 2.7 & 7.4)** predicted neck/shoulder discomfort and tension neck syndrome; **limited rest break opportunities (OR = 3.3) and low task flexibility (OR = 3.2)** predicted any shoulder diagnoses; **extreme peer contacts (OR = 2.1) & extensive overtime (OR = 2.2)** predicted arm/hand discomfort – note also low keyboard placement in model **extreme peer contacts (OR = 4.5) and limited rest break opportunities (OR = 2.7)** predicted any arm/hand diagnoses Note: All UE outcomes based on self-report

Bergqvist et al. (1995)	353 office workers	cross-sectional	• limited/excessive peer contacts • limited rest break opportunities • limited work task flexibility • frequent overtime	questionnaire	**combined VDT work with limited rest break opportunities (OR = 4.8)** predicted self-reported neck/shoulder discomfort ; **limited rest break opportunities with lower arm support and ≥20 hrs/week (OR = 4.6)** predicted clinical arm/hand diagnoses
Bernard et al. (1994)	1050 newspaper employees	cross-sectional	• work organization • psychosocial work environment	NIOSH questionnaire	**work variance (OR = 1.7)** predicted neck symptoms; **low decision latitude (OR = 1.6)** and **perceived increased job pressure (OR = 1.5)** predicted shoulder symptoms; **time spent on deadlines (OR = 1.6) and perceived lack of supervisor support (OR = 1.4)** predicted hand/wrist symptoms Note: All UE outcomes based on self-report
Bru et al. (1996)	586 female hospital staff	cross-sectional	• institutional policy • work overload • social relations • perception of responsibility • work content	Cooper stress check (Cooper, 1981); Reidar J. Mykletun work environment scale - developed specifically for study	**institutional policy, work overload, social relations, work content** predicted self-reported neck symptoms; **social relations, work content** predicted self-reported shoulder symptoms
deZwart et al. (1997)	44486 employees given POHS (define)	cross-sectional	• work demands - sedentary occupation; mentally demanding tasks	periodical occupational health survey	**mentally /physically demanding work** associated with rates differences in self-reported neck, upper extremity complaints for age group 25-34 and 35-44 in males; **mentally/physically demanding work** associated with rate differences in 45-54 aged women
Engstrom et al. (1999)	67 assembly operators (28% females)	cross-sectional	• decision latitude • social support at work • psychological work load	questionnaire by Rubenowitz (1997)	**decision latitude** correlated with upper back symptoms; **psychological work load** correlated with neck/shoulders, upper back Note: All UE outcomes based on self-report

Faucett & Rempel (1994)	150 newspaper employees	cross-sectional	• psychological work load • decision latitude • job insecurity • job dissatisfaction • job strain	Job Content Instrument (Karasek, 1985)	**decision latitude, coworker support, and decision latitude, job insecurity, supervisor support, and supervisor conflict independently interacting with keyboard height** predicted self-reported UE numbness severity
Ferreira et al. (1997)	24 telephone call center workers	retrospective	• time pressure • management support • overtime • management instability • risk of dismissal • work/rest schedule • training	interview	**time pressure, work/rest schedule, training** predicted cases with physically diagnosed UE disorder
Feuerstein et al. (1997)	48 office workers	cross-sectional	• work pressure • uncertainty about job future • physical/mental exhaustion • quantitative workload • surges in workload • social support	questionnaire from Hales et al., 1994	cases with self-reported UE symptoms had **higher workload variance pressure & lower social support** than controls
Fredriksson et al. (1999)	484 Swedish workers	retrospective	• mental work load • monotonous work • social support at work • shift work • overtime	structured interview	Women: **High mental workload + dissatisfactory leisure time** – prevalence **(PR = 2.8)** of neck disorders; **overtime** – prevalence **(PR =2.7)** of shoulder disorders; Men: **shift work** – prevalence **(PR = 4.4)**of neck disorders; **shift work** – cumulative incidence **(CIR = 3.1)**of shoulder disorders and prevalence **(PR = 2.5)** Note: All UE outcomes medically examined

Hagen et al. (1998)	645 manual workers; 66 machine operators; 124 adminstrative workers	cross-sectional	• psychological demands • intellectual discretion • authority over decisions	questionnaire – items from Karasek (1979)	**medium (OR = 1.5) / low (OR = 1.6) intellectual discretion and medium (OR = 1.5) and high (OR = 2.4) psychological demands** associated with self-reported neck/shoulder symptoms over past 12 months
Hales et al. (1994)	111 telecommunication employees	cross-sectional	• overtime hours • co-worker use of same workstation • task rotation • hours spent at VDT • rest breaks • job control • work pressure • workload • interaction with others/co-workers • customer hostility	Job Characteristics Inventory (Sims et al., 1976), Job Diagnostic Survey (Hackman et al., 1980)	**lack of decision making opportunities (OR = 4.2), high information process demands (OR = 3.0); fear of being replaced by computers (OR = 3.0); job requiring a variety of tasks (OR = 2.9); increasing work procedure (OR = 2.4)** predicted neck disorders; **fear of being replaced by computers (OR = 2.7)** associated with shoulder disorders; **fear of being replacing computers (OR = 2.9); lack of decision making opportunities (OR = 2.8); surges in workload (OR = 2.4)** predicted elbow problems; **high info processing demands (OR = 2.3)** predicted hand/wrist disorders Note: All UE outcomes based on self-report
Higgs et al. (1992)	157 meat-processing workers	cohort/cross-sectional	• job rotation		workers who **rotated jobs** had lower self-reported & physically examined impairment ratings
Himmelstein et al. (1995)	124 WRUED clinic patients	cross-sectional	• work satisfaction • coworker sharing • coworker response • supervisor rapport • task enjoyment • anger with employer	questionnaire adapted form Bigos et al. (1991)	no significant psychosocial differences between "indeterminate" and "classic" physically diagnoses cases of WRUEDs; chronic physically diagnosed cases **enjoyed work tasks** less than acute/subacute cases

Holmstrom et al. (1992)	1773 construction workers	cross-sectional	• discretion • qualitative demands • quantitative demands • solitary work • support • understimulation • job satisfaction • stress	items adapted from Swedish general health care questionnaire	**quantitative demands (PRR = 1.4), stress (PRR = 1.5)** associated with self-reported neck/shoulder trouble; **quantitative demands (PRR = 3.0), solitary work (PRR = 1.5), stress (PRR = 3.4)** associated with neck/shoulder pain
Holness et al. (1998)	39 bank office workers	cross-sectional	• "work organization" • job content	Karasek (1985); NIOSH General Job Stress Questionnaire (1990)	**psychological job demands and conflicting demands** associated with self-reported UE symptoms occurring at least 3 times in past year
Hughes et al. (1997)	121 aluminum smelter workers	cross-sectional	• job satisfaction • supervisor support • job demands • decision latitude	Karasek & Theorell (1979); Work Apgar (Bigos et al., 1991)	no work org variables predicted hand/wrist or arm/elbow disorders; **low decision latitude (OR = 4.5)** predicted physically diagnosed/self-reported shoulder disorders
Kamwendo et al. (1991)	420 medical secretaries	cross-sectional	• work stimulation • work variation • supervisor & co-worker support • job cooperation • job control • work demands • fear of re-organization	questionnaire - items specified in paper	**cooperation, job control; work demands** predicted self-reported neck & shoulder pain

Lagerstrom et al. (1995)	688 female nursing personnel	cross-sectional	• work commitment • supervisor support • work load/demands • stimulation at work • work control	questionnaire – included Karasek and Theorell (1990)	**low work commitment (OR = 1.7) and low supervisor support (OR = 2.0)** predicted neck symptoms; **high work demands (OR = 1.8)** predicted severe neck symptoms; **low work control (OR = 1.7)** predicted shoulder symptoms; **high work demands (OR = 1.7)** predicted severe shoulder symptoms; **lack of stimulation (OR = 1.6)** predicted hand symptoms Note: All UE outcomes based on self-report
Leclerc et al. (1998)	1006 workers in various occupations including 127 workers with CTS	cross-sectional	• job satisfaction • control • cycle time • autonomy • just-in-time production	questionnaire; index	**low job control (OR = 1.6) & just-in-time production (OR = 2.2)** associated with physically diagnosed CTS status
Leino & Hanninen (1995)	902 blue & white collar workers; 654 in 10 yr follow-up	prospective	• work content • work control • social relationships at work • overstrain (mental demands)	questionnaire – items given	white-collar men: **social relations & overstrain** correlated with neck/shoulder/upper limb self-reported symptoms 10 yrs post; white collar women: **work control** correlated with UE physical findings 10 yrs post blue-collar men: **social relations** correlated with UE physical findings 10 yrs post
Lemasters et al. (1998)	490 union carpenters	cross-sectional	• job control • work demands • availability of materials • policies/procedures • pace of work • quality of work	questionnaire (Hurrell & McLaney, 1984)	**minimal work schedule influence (OR = 1.9)** predicted self-reported shoulder symptoms

Lindstrom et al. (1997)	144 VDT employees at insurance company	prospective	• job demands – cognitive & social demands; psychomotor demands • Perceived job stressors – physical workload, quantitative workload, lack of context variety/control, poor interpersonal relations • Job satisfaction • VDT breakdowns • VDT-based scheduling • Perceived mastering of VDT • Length of continuous VDT use	Occupational Stress Questionnaire (Elo et al., 1992)	Stable relations across three time periods between self-reported neck & upper limb complaints and **VDT breakdowns; amount of VDT use; high physical workload, lack of content variety/control**
Linton & Kamwendo (1989)	420 office secretaries	cross-sectional	• work content • psychological work demand • social support at work	questionnaire – items from Hane et al. (1984)	work content associated with neck/shoulder pain; "poor" psychological work environment associated with higher frequency of neck and shoulder pain
Marcus & Gerr (1996)	416 female office workers with neck/shoulder symptoms; 409 females office workers with arm/hand symptoms	cross-sectional	• skill discretion (skill usage) • decision latitude • job demands (workload, time pressure, deadline stress) • job strain • social support at work • job stress	Job Content Instrument (Karasek et al., 1985); job stress = 1 item question	**very stressful job stress (OR = 2.5) & not too likely/very likely to lose job (OR=2.2)** predicted self-reported neck/shoulder symptoms; **very stressful job stress (OR = 2.0)** predicted self-reported hand/arm symptoms

Ohlsson et al. (1995)	82 women in pressing/assembly job; 64 females = controls	cross-sectional	• job control • work strain • stimulation • psychological climate • fellowship at work	questionnaire by Rubenowitz (1984)	**work strain** associated with physically diagnosed neck/shoulder disorders; **no significant findings** in final multivariate model
Polyani et al. (1997)	1007 newspaper employees	cross-sectional	• task demands • work stress • job satisfaction • worker empowerment • worker support	questionnaire - included Canadian National Population Health Survey (Statistics Canada, 1995)	**weekly deadlines (OR = 4.1), psychological demands (OR = 1.4)** predicted self-reported UE symptoms in past year
Roquelaure et al. (1997)	65 blue collar workers	cross-sectional	• "freedom of action" (job control) • job rotation	interview; observation	**no job rotation (OR = 6.3)** predicted physically diagnosed CTS
Silverstein & Hughes (1996)	33 pulp/paper mill employees	cross-sectional	• job satisfaction • supervisor support • decision latitude • mental workload	questionnaire based on Karasek (1979) and Hart & Staveland (1988)	**high decision latitude** associated with abnormal median and ulnar nerve electrodiagnostic tests; no work organization variable predicted disorders in any location
Skov et al. (1996)	1306 salespeople	cross-sectional	• job demands • control • social support at work • sedentary work • perceived competition • role ambiguity • role conflict • uncertainty of employment prospects • work variation	questionnaire based on Karasek (1979), Marmot et al. (1991), Fisher & Gitelson (1983), Nord-Larsen et al. (1992)	**more frequent/all sedentary work (OR = 2.2 & 2.8), lowest variation of work (OR = 1.8), low control over time (OR = 1.4), high perceived competition (OR = 1.4)** predicted self-reported neck symptoms in past 12 months; **high work demands (OR = 1.5) and next to highest (OR = 1.8)/highest uncertainty of employment (OR = 1.5)** predicted self-reported shoulder symptoms in past 12 months

Smith et al. (1981)	204 VDT operators; 158 controls	cross-sectional	• job demands • job stress - work pace, workload, ambiguity, skill use, job stress level • job future - career growth, usefulness of skills, promotion possibilities, layoff, replacement by machines • job satisfaction	questionnaire developed by investigators; partially based on Caplan et al., 1975, Insel & Moos, 1974	workers having more self-reported arm pain, painful/stiff neck/shoulders, sore shoulder, neck pain, stiff/sore wrists reported significant differences in **interesting work, boring work, dislike workload, decision latitude, job dissatisfaction**
Stephens & Smith (1996)	550 keyboard users	cross-sectional	• work commitment • peer cohesion • staff support • autonomy • work climate • work pressure • clarity • control • innovation • job satisfaction • work pressure • variety in job • boredom • perceived stress	Work Environment Scale (Insel & Moos, 1974)	**peer cohesion, staff support, control, work pressure, autonomy, stress** differentiated self-reported high-pain and low-pain reporting groups (for neck/shoulder/arm)
Tola et al. (1988)	852 machine operators; 658 carpenters/ "dynamic physical work"; 657 office workers/ "sedentary"	cross-sectional	• job satisfaction	questionnaire	**moderate/poor job satisfaction (RR = 1.2)** predicted prevalence of self-reported shoulder/neck symptoms over 12 months

Toomingas et al. (1997)	358 workers in various jobs	cross-sectional	• psychological demands • decision latitude • social support • job strain (ratio = psychological demands/decision latitude	questionnaire based on Karasek & Theorell (1990) and Theorell et al. (1990)	**psychological demands (PR = 2.5), social support (PR = 1.6), and job strain (PR = 1.6)** predicted neck symptoms; **social support (PR = 1.8)** predicted wrist/hand symptoms; **psychological demands and job strain (PR = 2.1)** predicted medically examined neck tenderness; **job strain (PR = 2.0)** predicted trapezius tenderness **job strain (PR = 4.1)** predicted shoulder contraction pain Note: All UE outcomes based on self-report
Ylipaa et al. (1997)	364 dental hygienists	cross-sectional	• hours/week • solitary work • role conflicts • role competition • demands and control	questionnaire – some items based on Karasek (1979), Karasek & Theorell (1990)	**solitary work** predicted self-report of neck/shoulder/upper back and lower arm pain in past 12 months

TABLE 5
Top 15 Low Back and Upper Extremity Ambulatory Rates Among Enlisted Marines: 1997 - 1998 *

ICD – 9 Code	Description	Rate per 1000 person-years
724.2	Lumbago	27.53
847.2	Sprain / Strain of back - lumbar	11.05
726.9	Unspecified enthesopathies	10.54
847.0	Sprain / Strain - Other unspecified part of back - neck	10.34
729.1	Myalagia and myositis (unspecified)	8.98
846.0	Sprain / Strain – lumbosacral	8.27
840.9	Sprain / Strain - Unspecified site of shoulder & upper arm	7.61
726.10	Disorders of bursae & tendons in shoulder region (unspecified)	5.01
727.00	Synovitis and tenosynovitis, unspecified	4.37
722.1	Intervertebral disc displacement w/out myelopathy - lumbar	4.35
739.3	Nonallopathic lesions - lumbar region	3.37
354.0	Carpal tunnel syndrome	3.38
723.1	Cervicalgia	3.41
726.3	Enthesopathy of elbow region	2.54
724.3	Sciatica	2.16

* Rates based on first occurrences only

TABLE 6
Questionnaire Items

Category	Item(s) and Source
Demographics	• gender, education, marital status, length of service, length of time in MOS, base, rank, birth date (age)
Health behavior	• smoking status, aerobic activity (U.S. Army Health Risk Appraisal)
Physical demands	• Borg's (1998) Perceived Exertion Scale
Individual Psychosocial	
Family/home	• Family Environment Scale – Family Conflict subscale (Moos & Moos, 1981); No. of children supported
Life-related worries	• Frequency of life worries (U.S. Army Health Risk Appraisal)
Ergonomic	• Job Requirements and Physical Demands Survey (Marcotte et al., 1997)
Work Organization	
General Job Stress	• Frequency of job stress (U.S. Army Health Risk Appraisal)
Scheduling	• Work Environment Scale (WES) (Moos, 1994) • MJDQ
Job Design	• Job Content Questionnaire (JCQ) – Skill discretion subscale (Karasek et al., 1998) • JCQ – Decision authority subscale • Cognitive demands - NIOSH Work Questionnaire
Management Style	• Participatory management - NIOSH Work Questionnaire
Interpersonal	• Job Diagnostic Survey (JDS) – Dealing with others subscale (Hackman & Oldham, 1974) • JDS – Feedback from agents subscale
Career Concerns	• NIOSH Work Questionnaire
Organizational Characteristics	• JDS – Experienced responsibility subscale
Symptoms	• NIOSH symptom survey
Function	• SF-12 (Ware et al., 1996) - PCS (Physical function) & MCS (Mental Health) subscales

TABLE 7
Top 10 Occupational Categories Associated with Musculoskeletal-related Ambulatory Clinic Visits among Enlisted Marines (1998)*

Occupational Category	Back-related visit rate	Upper extremity-related visit rate	Back- & Upper extremity visit rate
Image Interpretation	31	19	51
Auditing & Accounting	25	18	44
Disbursing	23	18	42
Surveillance / Target Acquisition	26	14	40
Aircraft Launch Equipment	26	11	37
Legal	20	16	36
Transportation	23	13	35
Musicians	14	22	35
Explosive Ordnance Disposal / Underwater Demolition Team	21	12	33
Information & Education	12	21	33

* For occupational categories with ≥ 25 visits

Note: All rates per 100 person-years

TABLE 8
Top 10 Occupational Categories Associated with Back-related Ambulatory Clinic Visits among Enlisted Marines (1998)*

Occupational Category	ICD – 9 Diagnostic Code						All diagnoses
	722.1	724.2	724.3	739.3	846.0	847.2	
Image Interpretation	2	17	0	0	12	1	31
Aircraft Launch Equipment	1	18	0	2	1	4	26
Surveillance / Target Acquisition	12	10	0	0	1	2	26
Auditing & Accounting	0	14	0	0	5	6	25
Disbursing	4	10	1	1	5	2	23
Photography	8	13	0	0	0	2	23
Transportation	0	18	0	0	1	4	23
Teletype & Cryptograph	0	6	0	7	3	5	21
Explosive Ordnance Disposal / Underwater Demolition Team	5	10	1	1	2	2	21
Precision Equipment	1	10	1	4	1	5	21

* For occupational categories with ≥ 25 visits

Note: All rates per 100 person-years
722.1 = Intervertebral disc discplacement
724.2 = Lumbago
724.3 = Sciatica
739.3 = Nonallopathic lesions – lumbar region
846.0 = Lumbosacral sprain/strain
847.2 = Lumbar sprain/strain

TABLE 9
Top 10 Occupational Categories Associated with Upper extremity-related Ambulatory Clinic Visits among Enlisted Marines (1998)*

Occupational Category	ICD – 9 Diagnostic Code									All diagnoses
	354.0	723.1	726.10	726.3	726.9	727.00	729.1	840.9	847.0	
Unknown	0	0	0	0	7	4	8	5	1	26
Musicians	2	2	0	3	2	4	3	3	2	22
Investigations	2	1	8	2	3	1	2	2	1	21
Armament Maintenance	0	3	3	0	0	3	3	3	6	21
Information & Education	0	3	2	2	2	0	5	2	5	21
Image Interpretation	13	1	1	0	2	2	0	1	2	19
Disbursing	2	1	3	1	4	1	2	2	2	18
Lithography	4	0	1	0	2	2	6	1	1	18
Auditing & Accounting	0	0	1	2	4	1	3	1	6	18
Utilities	1	1	1	2	6	0	2	1	4	18

* For occupational categories with ≥ 25 visits

Note: All rates per 100 person-years
354.0 = Carpal tunnel syndrome
723.1 = Cervicalgia
726.10 = Disorders – Bursae & tendons (shoulder region)
726.3 = Enthesopathy of elbow region
726.9 = Unspecified enthesopathies
727.00 = Synovitis & tenosynovitis, unspecified
729.1 = Myalgia & myositis, unspecified
840.9 = Sprain/strain – shoulder & upper arm
847.0 = Sprain/strain - neck

TABLE 10
Demographic Characteristics

	Controls (n = 90)	Back only cases (n = 59)	Upper extremity only cases (n = 57)	Back & Upper extremity cases (n = 83)	Total Sample (n = 289)
Age (in years)					
Mean (SD)	26.9 (6.5)	28.0 (7.8)	26.5 (6.6)	30.3 (7.6)	28.0 (7.2)[a]
	n (%)*	n (%)*	n (%)*	n (%)*	n (%)*
Gender					
Males	80 (88.9)	51 (86.4)	52 (91.2)	72 (86.7)	255 (88.2)
Females	10 (11.1)	8 (13.6)	5 (8.8)	11 (13.3)	34 (11.8)
Race					
White/Caucasian	46 (51.1)	31 (52.5)	34 (59.6)	38 (45.8)	149 (51.6)
Black/African American	21 (23.3)	17 (28.8)	12 (21.1)	24 (28.9)	74 (25.6)
Hispanic/Latino	21 (23.3)	9 (15.3)	8 (14.0)	18 (21.7)	56 (19.4)
Asian	2 (2.2)	2 (3.4)	2 (3.5)	1 (1.2)	7 (2.4)
American Indian	0 (0)	0 (0)	0 (0)	1 (1.2)	1 (0.3)
Education					
H.S. Grad/GED	37 (41.1)	29 (49.2)	25 (43.9)	32 (38.6)	123 (42.6)
Some college/ Other Post H.S.	41 (45.6)	24 (40.7)	25 (43.9)	42 (50.6)	132 (45.7)
2 year degree	7 (7.8)	2 (3.4)	1 (1.8)	5 (6.0)	15 (5.2)
4 year degree / college	2 (2.2)	4 (6.8)	1 (1.8)	1 (1.2)	8 (2.8)
Some graduate work	1 (1.1)	0 (0)	2 (3.5)	2 (2.4)	5 (1.7)
Marital Status					
Single	30 (33.3)	23 (39.0)	26 (45.6)	30 (36.1)	109 (37.7)
Married	36 (40.0)	26 (44.1)	17 (29.8)	36 (43.3)	115 (39.8)
Separated	4 (4.4)	0 (0)	1 (1.8)	6 (7.2)	11 (3.8)
Divorced	3 (3.3)	5 (8.5)	6 (10.5)	2 (2.4)	16 (5.5)
Rank					
E2 – Private First Class	5 (5.6)	2 (3.4)	3 (5.3)	2 (2.4)	12 (4.2)
E3 – Lance Corporal	18 (20.0)	14 (23.7)	14 (24.6)	13 (15.7)	59 (20.4)
E4 – Corporal	16 (17.8)	10 (16.9)	17 (29.8)	7 (8.4)	50 (17.3)
E5 – Sergeant	25 (27.8)	17 (28.8)	8 (14.0)	27 (32.5)	77 (26.6)
E6 – Staff Sergeant	12 (13.3)	4 (6.8)	8 (14.0)	10 (12.0)	34 (11.8)
E7 – Gunnery Sergeant	8 (8.9)	4 (6.8)	4 (7.0)	12 (14.5)	28 (9.7)
E8 – Master Sergeant or First Sergeant	4 (4.4)	4 (6.8)	3 (5.3)	8 (9.6)	19 (6.6)
E9 – Master Gunnery Sergeant or Sergeant Major	2 (2.2)	4 (6.8)	0 (0)	4 (4.8)	10 (3.5)

* Note: Percentage of group; total n for category may not equal total n for group because of missing data
[a] t-test comparing group to controls: $t = -3.15$, $df = 171$, $p < 0.01$

TABLE 11
Factor Analyses Results

	Factor Loading	Initial Eigenvalue	Variance (%)
Job Design *		8.63	18.0
Skill Discretion			
• My job requires that I learn new things.	0.696		
• My job requires me to be creative.	0.691		
• My job requires a high level of skill.	0.720		
• I get to do a variety of different things on my job.	0.720		
• I have an opportunity to develop my own special skills.	0.731		
• My job allows me to make a lot of decisions on my own.	0.545		
Cognitive Demands			
• My job requires me to make many decisions.	0.510		
• To do my job well, I have to be able to do a lot of things mentally at the same time.	0.562		
• My job requires me to remember a great deal of information for brief periods of time.	0.526		
• My job often requires me to learn new procedures.	0.721		
• My job requires me to remember many different things.	0.660		
Management Style		4.78	9.9
• To what extent do supervisors or co-workers let you know how well you are doing on the job?	0.665		
• The supervisors and co-workers on this job almost never give me any "feedback" about how well I am doing in my work.	0.546		
• Supervisors often let me know how well they think I am performing on the job.	0.644		
• How much do you take part with others in making decisions that affect you?	0.689		
• How much do you participate with others in helping set the way things are done on your job?	0.673		
• How much do you decide with others what part of a task you will do?	0.668		
Time Pressure		2.79	5.8
• In my group, people cannot afford to relax.	0.714		
• In our group, there is constant pressure to keep working.	0.736		
• In my group, there is a sense of urgency about everything.	0.659		
Organizational Climate		2.11	4.4
• It's hard, on this job, for me to care very much about whether or not the work gets done right.	0.464		
• I feel a very high degree of personal responsibility for the work I do on this job.	0.590		
• I feel I should personally take credit or blame for the results of my work on this job.	0.645		
• Whether or not this job gets done right is clearly my responsibility.	0.716		
• Most people on this job feel a great deal of personal responsibility for the work they do.	0.650		
• Most people on this job feel that whether or not the job gets done right is clearly their own responsibility.	0.691		
Career Concerns		2.07	4.3
• How certain are you about what your future career picture looks like?	0.760		
• How certain are you of the opportunities for promotion and advancement which will exist in the next few years?	0.699		
• How certain are you about whether your job skills will be of use and value five years from now?	0.599		
• How certain are you about what your responsibilities will be six months from now?	0.674		
• If you lost your job, how certain are you that you could support yourself?	0.584		
Cognitive Uncertainty		1.82	3.8
• I can easily see or hear the information I have to use in my job.	0.441		
• The information I receive is organized for me in ways that seem natural and easy to deal with.	0.462		
• I can perform the activities associated with my job without thinking about them.	0.478		
• Most of the decisions I make are routine and easy to make.	0.567		
• In my job, there are set rules that I follow over and over again.	0.716		
Interpersonal Demands		1.61	3.4
• To what extent does your job require you to work closely with other people?	0.564		
• The job requires a lot of cooperative work with other people.	0.672		
		Cumulative Variance	49.6

* Note: The Job Design factor was separated into the two original scales (Skill Discretion & Cognitive Demands) from which the items came.

TABLE 12
Internal Consistency of Work Organization Variables

Work Organization Factor	Cronbach's Alpha
Skill discretion	0.797
Cognitive demands	0.827
Management style	0.777
Time pressure	0.816
Organizational climate	0.783
Career concerns	0.767
Cognitive uncertainty	0.604
Interpersonal demands	0.709

TABLE 13
Correlation among Individual and Occupational Psychosocial Variables

	Skill Discretion	Cognitive Demands	Mgmt Style	Time Pressure	Org. Climate (Job Responsibility)	Career Concerns	Cognitive Uncertainty	Interpersonal Demands	Family Conflict	Life-related Worries
Cognitive Demands	-0.619**									
Mgmt Style	-0.275**	0.282**								
Time Pressure	-0.050	0.211**	-0.081							
Org. Climate	-0.361**	0.350**	0.363**	-0.147*						
Career Concerns	-0.247**	0.242**	0.375**	-0.180**	0.332**					
Cognitive Uncertainty	-0.041	-0.093	-0.221**	0.025	-0.140*	-0.246**				
Interpersonal Demands	-0.209**	0.258**	0.218**	0.062	0.235*	0.194**	-0.118*			
Frequency of Job Stress	-0.101	0.202	-0.208**	0.411**	-0.128*	-0.153**	0.158**	0.137*		
Family Conflict	0.054	-0.103	-0.217**	0.152*	-0.148*	-0.208**	0.060	-0.058	0.112	
Life-related Worries	-0.056	0.040	-0.187**	0.170**	-0.170**	-0.146*	0.086	0.107	0.486**	0.163**

$\underline{n} = 289$ * $\underline{p} < 0.05$ ** $\underline{p} < 0.01$

TABLE 14
Correlates of Pain Intensity, Physical Function, & Mental Health

Outcome	Correlates	Beta	ΔR^2	Variance
Pain intensity over the last week	Age	0.15	0.02	0.13
	Life-related worries	0.16	0.02	
	JRPDS	0.31	0.09	
Physical Function (SF12 – PCS subscale)	Age	-0.16	0.02	0.13
	Exercise	0.13	0.02	
	Perceived exertion	-0.16	0.02	
	JRPDS	-0.24	0.06	
	Organizational climate	0.14*	0.02	
Mental Health (SF12 – MCS subscale)	Age	0.17	0.03	0.36
	Family conflict	-0.15	0.02	
	Life-related worries	-0.39	0.21	
	Career concerns	0.25	0.10	

Note: all $p < 0.05$ unless indicated by * where $p < 0.01$

TABLE 15
Univariable Logistic Regression: Demographic, Health Behavior, Physical Demand, & Individual Psychosocial Variables

Variable	Back symptoms (n = 149)		UE symptoms (n = 147)		Back & UE symptoms (n = 173)	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Demographic						
Age	1.02 (0.97-1.07)	0.39	0.99 (0.94-1.04)	0.70	**1.07 (1.02-1.12)**	**0.01**
Gender	1.12 (0.68-1.84)	0.65	0.88 (0.50-1.54)	0.65	1.11 (0.70-1.75)	0.67
Education level		0.70		0.72		0.83
Some college/ other post HS	0.90 (0.54-1.49)	0.68	1.11 (0.65-1.90)	0.70	1.15 (0.73-1.80)	0.55
2 yr/college/ grad school	0.92 (0.45-1.88)	0.82	0.73 (0.33-1.64)	0.45	0.90 (0.47-1.73)	0.75
Health Behaviors						
Freq. of Exercise		0.46		0.69		0.54
Rarely/never	0.91 (0.27-3.10)	0.88	1.29 (0.43-3.91)	0.65	1.42 (0.53-3.82)	0.49
1 or 2 times/wk	1.37 (0.62-2.99)	0.44	1.02 (0.48-2.17)	0.97	0.97 (0.49-1.93)	0.94
Physical Demands						
Borg scale (perceived exertion at work)	0.98 (0.81-1.19)	0.84	**1.14 (0.93-1.40)**	**0.21**	**1.10 (0.93-1.30)**	**0.25**
Individual Psychosocial						
Life-related worries		**0.19**		0.59		0.28
Seldom	1.38 (0.79-2.41)	0.26	0.74 (0.43-1.27)	0.28	0.91 (0.56-1.48)	0.70
Sometimes	1.72 (0.97-3.04)	0.06	1.14 (0.67-1.95)	0.63	1.34 (0.82-2.19)	0.25
Often	0.88 (0.37-2.07)	0.76	1.38 (0.69-2.80)	0.37	1.45 (0.75-2.78)	0.27
Family Conflict	**1.31 (1.07-1.60)**	**0.01**	**1.27 (1.06-1.52)**	**0.01**	**1.19 (0.98-1.44)**	**0.08**

Note: Items indicated in bold were selected for final multivariate model based on significance level of $p \leq 0.25$.

TABLE 16
Univariable Logistic Regression: Work-related Stressors

Variable	Back symptoms (n = 149)		UE symptoms (n = 147)		Back & UE symptoms (n = 173)	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Ergonomic Risk Exposure						
JRPDS	**1.03 (1.01-1.05)**	**0.01**	**1.03 (1.01-1.05)**	**0.01**	**1.03 (1.01-1.05)**	**0.01**
Work Organization						
Skill discretion	1.01 (0.97-1.05)	0.60	1.00 (0.96-1.05)	0.97	**1.08 (1.01-1.16)**	**0.02**
Cognitive demands	1.01 (0.92-1.12)	0.82	1.02 (0.92-1.13)	0.76	**1.09 (1.00-1.20)**	**0.06**
Management style	0.98 (0.89-1.07)	0.63	0.97 (0.89-1.07)	0.55	0.97 (0.89-1.05)	0.39
Time pressure	**1.17 (1.03-1.32)**	**0.02**	**1.19 (1.05-1.36)**	**0.01**	**1.11 (0.99-1.24)**	**0.08**
Organizational climate	0.84 (0.62-1.14)	0.27	0.97 (0.70-1.35)	0.87	1.02 (0.78-1.34)	0.88
Career concerns	**0.95 (0.87-1.02)**	**0.16**	0.97 (0.90-1.05)	0.49	0.97 (0.91-1.05)	0.47
Cognitive uncertainty	1.01 (0.88-1.16)	0.86	0.98 (0.87-1.11)	0.76	**1.08 (0.96-1.21)**	**0.20**
Interpersonal demands	**0.82 (0.63-1.06)**	**0.13**	0.96 (0.72-1.30)	0.81	**1.25 (0.92-1.69)**	**0.15**

Note: Items indicated in bold were selected for final multivariate model based on significance level of $p \leq 0.25$.

TABLE 17
Risk Factors for Musculoskeletal Symptoms

Variable (range)	Back symptoms (n = 149)		Upper extremity symptoms (n = 147)		Back & UE symptoms (n = 173)	
	OR (95% CI)	B	OR (95% CI)	B	OR (95% CI)	B
Demographic						
Age	1.09 (1.02 – 1.16)*	0.08	1.05 (0.98 – 1.12)	0.04	1.13 (1.07 – 1.20)**	0.12
Gender – Female	1.04 (0.58 – 1.85)	0.04	0.84 (0.25 – 2.86)	-0.17	0.80 (0.46 – 1.41)	-0.22
Education level						
Some college / Post HS	0.78 (0.44 – 1.38)	-0.25	1.02 (0.57 – 1.84)	0.02	1.10 (0.64 – 1.88)	0.09
2 yr deg / college / grad school	1.14 (0.48 – 2.70)	0.13	0.79 (0.31 – 1.97)	-0.24	0.63 (0.28 – 1.42)	-0.46
Physical Demands	N/E		1.04 (0.82 – 1.31)	0.04	1.08 (0.87 – 1.35)	0.08
Individual Psychosocial						
Life-related worries			N/E		N/E	
Seldom	1.73 (0.92 – 3.25)	0.55				
Sometimes	1.25 (0.65 – 2.42)	0.22				
Often	0.86 (0.31 – 2.35)	-0.15				
Family Conflict (0 – 8)	1.30 (1.03 – 1.64)*	0.26	1.27 (1.04 – 1.55)*	0.24	1.20 (0.95 – 1.52)	0.18
Ergonomic Risk Exposure						
JRPDS (0 – 152)	1.03 (1.00 – 1.05)*	0.03	1.02 (1.00 – 1.05)*	0.02	1.04 (1.01 – 1.06)**	0.04
Work Organization						
Time pressure (3 – 15)	1.18 (1.00 – 1.38)*	0.16	1.16 (1.00 – 1.34)*	0.15	1.12 (0.97 – 1.29)	0.11
Interpersonal demands (1 – 7)	0.73 (0.54 – 1.00)*	-0.31	N/E		1.56 (1.05 – 2.33)*	0.44
Career concerns (5 – 25)	1.01 (0.91 – 1.11)	0.01	N/E		N/E	
Skill discretion (10 – 50)	N/E		N/E		1.09 (1.02 – 1.15)**	0.08
Cognitive demands (5 – 25)	N/E		N/E		1.20 (1.04 – 1.39)*	0.18
Cognitive uncertainty (5 – 25)	N/E		N/E		1.22 (1.05 – 1.43)*	0.20

N/E – Variable not entered into final multivariable logistic regression model.
* $p \leq 0.05$ ** $p < 0.01$

TABLE 18
Distribution of High & Low Level Workplace Exposures

		Back (n = 149)		Upper extremity (n = 147)		Back & UE (n = 173)	
		High Ergo n (%)	Low Ergo n (%)	High Ergo n (%)	Low Ergo n (%)	High Ergo n (%)	Low Ergo n (%)
Skill discretion	High	34 (22.8)	45 (30.2)	30 (20.4)	41 (27.9)	40 (23.1)	48 (27.7)
	Low	33 (22.1)	37 (24.8)	36 (24.5)	40 (27.2)	43 (24.9)	42 (24.3)
Cognitive demands	High	32 (21.5)	31 (20.8)	32 (21.8)	31 (21.1)	46 (26.6)	37 (21.4)
	Low	35 (23.5)	51 (34.2)	34 (23.1)	50 (34.0)	37 (21.4)	53 (30.6)
Participatory management	High	35 (23.5)	33 (22.1)	34 (23.1)	34 (23.1)	44 (25.4)	38 (22.0)
	Low	32 (21.5)	49 (32.9)	32 (21.8)	47 (32.0)	39 (22.5)	52 (30.1)
Time pressure	High	43 (28.9)	28 (18.8)	42 (28.6)	28 (19.0)	47 (27.2)	32 (18.5)
	Low	24 (16.1)	54 (36.2)	24 (16.3)	53 (36.1)	36 (20.8)	58 (33.5)
Organizational climate	High	34 (22.8)	42 (28.2)	36 (24.5)	41 (27.9)	43 (24.9)	50 (28.9)
	Low	33 (22.1)	40 (26.8)	30 (20.4)	40 (27.2)	40 (23.1)	40 (23.1)
Career concerns	High	28 (18.8)	50 (33.6)	28 (19.0)	51 (34.7)	36 (20.8)	54 (31.2)
	Low	39 (26.2)	32 (21.5)	38 (25.9)	30 (20.4)	47 (27.2)	36 (20.8)
Cognitive processing	High	33 (22.1)	32 (21.5)	33 (22.4)	31 (21.1)	48 (27.7)	43 (24.9)
	Low	34 (22.8)	50 (33.6)	33 (22.4)	50 (34.0)	35 (20.2)	47 (27.2)
Interpersonal demands	High	30 (20.1)	45 (30.2)	36 (24.5)	43 (29.3)	47 (27.2)	54 (31.2)
	Low	37 (24.8)	37 (24.8)	30 (20.4)	38 (25.9)	36 (20.8)	36 (20.8)

Note: Percentages represent number of subjects within each comparison group (i.e., controls & back; controls & UE; controls & back and UE)

TABLE 19
Multivariable Logistic Regression:
Ergonomic Exposure & Time Pressure

Variable	Back symptoms (n = 149)		UE symptoms (n = 147)		Back & UE symptoms (n = 173)	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Demographic						
Age	1.07 (1.01-1.14)	0.03	1.04 (0.98-1.11)	0.21	1.13 (1.07-1.19)	0.01
Gender	0.96 (0.54-1.73)	0.90	0.79 (0.41-1.49)	0.46	0.85 (0.50-1.44)	0.54
Education level		0.62		0.51		0.77
High School/ GED	1.21 (0.66-2.20)	0.55	1.43 (0.76-2.70)	0.26	1.20 (0.68-2.11)	0.53
Some college/ other post HS	0.81 (0.46-1.42)	0.46	0.93 (0.51-1.71)	0.82	1.12 (0.66-1.89)	0.68
Health Behaviors						
Freq. of Exercise		0.50		0.53		0.58
Rarely/never	0.93 (0.23-3.81)	0.92	1.45 (0.41-5.10)	0.56	1.06 (0.32-3.47)	0.93
1 or 2 times/wk	1.38 (0.57-3.34)	0.47	1.04 (0.44-2.46)	0.92	1.24 (0.56-2.76)	0.60
Physical Demands						
Borg scale	0.98 (0.78-1.23)	0.84	1.12 (0.87-1.43)	0.40	1.10 (0.90-1.34)	0.37
Individual Psychosocial						
Life-related worries		0.36		0.82		0.51
Seldom	1.62 (0.87-3.01)	0.13	0.84 (0.45-1.57)	0.57	0.99 (0.56-1.74)	0.96
Sometimes	1.37 (0.73-2.58)	0.32	0.89 (0.47-1.69)	0.72	0.98 (0.55-1.74)	0.95
Often	0.80 (0.30-2.15)	0.66	1.50 (0.64-3.53)	0.35	1.75 (0.79-3.87)	0.17
Family Conflict	1.33 (1.06-1.68)	0.02	1.30 (1.05-1.60)	0.02	1.14 (0.91-1.44)	0.26
Ergonomic Exposure & Time Pressure		**0.02**		**0.01**		**0.02**
High / Low	0.63 (0.29-1.35)	0.23	0.46 (0.20-1.07)	0.07	1.18 (0.64-2.17)	0.59
Low / High	1.00 (0.48-2.09)	0.99	1.05 (0.50-2.21)	0.90	0.88 (0.44-1.76)	0.72
High / High	**2.61 (1.39-4.91)**	**0.01**	**2.90 (1.49-5.66)**	**0.01**	**2.21 (1.19-4.10)**	**0.01**
Constant	0.05	0.01	0.09	0.04	0.02	0.01

TABLE 20
Multivariable Logistic Regression:
Ergonomic Exposure & Cognitive Demands

Variable	Back symptoms (n = 149)		UE symptoms (n = 147)		Back & UE symptoms (n = 173)	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Demographic						
Age	1.05 (1.00-1.12)	0.08	1.03 (0.96-1.09)	0.44	1.12 (1.06-1.18)	0.00
Gender	1.00 (0.57-1.77)	1.00	0.87 (0.47-1.61)	0.65	0.94 (0.56-1.59)	0.82
Education level		0.71		0.66		0.67
High School/ GED	1.14 (0.63-2.06)	0.66	1.32 (0.72-2.42)	0.38	1.29 (0.73-2.30)	0.38
Some college/ other post HS	0.83 (0.48-1.43)	0.50	0.96 (0.54-1.71)	0.90	1.07 (0.63-1.80)	0.82
Health Behaviors						
Freq. of Exercise		0.58		0.66		0.42
Rarely/never	0.99 (0.26-3.79)	0.99	1.28 (0.37-4.48)	0.70	1.24 (0.37-4.14)	0.73
1 or 2 times/wk	1.28 (0.55-3.03)	0.57	1.07 (0.46-2.50)	0.88	1.20 (0.54-2.67)	0.66
Physical Demands						
Borg scale	0.97 (0.78-1.20)	0.77	1.12 (0.88-1.42)	0.35	1.10 (0.90-1.34)	0.36
Individual Psychosocial						
Life-related worries		0.29		0.73		0.45
Seldom	1.60 (0.87-2.94)	0.13	0.74 (0.40-1.35)	0.32	1.11 (0.63-1.95)	0.73
Sometimes	1.52 (0.82-2.80)	0.18	1.03 (0.57-1.86)	0.93	1.08 (0.61-1.90)	0.80
Often	0.74 (0.28-1.92)	0.53	1.43 (0.63-3.26)	0.40	1.64 (0.74-3.62)	0.22
Family Conflict	1.34 (1.07-1.69)	0.01	1.27 (1.04-1.54)	0.02	1.15 (0.91-1.44)	0.24
Ergonomic Exposure & Cognitive Demands		0.26		0.46		**0.01**
High / Low	1.31 (0.69-2.49)	0.41	1.15 (0.60-2.18)	0.68	1.15 (0.61-2.15)	0.67
Low / High	0.79 (0.40-1.57)	0.50	0.86 (0.43-1.74)	0.68	0.88 (0.46-1.69)	0.71
High / High	1.54 (0.81-2.96)	0.19	1.50 (0.77-2.93)	0.24	**2.25 (1.24-4.09)**	**0.01**
Constant	0.09	0.02	0.17	0.12	0.02	0.01

TABLE 21
Multivariable Logistic Regression:
Ergonomic Exposure & Management Style

Variable	Back symptoms (n = 149)		UE symptoms (n = 147)		Back & UE symptoms (n = 173)	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Demographic						
Age	1.06 (1.00-1.12)	0.06	1.02 (0.97-1.10)	0.39	1.14 (1.07-1.20)	0.00
Gender	1.01 (0.57-1.77)	0.98	0.87 (0.47-1.62)	0.66	0.81 (0.48-1.38)	0.44
Education level		0.70		0.59		0.56
High School/ GED	1.20 (0.66-2.20)	0.55	1.39 (0.74-2.60)	0.31	1.36 (0.76-2.44)	0.30
Some college/ other post HS	0.85 (0.49-1.50)	0.59	1.00 (0.56-1.79)	0.99	1.14 (0.66-1.92)	0.66
Health Behaviors						
Freq. of Exercise		0.71		0.73		0.49
Rarely/never	0.93 (0.24-3.62)	0.91	1.18 (0.34-4.15)	0.80	1.10 (0.35-3.51)	0.87
1 or 2 times/wk	1.27 (0.53-3.00)	0.59	1.10 (0.47-2.58)	0.83	1.25 (0.57-2.77)	0.58
Physical Demands						
Borg scale	0.95 (0.76-1.19)	0.65	1.12 (0.88-1.42)	0.35	1.12 (0.92-1.38)	0.27
Individual Psychosocial						
Life-related worries		0.18		0.83		0.58
Seldom	1.82 (0.97-3.42)	0.06	0.77 (0.42-1.42)	0.40	1.06 (0.60-1.89)	0.84
Sometimes	1.54 (0.83-2.86)	0.17	1.00 (0.55-1.82)	0.99	0.99 (0.55-1.75)	0.96
Often	0.70 (0.27-1.80)	0.45	1.34 (0.58-3.12)	0.49	1.64 (0.72-3.73)	0.24
Family Conflict	1.31 (1.03-1.65)	0.03	1.22 (1.00-1.50)	0.06	1.10 (0.87-1.38)	0.43
Ergonomic Exposure & Management Style		0.09		0.35		**0.01**
High / High	0.90 (0.47-1.75)	0.76	1.05 (0.53-2.08)	0.88	1.17 (0.64-2.14)	0.60
Low / Low	0.67 (0.34-1.32)	0.25	0.93 (0.49-1.78)	0.83	0.98 (0.53-1.84)	0.95
High / Low	2.34 (1.19-4.63)	0.01	1.67 (0.85-3.30)	0.14	**2.50 (1.30-4.81)**	**0.01**
Constant	0.08	0.01	0.15	0.11	0.02	0.01

TABLE 22
Multivariable Logistic Regression:
Ergonomic Exposure & Organizational Climate

Variable	Back symptoms (n = 149)		UE symptoms (n = 147)		Back & UE symptoms (n = 173)	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	P
Demographic						
Age	1.05 (0.99-1.11)	0.10	1.02 (0.96-1.09)	0.48	1.11 (1.06-1.18)	0.00
Gender	1.04 (0.59-1.82)	0.91	0.88 (0.47-1.63)	0.68	0.89 (0.53-1.50)	0.67
Education level		0.75		0.70		0.87
High School/ GED	1.12 (0.61-2.03)	0.72	1.30 (0.70-2.39)	0.40	1.12 (0.63-2.00)	0.70
Some college/ other post HS	0.83 (0.48-1.45)	0.52	0.98 (0.55-1.76)	0.95	1.11 (0.66-1.88)	0.69
Health Behaviors						
Freq. of Exercise		0.66		0.57		0.41
Rarely/never	1.03 (0.27-3.98)	0.96	1.38 (0.38-4.94)	0.62	1.25 (0.38-4.14)	0.72
1 or 2 times/wk	1.23 (0.52-2.89)	0.64	1.07 (0.46-2.52)	0.87	1.20 (0.54-2.67)	0.66
Physical Demands						
Borg scale	0.97 (0.77-1.20)	0.76	1.12 (0.88-1.43)	0.35	1.11 (0.90-1.35)	0.33
Individual Psychosocial						
Life-related worries		0.27		0.72		0.55
Seldom	1.62 (0.88-2.97)	0.12	0.73 (0.40-1.34)	0.31	1.05 (0.60-1.84)	0.86
Sometimes	1.51 (0.82-2.79)	0.19	1.04 (0.58-1.89)	0.89	1.10 (0.63-1.95)	0.73
Often	0.76 (0.29-1.95)	0.56	1.43 (0.62-3.29)	0.40	1.56 (0.70-3.45)	0.28
Family Conflict	1.34 (1.07-1.69)	0.01	1.28 (1.05-1.56)	0.02	1.16 (0.92-1.46)	0.21
Ergonomic Exposure & Organizational Climate		0.21		0.47		**0.03**
High / High	1.78 (0.93-3.39)	0.08	1.32 (0.66-2.64)	0.43	**2.15 (1.14-4.06)**	**0.02**
Low / Low	0.78 (0.41-1.51)	0.47	0.91 (0.47-1.77)	0.79	0.76 (0.41-1.42)	0.39
High / Low	1.16 (0.61-2.20)	0.65	1.32 (0.70-2.51)	0.40	1.34 (0.71-2.41)	0.34
Constant	0.10	0.03	0.18	0.14	0.03	0.01

TABLE 23
Multivariable Logistic Regression:
Ergonomic Exposure & Cognitive Uncertainty

Variable	Back symptoms (n = 149)		UE symptoms (n = 147)		Back & UE symptoms (n = 173)	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	P
Demographic						
Age	1.06 (1.00-1.12)	0.05	1.03 (0.97-1.10)	0.32	1.12 (1.06-1.18)	0.00
Gender	0.95 (0.54-1.66)	0.85	0.86 (0.46-1.60)	0.63	0.91 (0.54-1.53)	0.72
Education level		0.56		0.70		0.74
High School/ GED	1.20 (0.65-2.20)	0.56	1.29 (0.69-2.39)	0.43	1.20 (0.68-2.14)	0.53
Some college/ other post HS	0.78 (0.44-1.37)	0.38	0.94 (0.53-1.69)	0.84	1.15 (0.68-1.95)	0.61
Health Behaviors						
Freq. of Exercise		0.62		0.63		0.45
Rarely/never	0.98 (0.25-3.91)	0.98	1.46 (0.39-5.48)	0.57	1.15 (0.35-3.79)	0.82
1 or 2 times/wk	1.27 (0.53-3.03)	0.59	0.99 (0.41-2.38)	0.98	1.24 (0.56-2.78)	0.60
Physical Demands						
Borg scale	0.98 (0.78-1.22)	0.84	1.14 (0.89-1.44)	0.30	1.12 (0.92-1.37)	0.26
Individual Psychosocial						
Life-related worries		0.22		0.67		0.46
Seldom	1.68 (0.90-3.12)	0.10	0.70 (0.38-1.30)	0.26	1.04 (0.60-1.83)	0.88
Sometimes	1.58 (0.85-2.95)	0.15	1.06 (0.58-1.95)	0.84	1.12 (0.63-1.97)	0.70
Often	0.70 (0.27-1.85)	0.48	1.41 (0.61-3.22)	0.42	1.65 (0.75-3.66)	0.22
Family Conflict	1.37 (1.09-1.73)	0.01	1.28 (1.05-1.56)	0.02	1.12 (0.89-1.41)	0.33
Ergonomic Exposure & Cognitive Uncertainty		0.10		0.23		**0.02**
High / Low	1.53 (0.80-2.90)	0.20	1.62 (0.83-3.17)	0.16	1.30 (0.69-2.42)	0.42
Low / High	0.39 (0.19-0.84)	0.02	0.46 (0.21-1.00)	0.05	0.80 (0.43-1.48)	0.47
High / High	1.59 (0.81-3.12)	0.18	1.25 (0.63-2.49)	0.53	**2.08 (1.16-3.75)**	**0.02**
Constant	0.06	0.01	0.13	0.08	0.03	0.01

TABLE 24
Multivariable Logistic Regression:
Ergonomic Exposure & Interpersonal Demands

Variable	Back symptoms (n = 149)		UE symptoms (n = 147)		Back & UE symptoms (n = 173)	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Demographic						
Age	1.06 (1.00-1.12)	0.07	1.03 (0.97-1.10)	0.39	1.12 (1.06-1.18)	0.00
Gender	0.99 (0.57-1.75)	0.98	0.87 (0.47-1.61)	0.66	0.90 (0.53-1.51)	0.68
Education level		0.69		0.66		0.75
High School/ GED	1.15 (0.63-2.07)	0.65	1.30 (0.70-2.40)	0.40	1.22 (0.69-2.15)	0.50
Some college/ other post HS	0.82 (0.47-1.43)	0.48	0.93 (0.51-1.68)	0.81	1.12 (0.66-1.90)	0.67
Health Behaviors						
Freq. of Exercise		0.62		0.59		0.53
Rarely/never	1.01 (0.27-3.76)	0.99	1.10 (0.31-3.86)	0.88	1.19 (0.36-3.97)	0.77
1 or 2 times/wk	1.25 (0.54-2.93)	0.60	1.23 (0.51-2.92)	0.65	1.17 (0.52-2.61)	0.70
Physical Demands						
Borg scale	0.97 (0.78-1.21)	0.80	1.13 (0.89-1.43)	0.32	1.10 (0.90-1.35)	0.33
Individual Psychosocial						
Life-related worries		0.26		0.75		0.55
Seldom	1.61 (0.88-2.95)	0.12	0.76 (0.41-1.41)	0.38	1.07 (0.61-1.88)	0.82
Sometimes	1.54 (0.83-2.84)	0.17	0.97 (0.53-1.78)	0.93	1.10 (0.62-1.93)	0.75
Often	0.76 (0.30-1.97)	0.57	1.49 (0.65-3.41)	0.34	1.55 (0.70-3.43)	0.29
Family Conflict	1.34 (1.07-1.68)	0.01	1.25 (1.02-1.52)	0.03	1.15 (0.91-1.44)	0.24
Ergonomic Exposure & Interpersonal Demands		0.28		0.22		**0.02**
High / Low	1.53 (0.83-2.83)	0.18	0.87 (0.43-1.77)	0.70	1.13 (0.61-2.03)	0.69
Low / High	0.65 (0.35-1.19)	0.16	0.65 (0.34-1.26)	0.21	0.64 (0.35-1.14)	0.13
High / High	1.33 (0.69-2.57)	0.39	1.93 (1.02-3.65)	0.04	**2.44 (1.34-4.41)**	**0.01**
Constant	0.08	0.02	0.15	0.10	0.08	0.01

TABLE 25
Multivariable Logistic Regression:
Ergonomic Exposure & Skill Discretion

Variable	Back symptoms (n = 149)		UE symptoms (n = 147)		Back & UE symptoms (n = 173)	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Demographic						
Age	1.06 (1.00-1.12)	0.06	1.02 (0.96-1.09)	0.52	1.12 (1.06-1.19)	0.01
Gender	0.97 (0.55-1.72)	0.92	0.89 (0.48-1.64)	0.70	0.89 (0.53-1.50)	0.66
Education level		0.63		0.74		0.71
High School/ GED	1.17 (0.65-2.13)	0.60	1.27 (0.69-2.34)	0.44	1.26 (0.71-2.22)	0.43
Some college/ other post HS	0.80 (0.46-1.40)	0.44	0.99 (0.56-1.77)	0.98	1.11 (0.66-1.86)	0.70
Health Behaviors						
Freq. of Exercise		0.72		0.65		0.52
Rarely/never	1.05 (0.28-3.90)	0.95	1.22 (0.35-4.25)	0.75	1.32 (0.40-4.36)	0.65
1 or 2 times/wk	1.18 (0.50-2.80)	0.70	1.11 (0.48-2.60)	0.80	1.10 (0.49-2.45)	0.82
Physical Demands						
Borg scale	0.97 (0.78-1.21)	0.80	1.12 (0.89-1.42)	0.34	1.12 (0.92-1.37)	0.27
Individual Psychosocial						
Life-related worries		0.26		0.74		0.51
Seldom	1.63 (0.89-2.99)	0.11	0.74 (0.40-1.36)	0.33	1.04 (0.59-1.82)	0.89
Sometimes	1.52 (0.82-2.81)	0.18	1.02 (0.57-1.85)	0.94	1.11 (0.63-1.95)	0.71
Often	0.74 (0.29-1.91)	0.54	1.42 (0.62-3.25)	0.40	1.57 (0.72-3.45)	0.26
Family Conflict	1.33 (1.06-1.67)	0.01	1.27 (1.05-1.55)	0.02	1.13 (0.90-1.42)	0.30
Ergonomic Exposure & Skill Discretion		0.19		0.44		0.03
High / High	1.41 (0.73-2.70)	0.31	1.61 (0.87-3.00)	0.13	1.76 (0.96-3.23)	0.07
Low / Low	0.91 (0.50-1.64)	0.74	0.75 (0.41-1.39)	0.36	0.83 (0.46-1.47)	0.52
High / Low	1.54 (0.82-2.92)	0.18	1.06 (0.53-2.11)	0.87	1.69 (0.93-3.81)	0.09
Constant	0.08	0.01	0.18	0.14	0.02	0.01

TABLE 26
Multivariable Logistic Regression:
Ergonomic Exposure & Career Concerns

Variable	Back symptoms (n = 149)		UE symptoms (n = 147)		Back & UE symptoms (n = 173)	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Demographic						
Age	1.06 (1.00-1.12)	0.07	1.02 (0.96-1.09)	0.48	1.12 (1.06-1.19)	0.01
Gender	1.00 (0.57-1.76)	0.99	0.88 (0.48-1.64)	0.69	0.90 (0.53-1.50)	0.68
Education level		0.71		0.66		0.76
High School/ GED	1.15 (0.64-2.07)	0.65	1.31 (0.71-2.40)	0.39	1.18 (0.67-2.07)	0.58
Some college/ other post HS	0.83 (0.48-1.45)	0.51	0.94 (0.52-1.71)	0.84	1.16 (0.68-1.97)	0.59
Health Behaviors						
Freq. of Exercise		0.61		0.67		0.41
Rarely/never	1.02 (0.27-3.81)	0.98	1.25 (0.35-4.37)	0.73	1.21 (0.37-4.00)	0.76
1 or 2 times/wk	1.25 (0.54-2.91)	0.61	1.09 (0.47-2.54)	0.84	1.22 (0.55-2.73)	0.63
Physical Demands						
Borg scale	0.97 (0.78-1.21)	0.81	1.12 (0.89-1.42)	0.33	1.12 (0.92-1.37)	0.25
Individual Psychosocial						
Life-related worries		0.26		0.72		0.46
Seldom	1.62 (0.88-2.96)	0.12	0.74 (0.40-1.36)	0.33	1.05 (0.60-1.83)	0.86
Sometimes	1.53 (0.83-2.81)	0.17	1.03 (0.57-1.85)	0.93	1.11 (0.63-1.96)	0.71
Often	0.75 (0.29-1.95)	0.56	1.47 (0.64-3.36)	0.37	1.62 (0.74-3.56)	0.23
Family Conflict	1.33 (1.06-1.68)	0.01	1.27 (1.04-1.55)	0.02	1.12 (0.92-1.37)	0.36
Ergonomic Exposure & Career Concerns		0.28		0.51		0.34
High / Low	1.36 (0.73-2.51)	0.33	1.20 (0.63-2.28)	0.57	1.69 (0.93-3.08)	0.08
Low / High	0.64 (0.35-1.18)	0.15	0.79 (0.43-1.45)	0.44	0.46 (0.25-0.84)	0.01
High / High	1.52 (0.77-3.00)	0.23	1.51 (0.74-3.10)	0.26	1.56 (0.82-2.90)	0.17
Constant	0.09	0.02	0.18	0.13	0.02	0.01

TABLE 27
Ergonomic Exposure & Work Organization Combinations
Associated with Musculoskeletal Symptoms

Variables Level ergonomic exposure / Level work organization	**Back symptoms** (n = 149)		**UE symptoms** (n = 147)		**Back & UE symptoms** (n = 173)	
	Odds Ratio (95% CI)	**p**	**Odds Ratio (95% CI)**	**p**	**Odds Ratio (95% CI)**	**p**
Ergonomic Risk Exposure & Cognitive Demands	NS		NS			**0.01**
High / Low					1.15 (0.61 – 2.15)	0.67
Low / High					0.88 (0.46 – 1.69)	0.71
High / High					**2.25 (1.23 – 4.09)**	**0.01**
Ergonomic Risk Exposure & Participatory Management	NS		NS			**0.01**
High / High					1.17 (0.64 – 2.14)	0.60
Low / Low					0.98 (0.52 – 1.84)	0.95
High / Low					**2.50 (1.30 – 4.81)**	**0.01**
Ergonomic Risk Exposure & Time Pressure		**0.02**		**0.01**		**0.02**
High / Low	0.63 (0.29 – 1.35)	0.23	0.46 (0.20 – 1.07)	0.07	**1.18 (0.64-2.17)**	**0.59**
Low / High	1.00 (0.48 – 2.09)	0.99	1.05 (0.50 – 2.21)	0.90	**0.88 (0.44-1.76)**	**0.72**
High / High	**2.61 (1.39 – 4.91)**	**0.01**	**2.90 (1.49 – 5.66)**	**0.01**	**2.21 (1.19-4.10)**	**0.01**
Ergonomic Risk Exposure & Organizational Climate	NS		NS			**0.03**
High / High					**2.15 (1.14 – 4.06)**	**0.02**
Low / Low					0.76 (0.41 – 1.42)	0.39
High / Low					0.35 (0.74 – 2.41)	0.34
Ergonomic Risk Exposure & Cognitive Uncertainty	NS		NS			**0.02**
High / Low					1.30 (0.79 – 2.42)	0.42
Low / High					0.80 (0.43 – 1.48)	0.47
High / High					**2.08 (1.16 – 3.75)**	**0.02**
Ergonomic Risk Exposure & Interpersonal Demands	NS		NS			**0.02**
High / Low					1.13 (0.61 – 2.08)	0.59
Low / High					0.64 (0.35 – 1.14)	0.13
High / High					**2.44 (1.35 – 4.41)**	**0.01**

Note: NS = Not significant

FIGURES

FIGURE 1
Model of Effort-Reward Imbalance at Work (Siegrist, 1998)

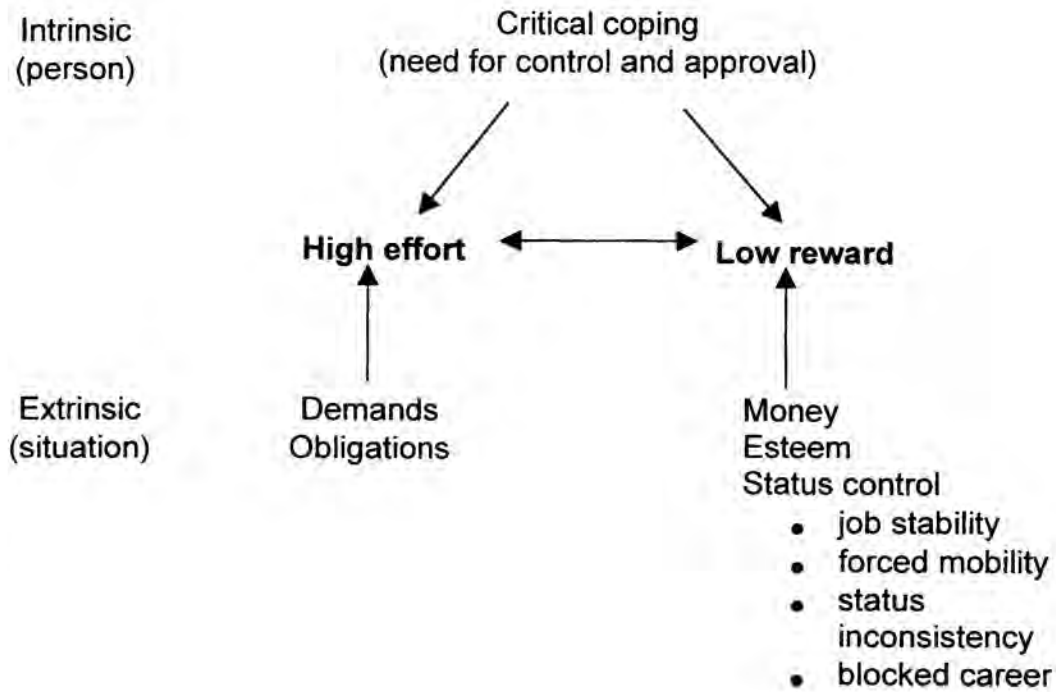


FIGURE 2
Psychological Demand/Decision Latitude Model (Karasek, 1979)

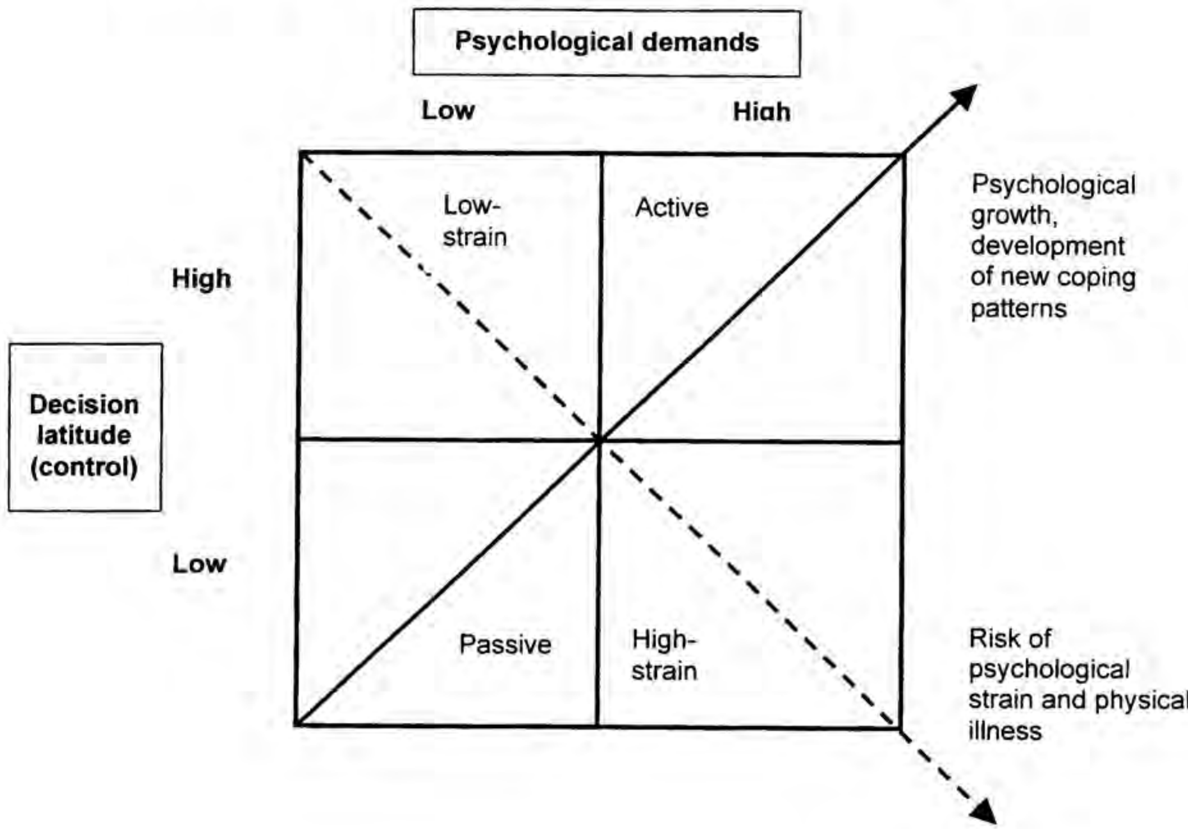


FIGURE 3
Model of Job Stress and Health (Hurrell & McLaney, 1988)

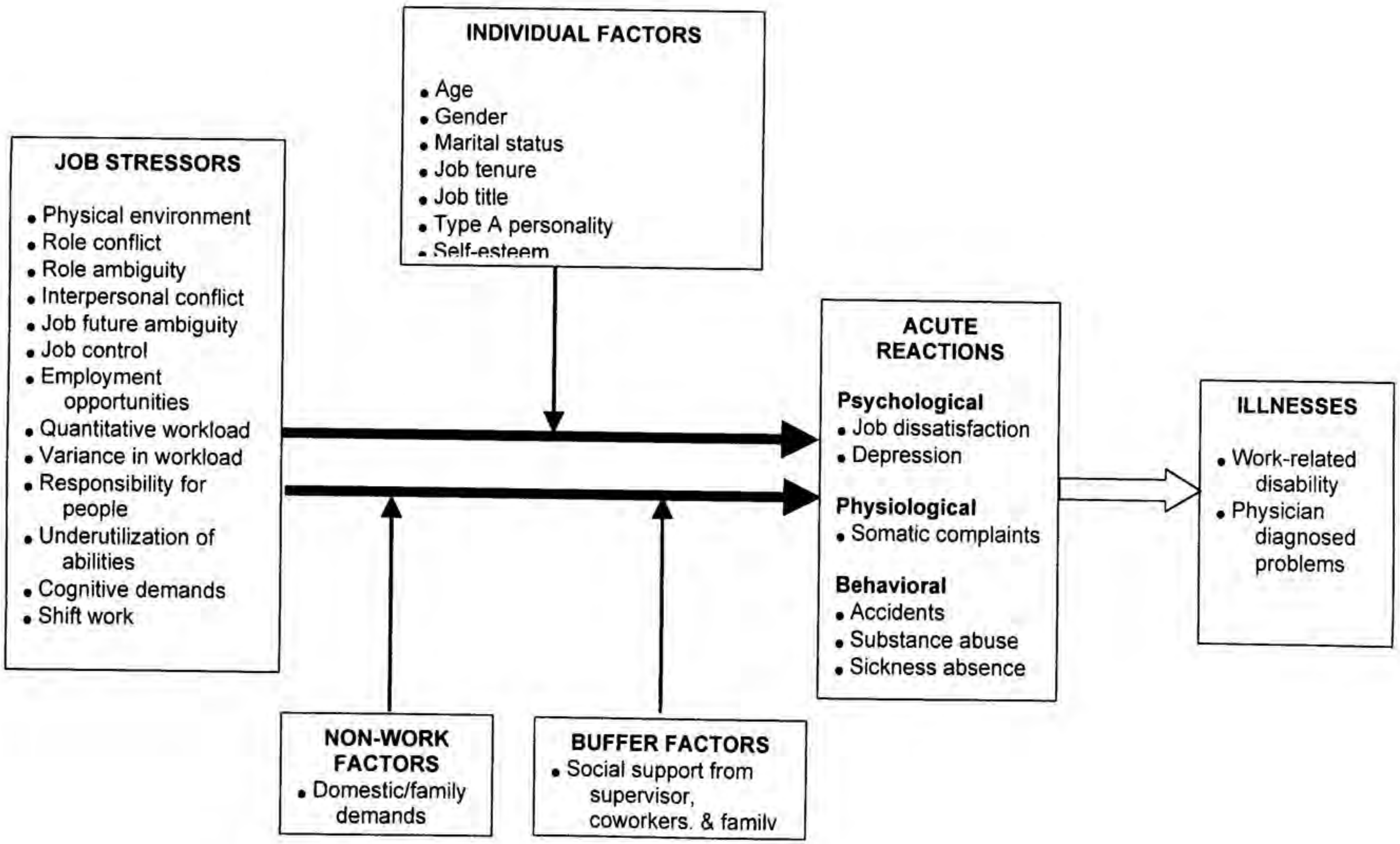


FIGURE 4
Dose-response Model for Work-related Neck and Upper Limb Musculoskeletal Disorders (Armstrong et al., 1993)

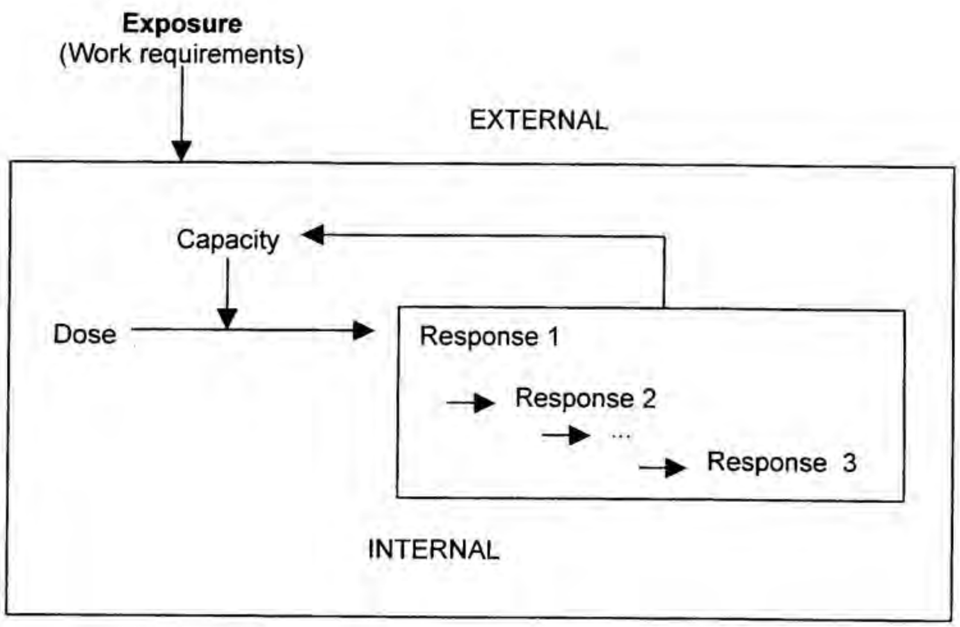


FIGURE 5
Epidemiological Model of Musculoskeletal Disorders (Bongers et al., 1993)

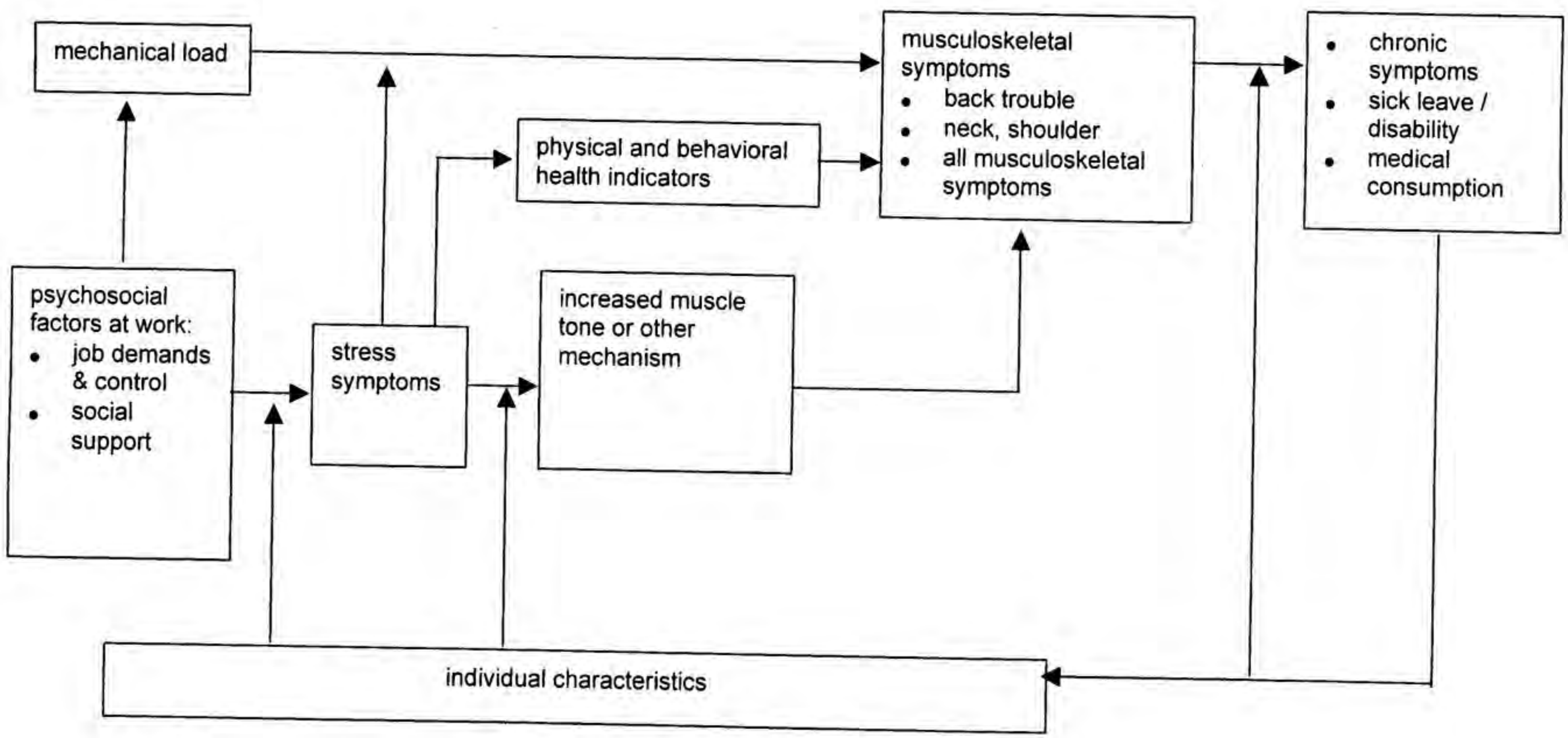


FIGURE 7
Biopsychosocial Model of Job Stress (Melin & Lundberg, 1997)

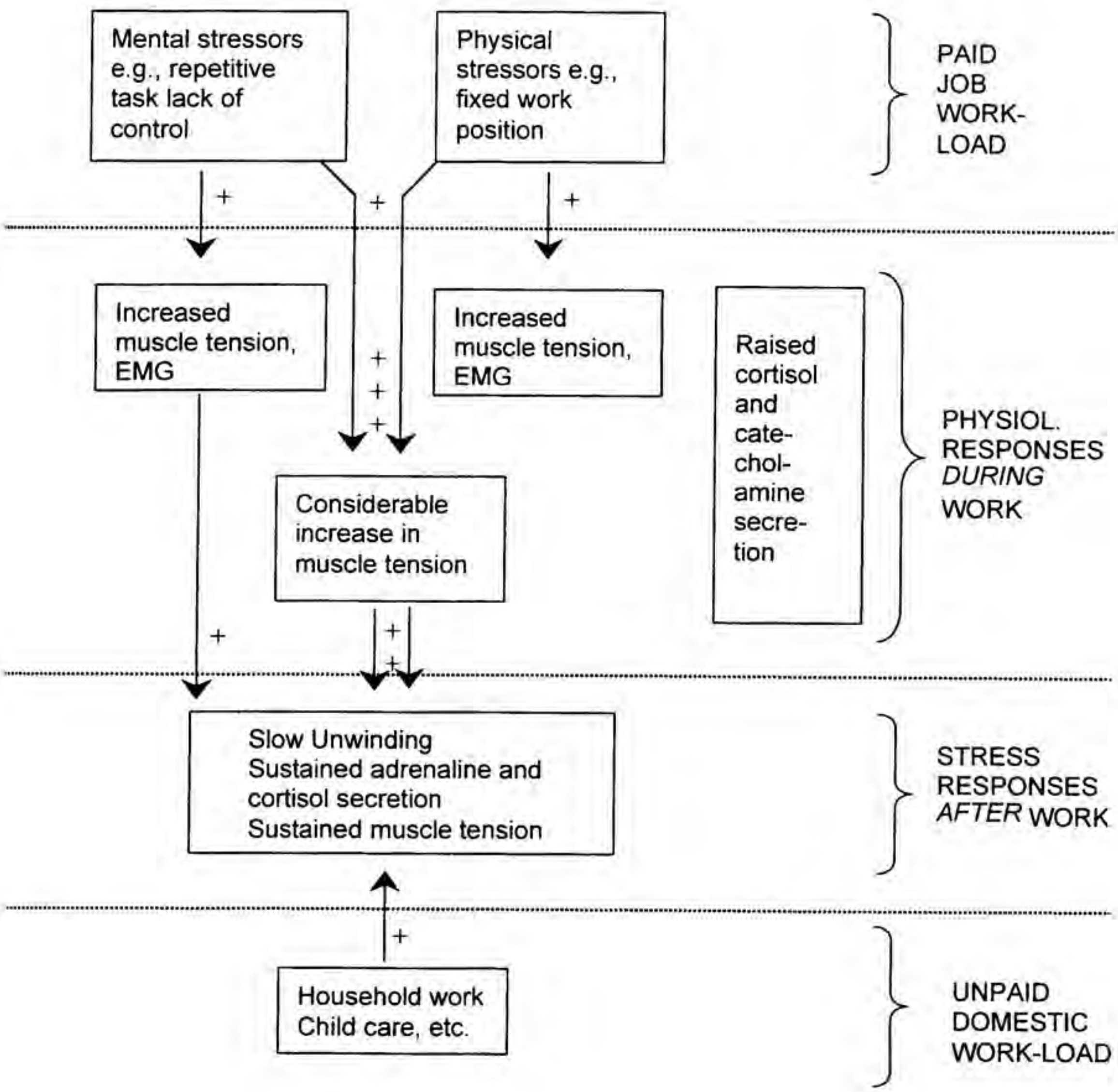


FIGURE 6
Ecological Model of Musculoskeletal Disorders (Sauter & Swanson, 1996)

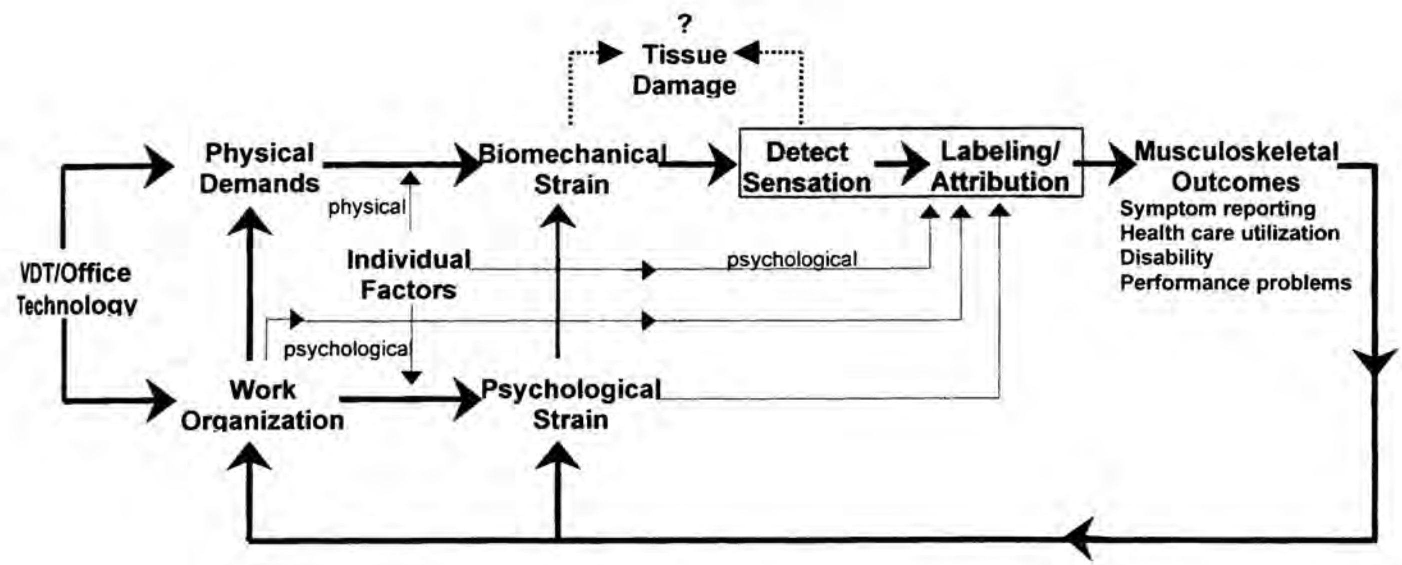


FIGURE 8
Balance Theory of Job Design and Stress (Smith & Carayon-Sainfort, 1989)

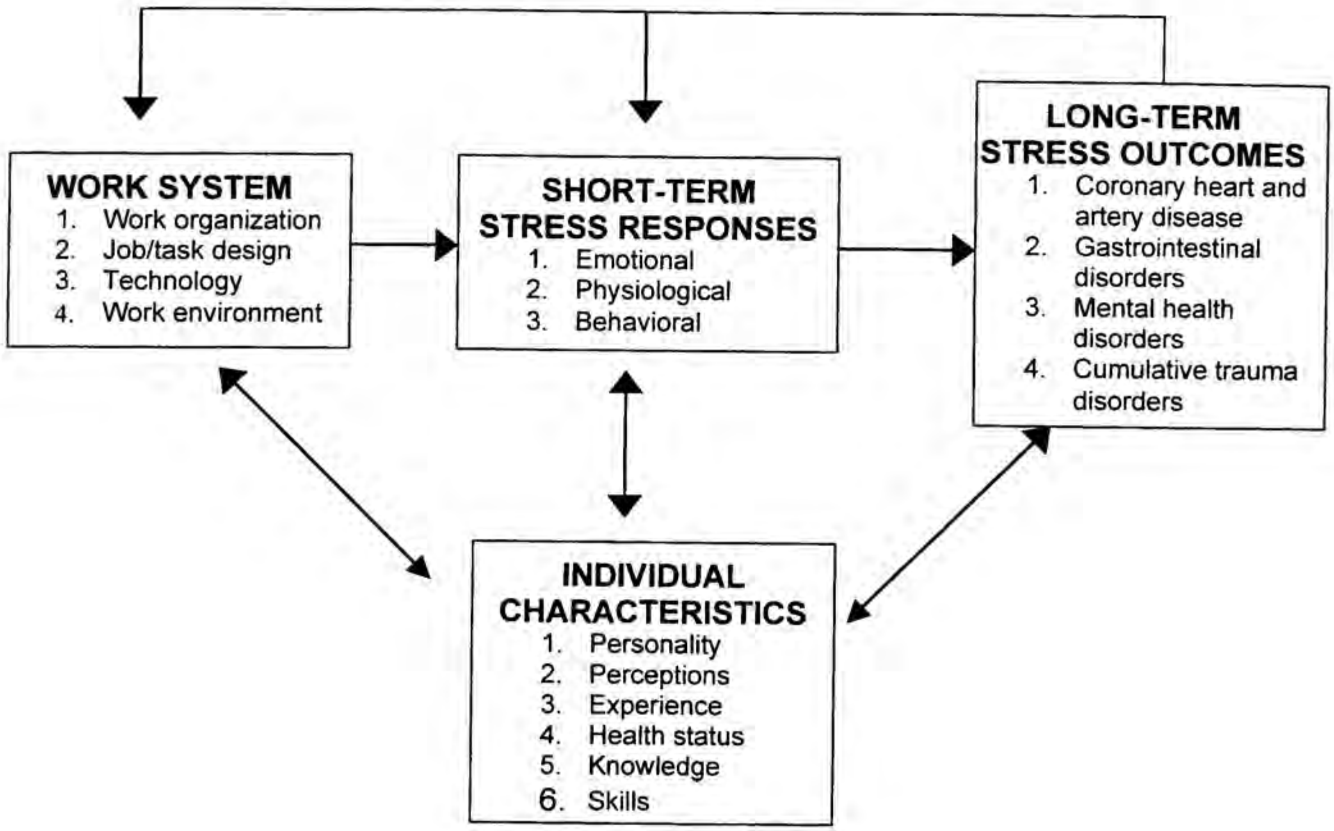


FIGURE 9
Work System Model (Carayon, Smith, & Haims, 1999)

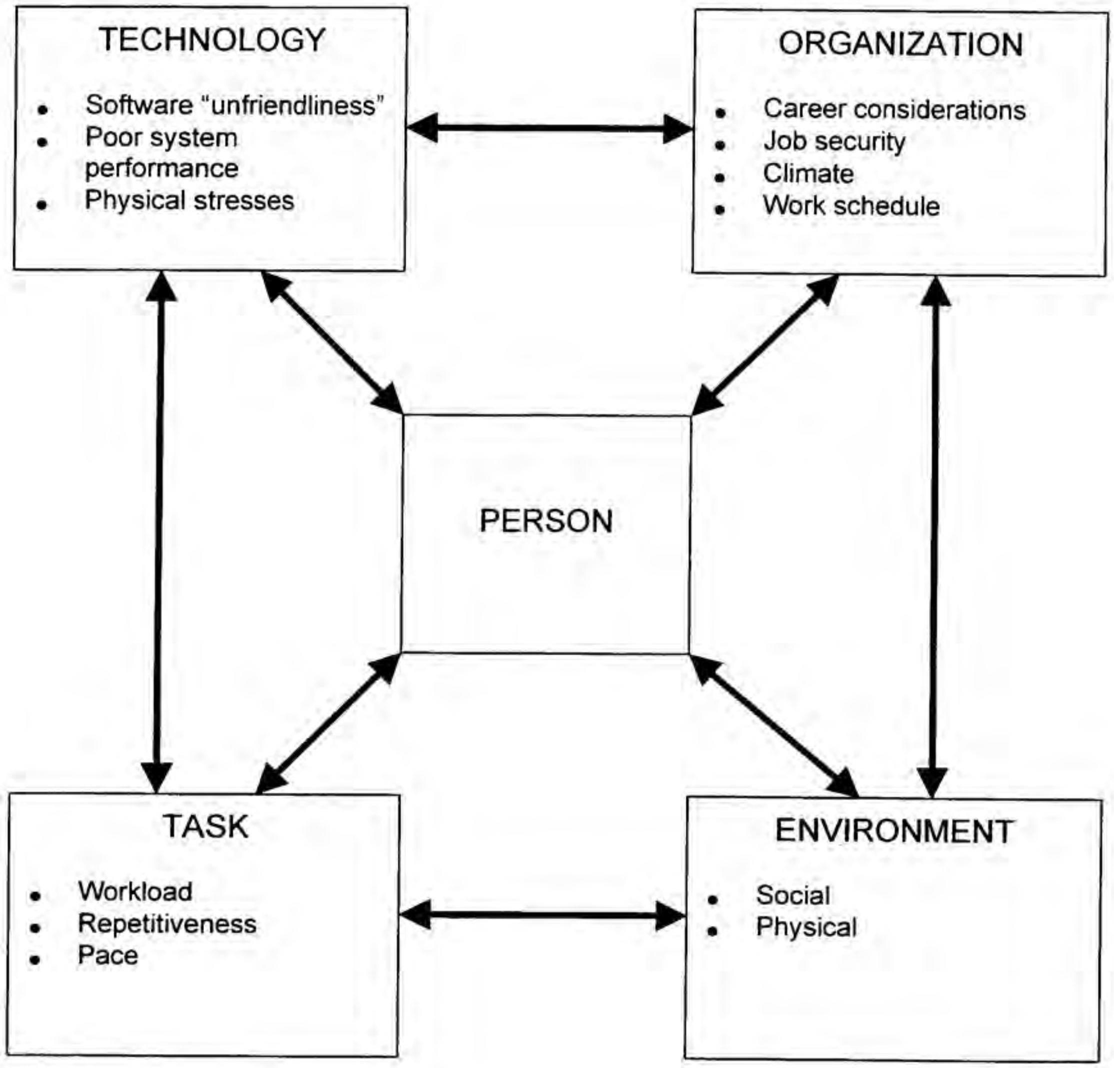


FIGURE 10
Workstyle Model (Feuerstein, 1996; Feuerstein, Huang, & Pransky, 1999)

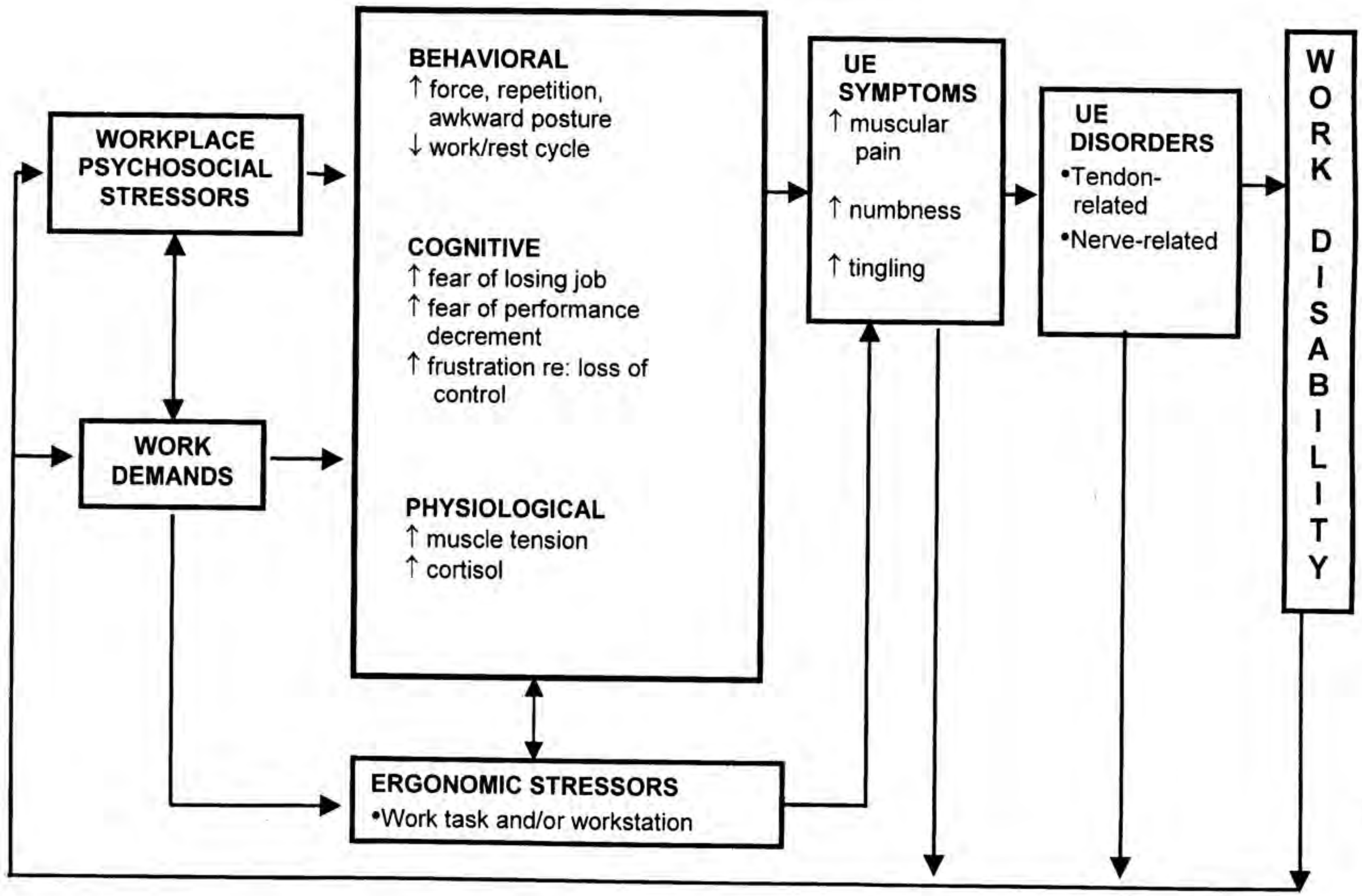


FIGURE 11
Proposed Model for Relationship between Work Organization & Ergonomic Stressors and Work-related Musculoskeletal Outcomes

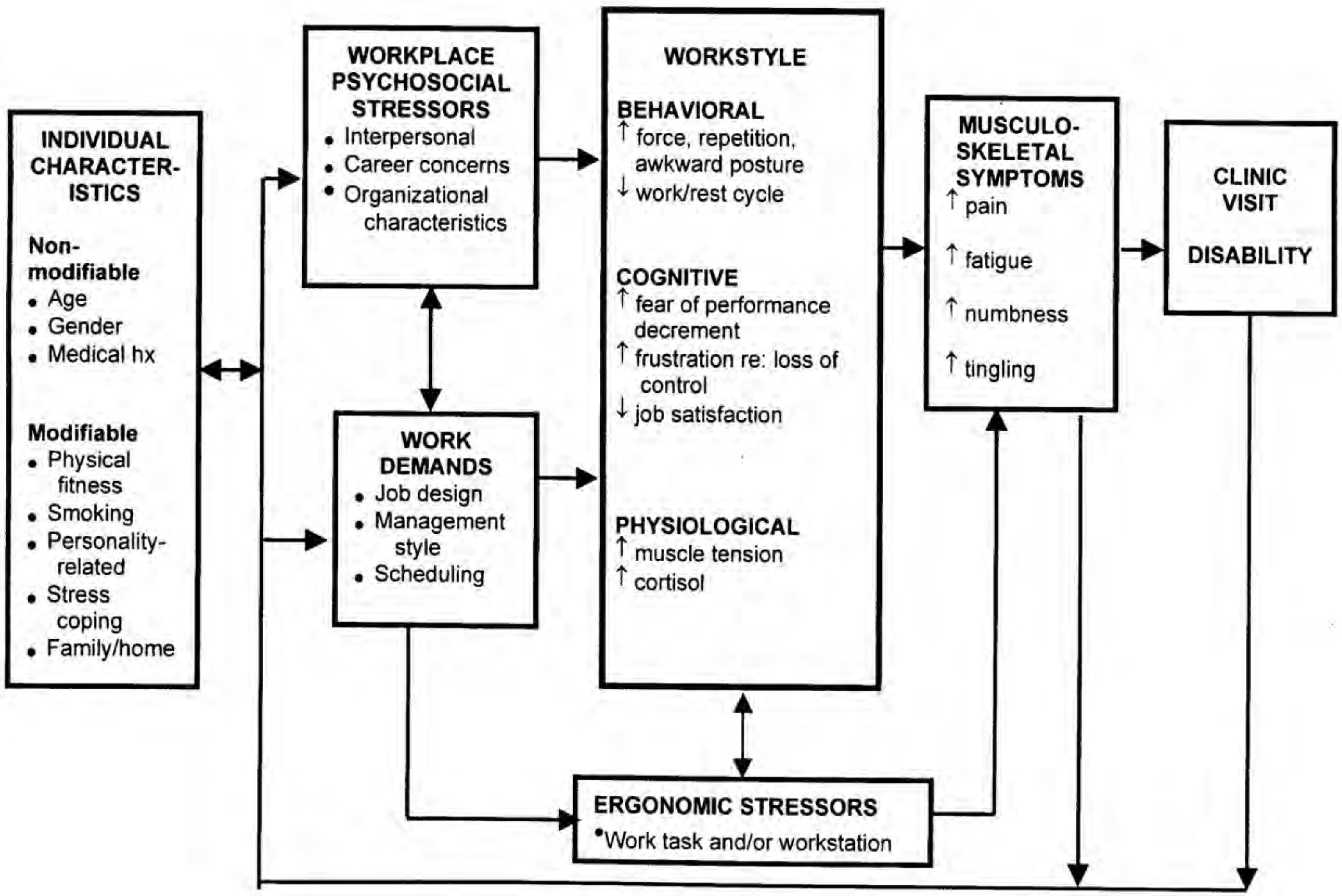


FIGURE 12
Distribution of Occupational Categories

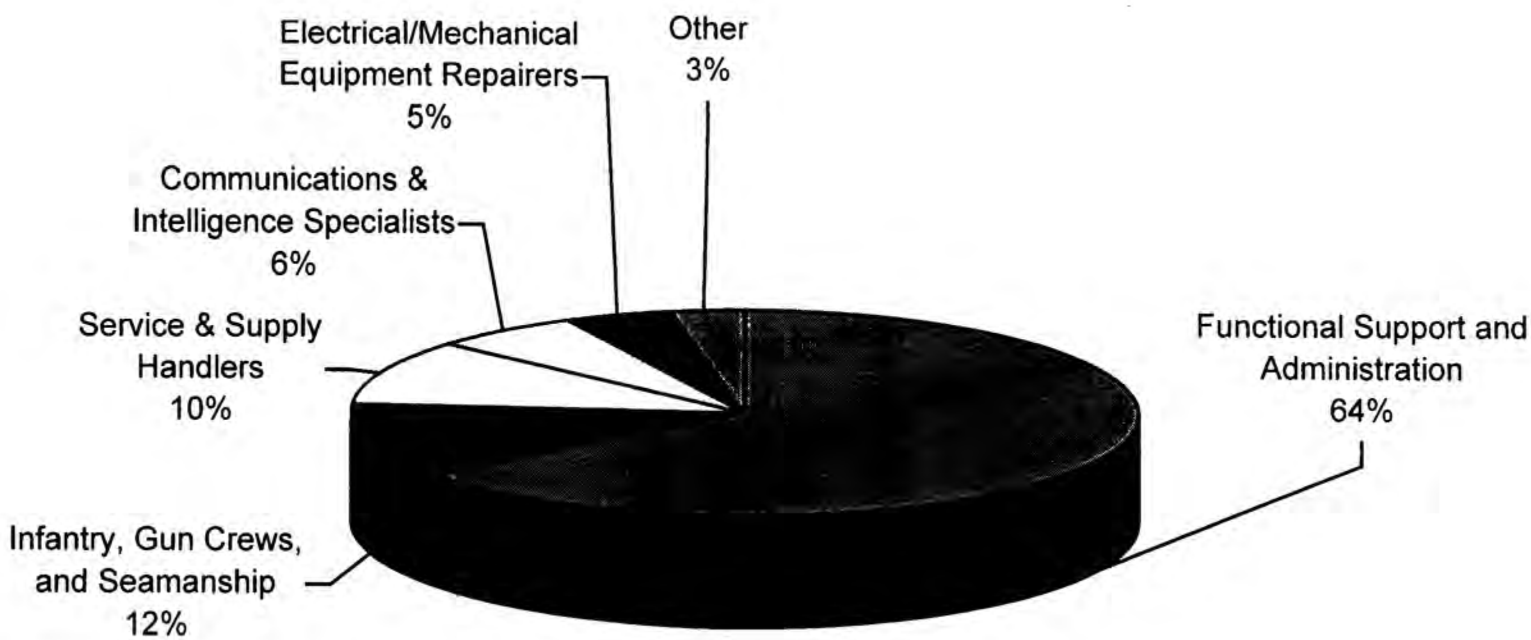
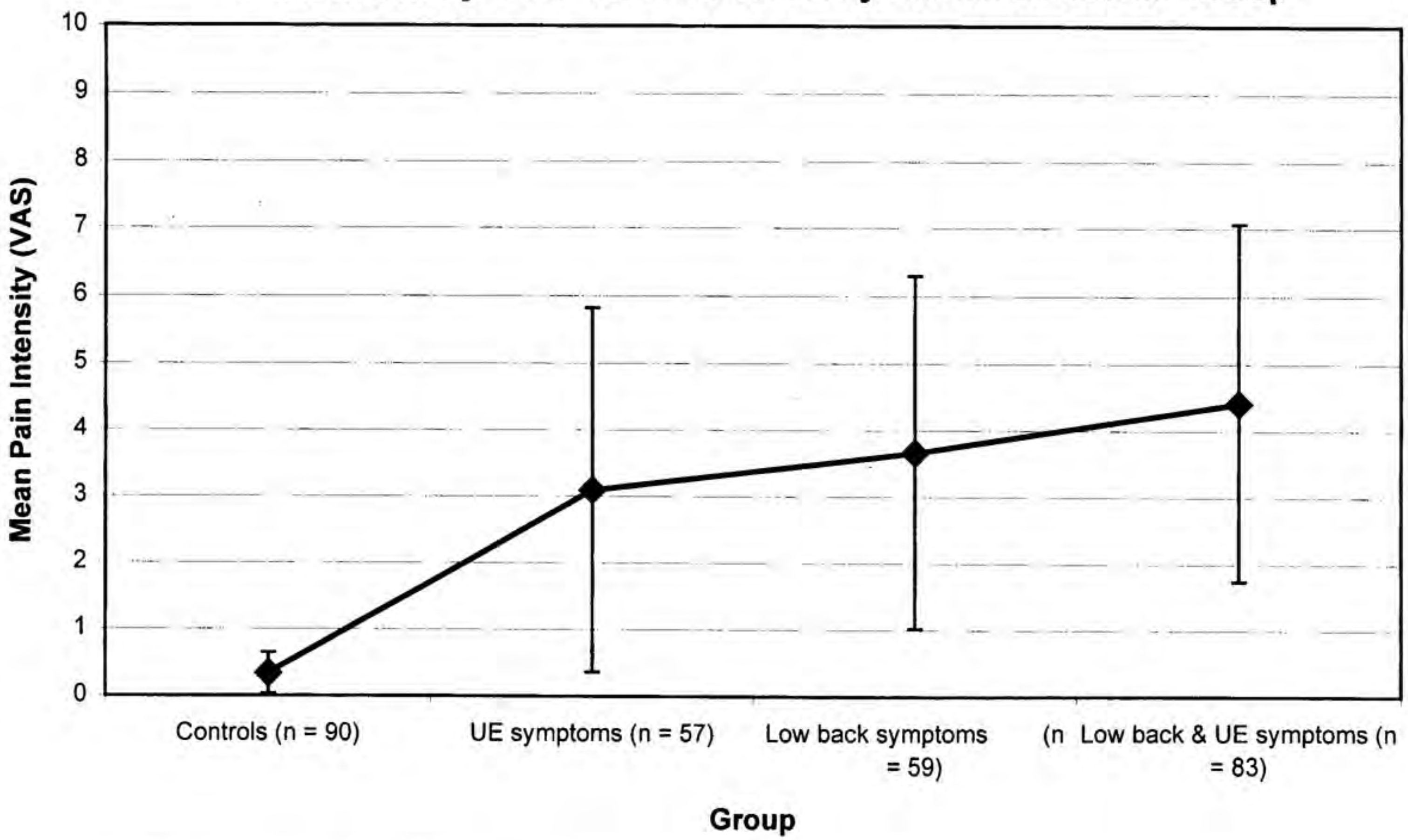
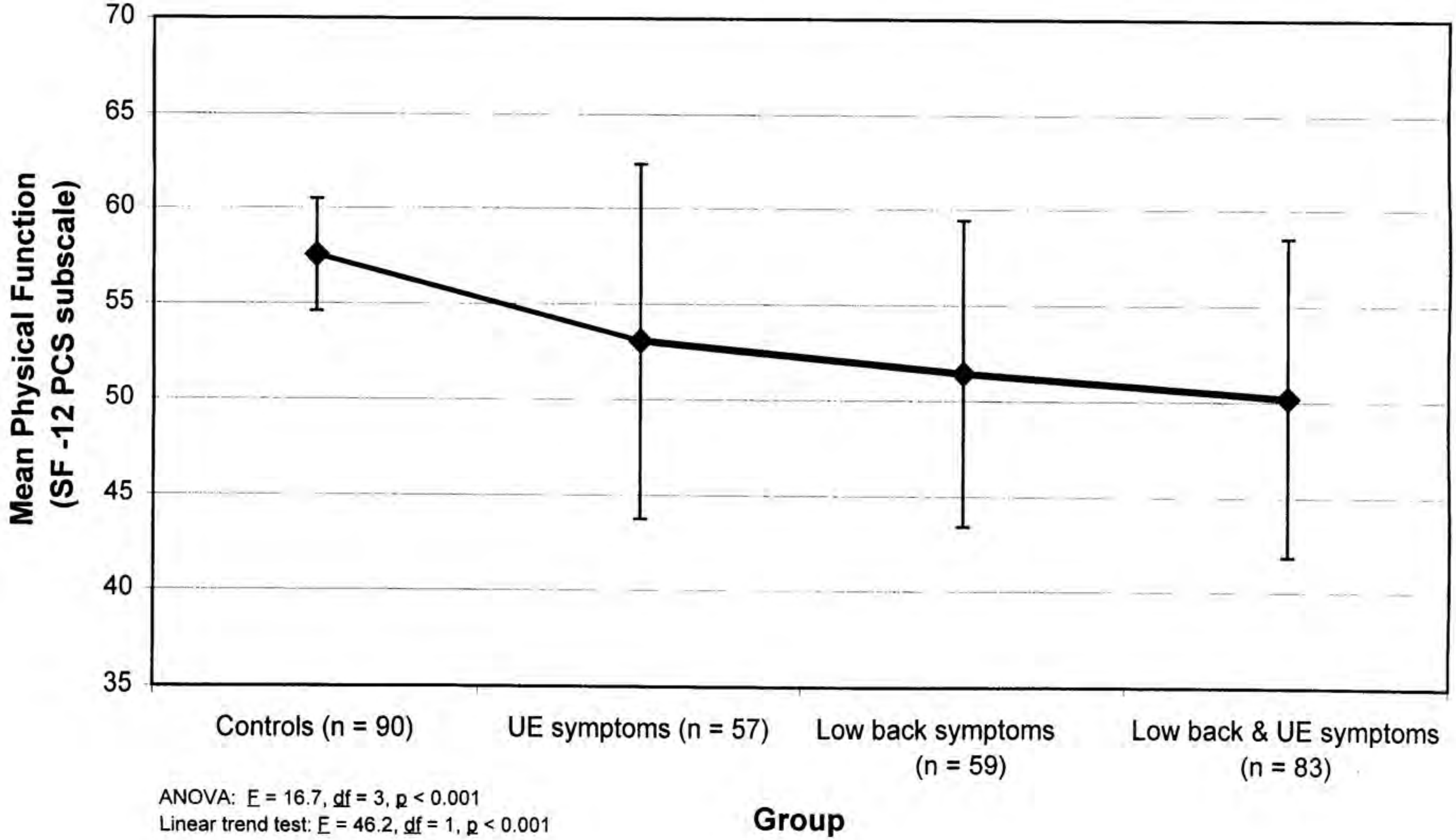


FIGURE 13
Pain Intensity Over the Last Week by Musculoskeletal Group



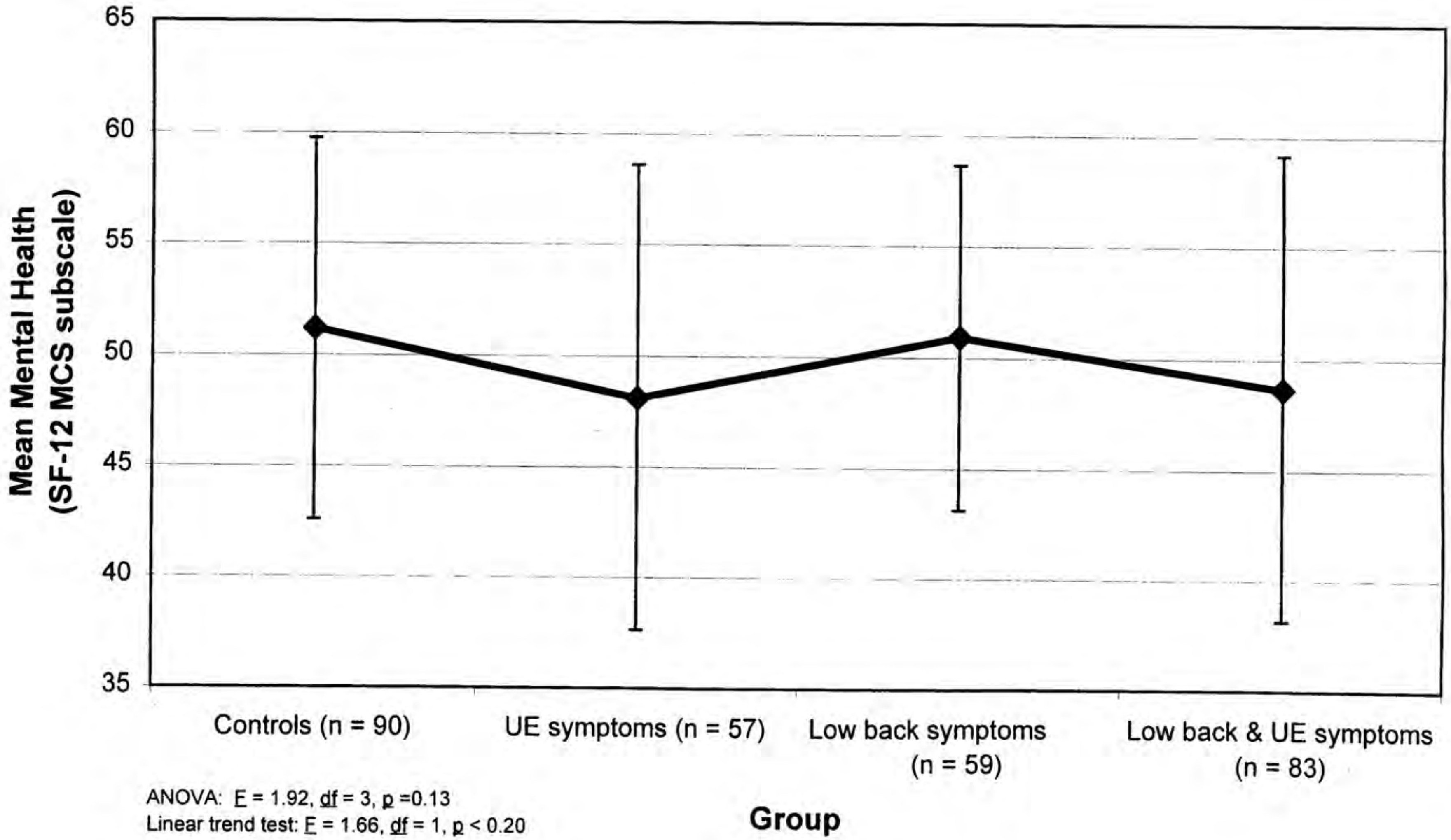
ANOVA: $F = 51.7$, $df = 3$, $p < 0.001$
Linear trend test: $F = 138.6$, $df = 1$, $p < 0.001$

FIGURE 14
Physical Function by Musculoskeletal Group



ANOVA: $F = 16.7$, $df = 3$, $p < 0.001$
Linear trend test: $F = 46.2$, $df = 1$, $p < 0.001$

FIGURE 15
Mental Health by Musculoskeletal Group



ANOVA: $F = 1.92$, $df = 3$, $p = 0.13$
Linear trend test: $F = 1.66$, $df = 1$, $p < 0.20$

FIGURE 16

Risks for the Occurrence of Low Back Symptoms (n = 149)

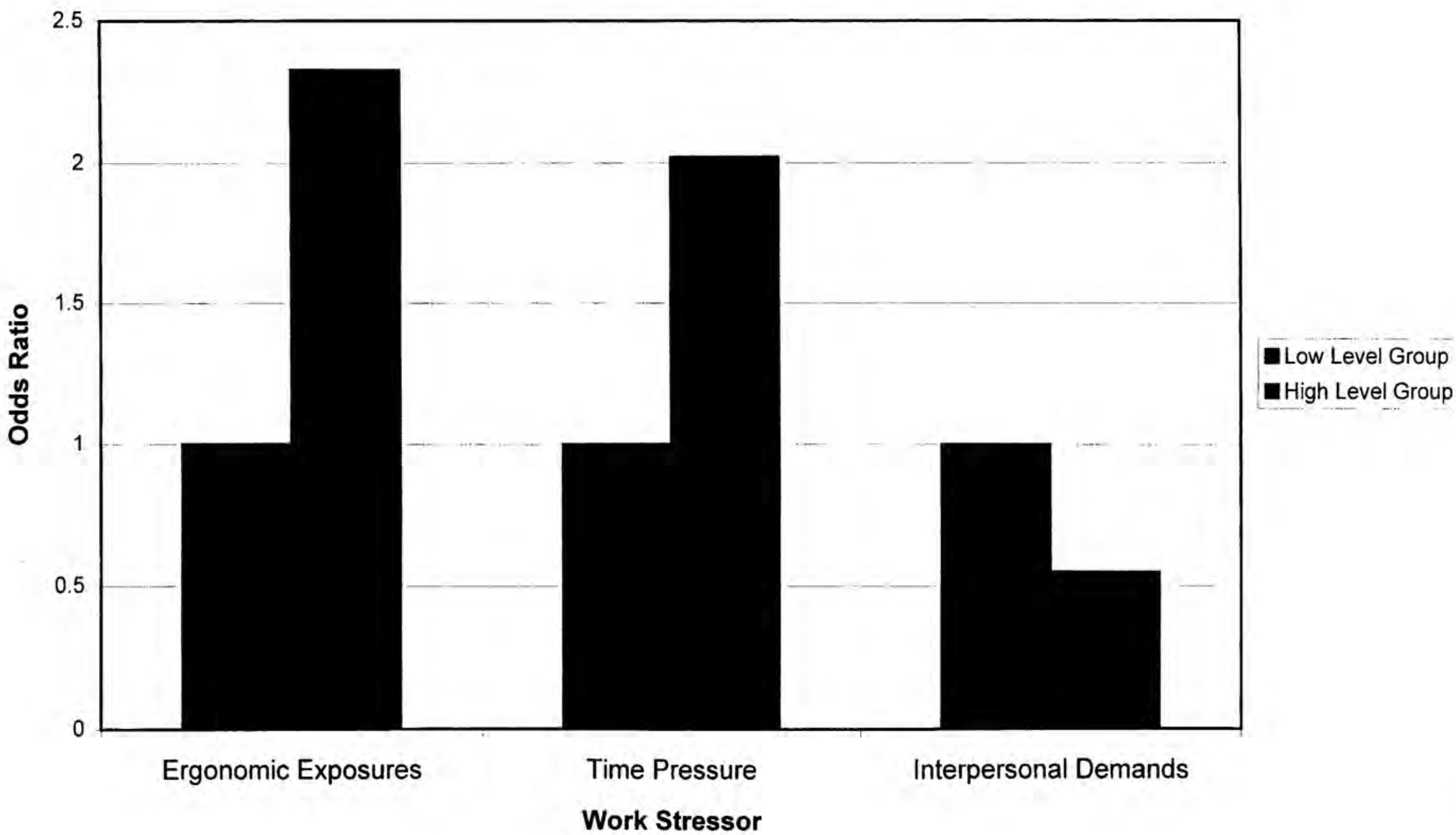


FIGURE 17

Risks for the Occurrence of Upper Extremity Symptoms (n = 147)

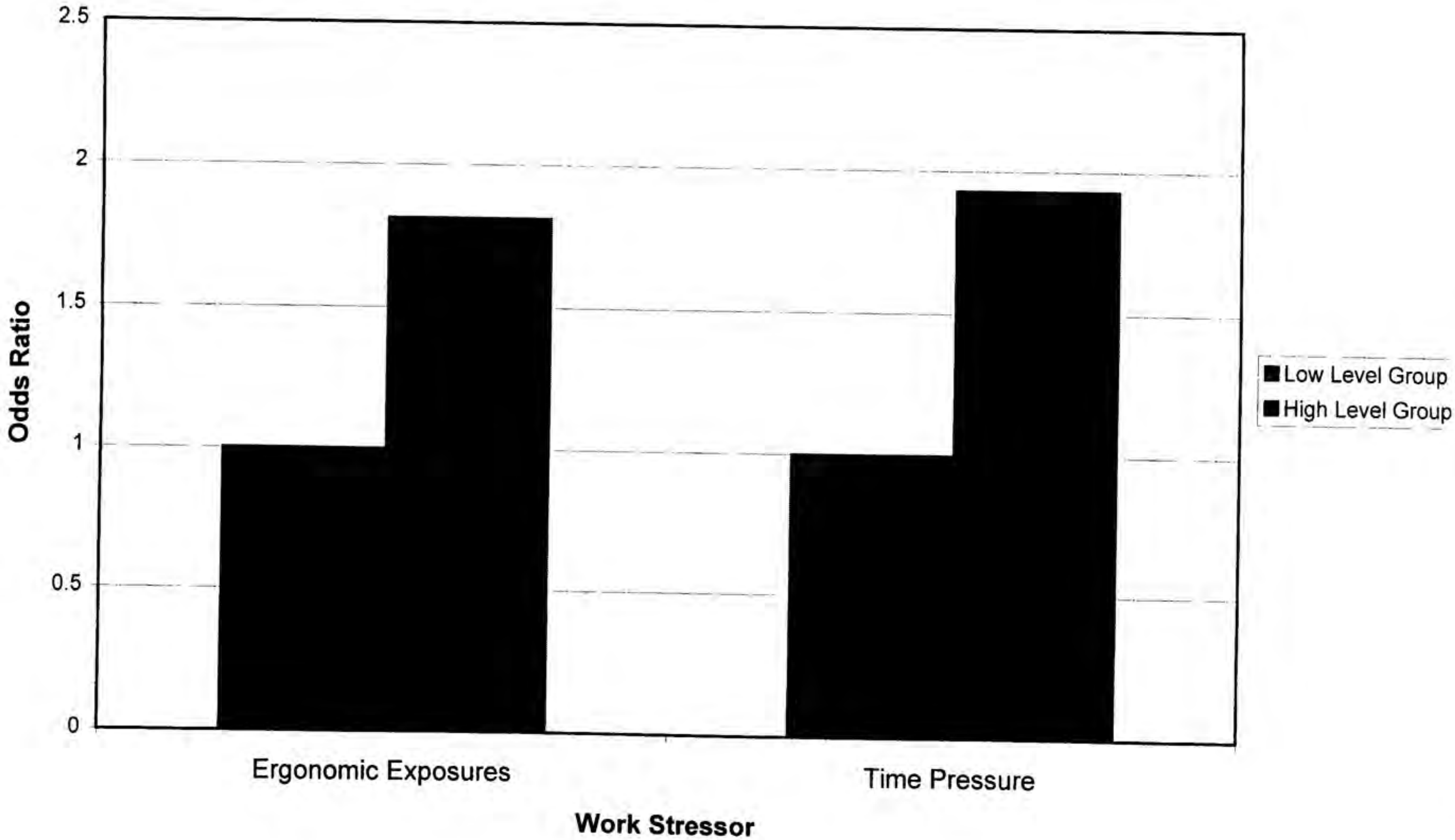


FIGURE 18
Risks for the Occurrence of Concurrent Low Back and Upper Extremity Symptoms (n = 173)

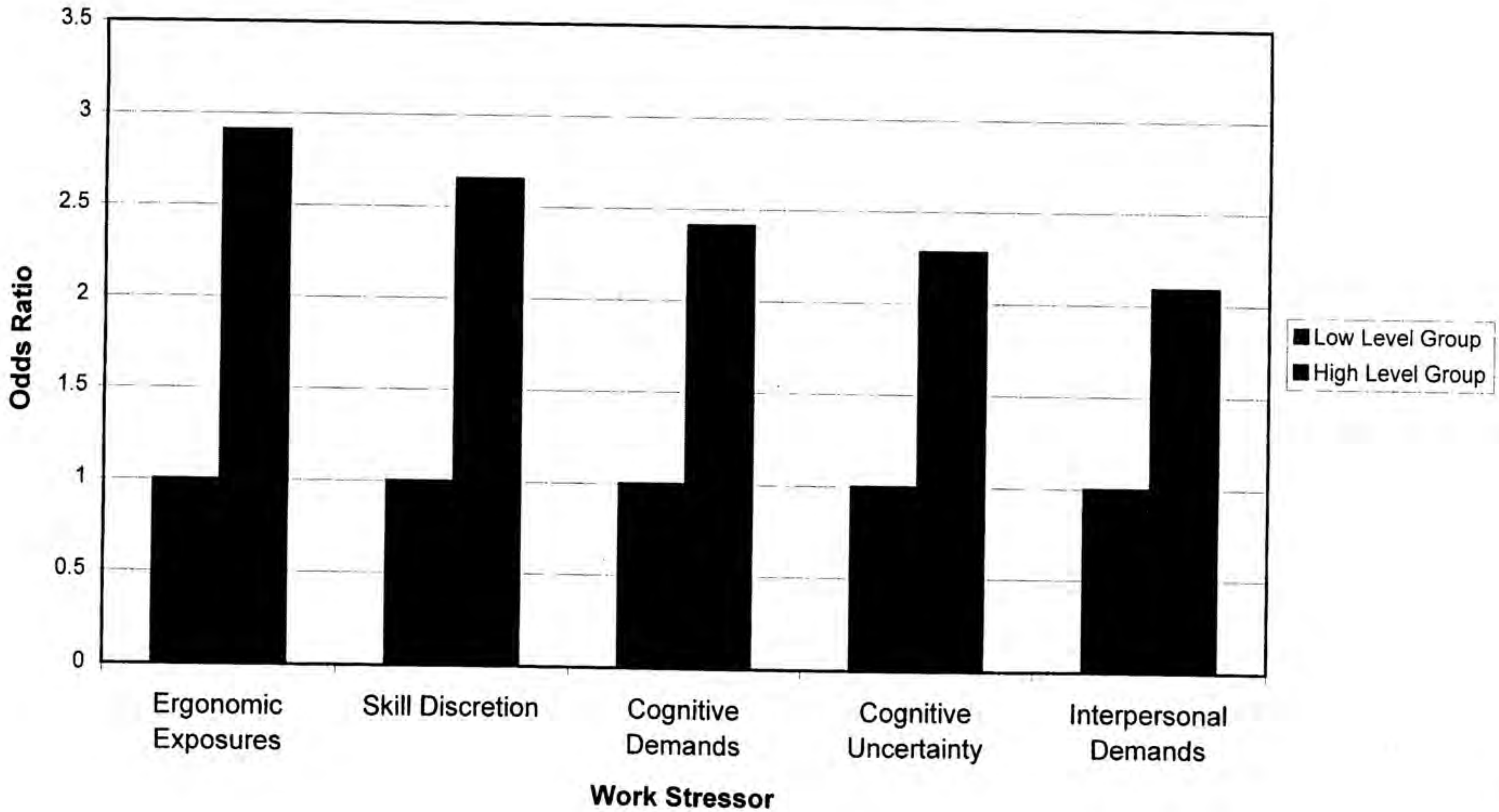


FIGURE 19
Risks Associated with Ergonomic Exposure & Time Pressure Combined: Low Back or Upper Extremity Symptoms

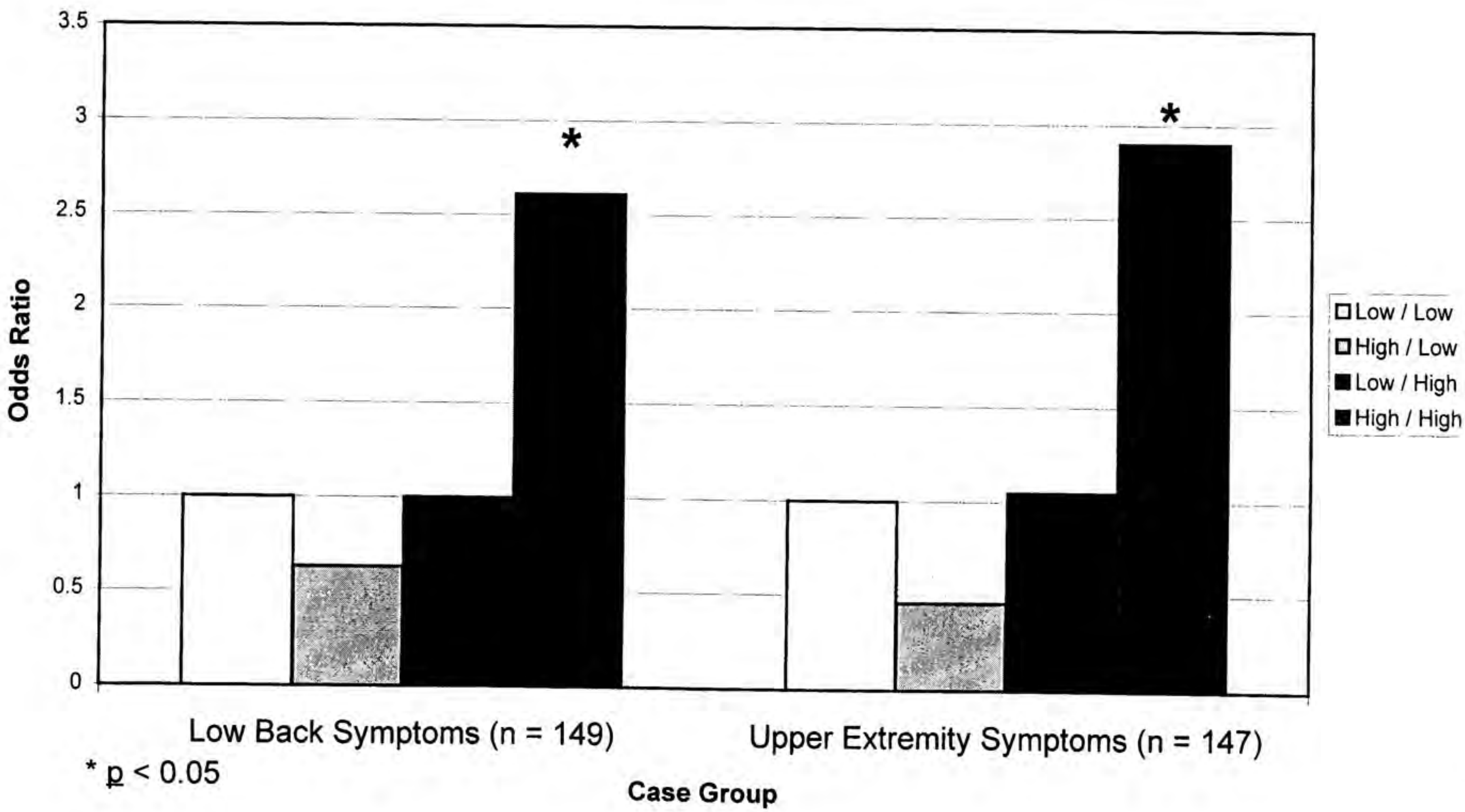
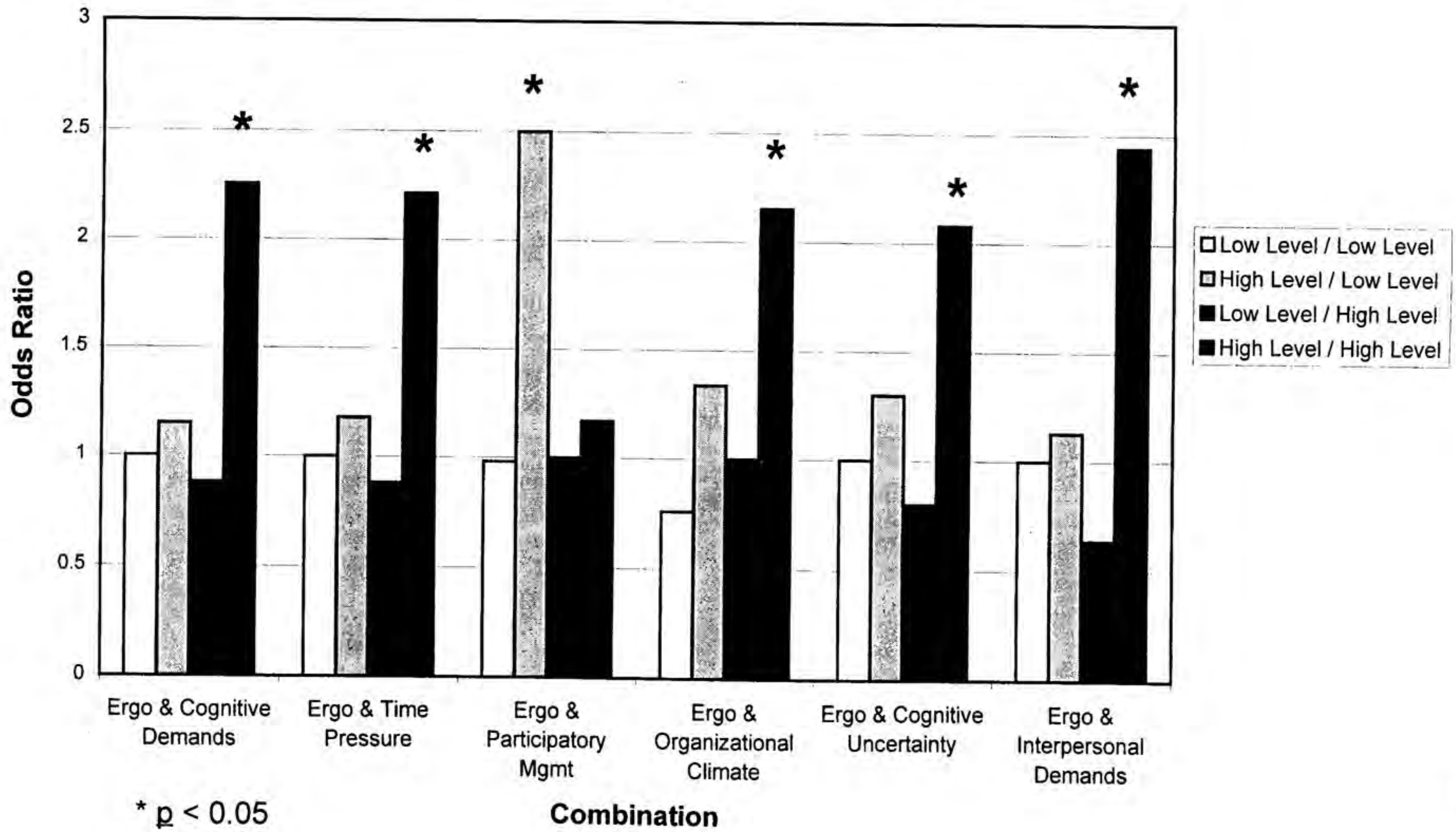


FIGURE 20
Risks Associated with Combined Ergonomic & Work Organization Stressors: Concurrent Low Back & Upper Extremity Symptoms (n = 173)



* $p < 0.05$

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APPENDIX A

UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES
4301 JONES BRIDGE ROAD
BETHESDA, MARYLAND 20814-4799

24

INFORMED CONSENT FORM
Research Study

Research Study Title: **The impact of work organization and ergonomic factors on musculoskeletal disorders in the U.S. Marine Corps**

Principal Investigator: Grant D. Huang, M.S., M.P.H. (with Michael Feuerstein, Ph.D.)

1. Purpose of the Study:

You are invited to participate in a research study that will examine musculoskeletal (back and hand/wrist/arm/elbow/shoulder/neck) symptoms and work. Currently, how workplace factors interact to contribute to work-related musculoskeletal disorders is not well understood. You were selected as a possible participant because we are trying to understand how various work factors have an impact on back and upper extremity symptoms and clinic visits among Marines.

2. Procedures involved in the Study:

If you decide to participate, you will be given a questionnaire to complete. This questionnaire will take approximately 45 to 60 minutes to complete. The questionnaire will ask you to select responses to questions related to your health, sources of stress, problem solving, and job characteristics. While it is strongly encouraged that you answer all questions to the best of your ability, you are not required to answer each of them. In addition, information regarding whether you have been to a clinic for a back or upper extremity problem and have had limited duty and/or lost time will be obtained from military administrative/medical records three months after you complete the questionnaire.

When you enter the study, you will be assigned a personal study identification (ID) number. Although your social security number (SSN) will be used to link your initial questionnaire to follow-up medical and administrative data, only the Principal Investigator (Mr. Huang) and his research team will have access to your SSN. Additionally, only the Principal Investigator (Mr. Huang) and his research team will be able to link your SSNs to names in the event that it is necessary for any unforeseen reason. You name and personal information will not be released to anyone.

3. Possible discomfort and risks involved:

To the best of our knowledge, you will not be exposed to any risks, discomforts, or inconveniences as a result of your participation in this study. You have the right to refuse or discontinue participation at any time.

USUHS IRB APPROVED 8 Nov 00

4. Privacy:

All information that you provide as part of this study will be kept confidential and protected to the fullest extent of the law. Information that you provide and other records related to this study will be kept private, accessible only to those persons directly involved in conducting this study, members of the Institutional Review Board at the Uniformed Services University of the Health Sciences, and other Federal agencies who provide oversight for human use protection. All questionnaires and forms will be kept in a restricted access, locked cabinet at the Uniformed Services University of the Health Sciences in Bethesda, Maryland when not in use. However, please be advised that under Federal Law, a military member's confidentiality cannot be strictly guaranteed.

To enhance your privacy of answers that you provide, data from questionnaires will be entered into a database in which individual responses are not identified. After verification of the database information, the hard copy of the questionnaires containing personal identifiers will be destroyed. Any reports of this study will only use data in the database and will not use your name or identify you personally. Results of this study will be provided to U.S. Marine Corps, Headquarters, Safety Division in the form of group data.

5. Recourse in the event of injury:

This study should not entail any physical or mental risk beyond those described above. We do not expect any complications to occur, but if, for any reason, you feel that continuing this study would constitute a hardship for you, we will immediately end your participation in the study.

In the event of a medical emergency while participating in this study, you will receive emergency treatment in the facility you are in or a nearby Department of Defense (military) medical facility (hospital or clinic). Emergency treatment/care will be provided even if you are not eligible to receive such care at a military medical facility. Care will be continued until the medical doctor treating you decides that you are out of immediate danger. If you are not entitled to care in a military facility, you may be transferred to a private civilian hospital. The attending doctor or member of the hospital staff will go over the transfer decision with you before it happens. The military will bill your health insurance for health care you receive which is not part of the study. If you are uninsured, you will not be personally billed for such care, and you WILL NOT be expected to pay for medical care at military hospitals.

In case you need additional care following discharge from the military hospital or clinic, a military health care professional will decide whether your need for care is directly related to being in this study. If your need for care is related to the study, the military may offer you limited health care at its medical facilities. If you believe the government or one of the government's employees (such as a military doctor) has injured you, a claim for damages (money) against the federal government (including the military) may be filed under the Federal Tort Claims Act. If you would like to file a claim please contact the University's Office of General Counsel and request the filing forms.

If at any time you believe that you have suffered an injury or illness as a result of participating in this research project, you should contact the Office of Research at the Uniformed Services University of Health Sciences, Bethesda, Maryland 30814 at (301) 295-3303. This office can review the matter with you, provide information about your rights as a subject, and may be able to identify resources available to you. Information about judicial avenues of compensation is available from the University's General Counsel at (301) 295-3028. Mr. Huang, the Principal Investigator, can be reached at (301) 295-9660.

6. Possible benefits involved:

This experiment is not designed to help you personally, but as a result of this study, the investigators hope to learn more about how biomechanical and psychological stress on the job influences musculoskeletal symptoms and clinic visits. This information will be very useful in designing more effective assessment, treatment, and prevention techniques for Marines with back and upper extremity symptoms.

7. Use of research results:

The results of this research will appear in medical and/or scientific journals. All data will be presented in group format and individual findings will not be revealed in these publications.

8. Special circumstances:

In the event of an emergency, please contact Mr. Huang at (301) 295-9660.

Your decision whether or not to participate will not prejudice future relations with the Uniformed Services University of the Health Sciences. If you decide not to participate at any time, you may withdraw from the study without prejudice. If for any reason, you decide not to participate or are excluded from the study, all of your records that are traceable to you will be destroyed.

Please direct questions or concerns to Mr. Huang at (301) 295-9660 at the Uniformed Services University of the Health Sciences, 4301 Jones Bridge Road, Bethesda, Maryland, 20814-4799. Questions regarding your rights as a research subject should be directed to the Director of Research Programs, Uniformed Services University of the Health Sciences, (301) 295-3303. The Director is your representative and has no connection to the investigators conducting the study.

Signatures

By signing the consent form, you are agreeing that the study has been explained to you and that you understand the study. You are signing that you agree to take part in this study. You will be given a copy of this consent form.

____________________________________ _______________

Signature of Participant Date

____________________________________ _______________

Signature of Witness Date

Investigator Statement

I certify that the research study has been explained to the above individual, by me or my research staff, and that the individual understands the nature and purpose of this study and the possible risks and benefits associated with taking part in this study. Any questions that have been raised, have been answered.

____________________________________ _______________

Signature of Investigator Date

APPENDIX B

The Binding of the survey that follows has some text missing on the left side since the binding is very tight.

Note: The binding of this survey is very tight with some of the left side cut off in places.

Marine Corps Musculoskeletal Health Questionnaire

optimum accuracy, please print in capital letters and avoid contact with the edge of the box. The following serve as an example:

B C D E F G H I J K L M N O P Q R S T U V W X Y Z

de circles like this: ●
ike this: ⊗ ✓

ase answer all of the following questions as best as you can. Thank you for completing this survey.

Name: Omit spaces, hyphens, apostrophes, and jr., III, etc.

T (family) NAME 15 letters | FIRST (given) NAME 12 letters | MI

hone Number ( ) -

3. Today's Date: MM / DD / YY

ocial Security Number - -

5. Birth Date: MM / DD / YY

Gender
O Male O Female

7. What is your Height? Feet Inches

8. What is your weight in LBS.?

9. Education Level
O H.S. Grad / GED
O Some College / Other Post H.S.
O 2 year degree
O 4 year degree (college)
O Some graduate work

10. Race
O American Indian / Alaska Native
O Asian
O Black or African American
O Native Hawaiian or Other Pacific Islander
O White

11. Ethnicity
O Hispanic / Latino
O Not Hispanic / Latino

12. Marital Status
O Single
O Married
O Separated
O Divorced
O Widowed

13. # of Children You Support
O 0 O 3
O 1 O 4
O 2 O 5+

14. Base:
O Camp Pendleton
O Camp Lejeune
O Quantico
O Headquarters
O Other

15. Rank
O E1 O E5 O E9
O E2 O E6 O Other
O E3 O E7
O E4 O E8

16. Length of Service in Marine Corps ___ Yrs ___ Months

17. MOS ____

18. Length of time in MOS ___ Yrs ___ Months

USMC Musculoskeletal Health Questionnaire - Page 2

What is your smoking status?
- **Current smoker**
- **Former smoker**
- **Never smoked**

20. Do you now smoke cigarettes
- O **Every day**
- O **Some days**
- O **Not at all**

21. On the average, about how many cigarettes a day do you now smoke?

Enter # of cigarettes.
Enter 00 if not current smoke

2. How often do you do at least 20 minutes of non-stop aerobic activity (vigorous exercise that greatly creases your breathing and heart rate such as running, fast working, biking, swimming, rowing, etc...)?

O **Rarely/never** O **1 or 2 times per week** O **3 or more times per week**

3. How often do you feel that your present work situation is putting you under too much stress?

O **Never** O **Seldom** O **Sometimes** O **Often**

4. In the past year, how often have worries interfered with your daily life?

O **Never** O **Seldom** O **Sometimes** O **Often**

5. How often are there people available that you can turn to for support in bad moments or illness?

O **Never** O **Seldom** O **Sometimes** O **Often**

6. How would you describe the physical effort required of your current job on a *typical* day?

O 0	O .5	O 1	O 2	O 3	O 4	O 5	O 6	O 7	O 8	O 9	O 1
Nothing at all	**Very, very easy**	**Very easy**	**Easy**	**Moderately hard**	**Some -what hard**	**Hard**			**Very hard**		**Very very hard**

Section B: Family/Home Environment

Indicate whether the following statements of *True or False* in reference to your family/home environment

31. We fight a lot in our family. -- O True O False

32. Family members rarely become openly angry.------------------------------------ O True O False

34. Family members sometimes get so angry they throw things. -------------------- O True O False

33. Family members hardly ever lose their tempers. -------------------------------- O True O False

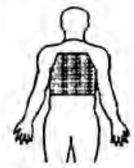
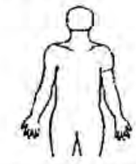
34. Family members often criticize each other.--------------------------------------- O True O False

35. If there's a disagreement in our family, we try hard to smooth things over and keep the peace. ------- O True O False

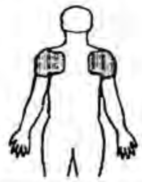
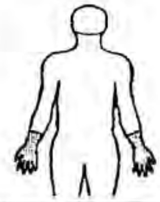
B6. Family members often try to one-up or out-do each other.------------------------ O True O False

B7. In our family, we believe you don't ever get anywhere by raising your voice.-------- O True O False

ection C: Health - Symptoms / Function

	Lower Back (incl. buttocks)	Upper Back	Neck
Do you experience physical ems with any of the following s of your body? *ach area that you answer "Yes," e complete the column below that If you answer "No" for that area, do omplete the column for that body but go on to the next column.*	O Yes O No 	O Yes O No 	O Yes O No 
When did you first notice the blem?	O Within past 12 mos. O 13 to 24 mos. ago O 25 to 36 mos. ago O more than 36 mos. ago	O Within past 12 mos. O 13 to 24 mos. ago O 25 to 36 mos. ago O more than 36 mos. ago	O Within past 12 mos. O 13 to 24 mos. ago O 25 to 36 mos. ago O more than 36 mos. ago
How often have you experienced problem?	O Almost always (Daily) O Frequently (1X / wk) O Sometimes (1X / mo.) O Rarely (every 2-3 mos) O Almost never (ea. 6 mo.)	O Almost always (Daily) O Frequently (1X / wk) O Sometimes (1X / mo.) O Rarely (every 2-3 mos) O Almost never (ea. 6 mo.)	O Almost always (Daily) O Frequently (1X / wk) O Sometimes (1X / mo.) O Rarely (every 2-3 mos) O Almost never (ea. 6 mo
On average, how long has each isode lasted?	O Less than 1 hr O 1 hr to 1 day O 1 day to 1 wk O 1 wk to 1 month O 1 to 3 months O More than 3 mos.	O Less than 1 hr O 1 hr to 1 day O 1 day to 1 wk O 1 wk to 1 month O 1 to 3 months O More than 3 mos.	O Less than 1 hr O 1 hr to 1 day O 1 day to 1 wk O 1 wk to 1 month O 1 to 3 months O More than 3 mos.
5. On average, how bad has this oblem been over the past year?	O No discomfort O Mild O Moderate O Severe O Unbearable	O No discomfort O Mild O Moderate O Severe O Unbearable	O No discomfort O Mild O Moderate O Severe O Unbearable
6. What symptoms do you have ith this problem? mark all that apply)	O Pain O Burning O Ache O Other O Stiffness	O Pain O Burning O Ache O Other O Stiffness	O Pain O Burning O Ache O Other O Stiffness
7. How much work did you miss i.e., "no duty or "quarters") in the past 12 months due to this problem?	O No periods of "No Duty" O 1 to 10 days O 11 to 30 days O 31+ days	O No periods of "No Duty" O 1 to 10 days O 11 to 30 days O 31+ days	O No periods of "No Duty" O 1 to 10 days O 11 to 30 days O 31+ days
C8. How much "limited duty" or 'profile" have you been assigned in the past 12 months due to this problem?	O No "Limited Duty" O 1 to 10 days O 11 to 30 days O 31+ days	O No "Limited Duty" O 1 to 10 days O 11 to 30 days O 31+ days	O No "Limited Duty" O 1 to 10 days O 11 to 30 days O 31+ days
C9. What do you think caused the problem? (Fill in your best guess)	O Work tasks O Phys fitness training O Off-duty activities O Traffic accident O Other______	O Work tasks O Phys fitness training O Off-duty activities O Traffic accident O Other______	O Work tasks O Phys fitness training O Off-duty activities O Traffic accident O Other______

USMC Musculoskeletal Health Questionnaire - Page 4

	Shoulder	Elbows/Forearms	Wrists/Hands
:Do you experience physical blems with any of the following s of your body? *ach area that you answer "Yes," se complete the column below that . If you answer "No" for that area, do omplete the column for that body , but go on to the next column.*	O Yes O No 	O Yes O No 	O Yes O No 
. When did you first notice the oblem?	O Within past 12 mos. O 13 to 24 mos. ago O 25 to 36 mos. ago O more than 36 mos. ago	O Within past 12 mos. O 13 to 24 mos. ago O 25 to 36 mos. ago O more than 36 mos. ago	O Within past 12 mos. O 13 to 24 mos. ago O 25 to 36 mos. ago O more than 36 mos. ago
How often have you experienced problem?	O Almost always (Daily) O Frequently (1X / wk) O Sometimes (1X / mo.) O Rarely (every 2-3 mos) O Almost never (ea. 6 mo.)	O Almost always (Daily) O Frequently (1X / wk) O Sometimes (1X / mo.) O Rarely (every 2-3 mos) O Almost never (ea. 6 mo.)	O Almost always (Daily) O Frequently (1X / wk) O Sometimes (1X / mo.) O Rarely (every 2-3 mos) O Almost never (ea. 6 mo.)
. On average, how long has each isode lasted?	O Less than 1 hr O 1 hr to 1 day O 1 day to 1 wk O 1 wk to 1 month O 1 to 3 months O More than 3 mos.	O Less than 1 hr O 1 hr to 1 day O 1 day to 1 wk O 1 wk to 1 month O 1 to 3 months O More than 3 mos.	O Less than 1 hr O 1 hr to 1 day O 1 day to 1 wk O 1 wk to 1 month O 1 to 3 months O More than 3 mos.
5. On average, how bad has this roblem been over the past year?	O No discomfort O Mild O Moderate O Severe O Unbearable	O No discomfort O Mild O Moderate O Severe O Unbearable	O No discomfort O Mild O Moderate O Severe O Unbearable
6. What symptoms do you have ith this problem? ark all that apply)	O Pain O Burning O Ache O Other O Stiffness	O Pain O Burning O Ache O Other O Stiffness	O Pain O Burning O Ache O Other O Stiffness
7. How much work did you miss e., "no duty or "quarters") in the ast 12 months due to this problem?	O No periods of "No Duty" O 1 to 10 days O 11 to 30 days O 31+ days	O No periods of "No Duty" O 1 to 10 days O 11 to 30 days O 31+ days	O No periods of "No Duty" O 1 to 10 days O 11 to 30 days O 31+ days
8. How much "limited duty" or profile" have you been assigned in he past 12 months due to this roblem?	O No "Limited Duty" O 1 to 10 days O 11 to 30 days O 31+ days	O No "Limited Duty" O 1 to 10 days O 11 to 30 days O 31+ days	O No "Limited Duty" O 1 to 10 days O 11 to 30 days O 31+ days
9. What do you think caused he problem? Fill in your best guess)	O Work tasks O Phys fitness training O Off-duty activities O Traffic accident O Other_____	O Work tasks O Phys fitness training O Off-duty activities O Traffic accident O Other_____	O Work tasks O Phys fitness training O Off-duty activities O Traffic accident O Other_____

10. On a scale from 0 to 10, how much pain in your back or hand/wrist/elbow/arm or neck/shoulder ave you had *over the past week* (7 days)?

lo Pain) ○ **0** ○ **1** ○ **2** ○ **3** ○ **4** ○ **5** ○ **6** ○ **7** ○ **8** ○ **9** ○ **10** (Worst Pain Possible)

11. Have you visited a medical treatment facility (MTF) / clinic or battalion station in the **ast 12 months** for:

a) a back problem? ○ **Yes** ○ **No**

b) neck / shoulder problem? ○ **Yes** ○ **No**

c) hand / wrist / arm / elbow problem? ○ **Yes** ○ **No**

2. In general, would you say your health is: ○ **Excellent** ○ **Very good** ○ **Good** ○ **Fair** ○ **Poor**

3. The following questions are about activities you might do during a typical day. **Does your health w limit you** in these activities? If so, how much?

	Yes, Limited A Lot	Yes, Limited A Little	No, Not Limited At All
Moderate activities, such as moving a table, pushing a acuum cleaner, bowling, or playing golf.	○	○	○
Climbing **several** flights of stairs.	○	○	○

4. During the past 4 weeks, have you had any of the following problems with your work or other regular ily activities as a result of your physical health?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a) **Accomplished less** than you would like.	○	○	○	○	○
b) Were limited in the **kind** or work or other activities.	○	○	○	○	○

5. During the **past 4 weeks**, have you had any of the following problems with your work or other regular ily activities as a result of any emotional problems (such as feeling depressed or anxious)?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a). **Accomplished less** than you would like.	○	○	○	○	○
b) Did work or other activities **less carefully than usual.**	○	○	○	○	○

6. During the past **4 weeks**, how much did pain interfere with your normal work (including both work side the home and housework)?

○ **Not at all** ○ **A little bit** ○ **Moderately** ○ **Quite a bit** ○ **Extremely**

7. These questions are about how you feel and how things have been with you during the **past 4 eks**. For each question, please give the one answer that comes closest to the way you have been ling. How much of the time during the **past 4 weeks...**

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a) Have you felt calm and peaceful?	○	○	○	○	○
b) Did you have a lot of energy?	○	○	○	○	○
c) Have you felt downhearted and depressed?	○	○	○	○	○

18. During the **past 4 weeks**, how much of the time has your physical health or emotional problems terfered with your social activities (like visiting with friends, relatives, etc.)?

All of the time	Most of the time	Some of the time	A little of the time	None of the time
○	○	○	○	○

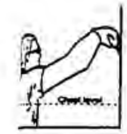
ection D: Ergonomic / Physical Demands

Please mark the degree to which you agree with the following statements about your job.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Doesn't apply / don't know
1. The job requires fairly little muscular strength.	○	○	○	○	○	○
2. The job requires fairly little lifting and/or the lifting is of very light weights.	○	○	○	○	○	○
3. The job requires fairly little muscular endurance.	○	○	○	○	○	○
4. The seating arrangements on the job are adequate.	○	○	○	○	○	○
5. The work place allows for all size differences between people in terms of clearance, reach, eye height, leg room and so forth.	○	○	○	○	○	○
6. The job allows the wrists to remain straight without excessive movements.	○	○	○	○	○	○
7. The work place is free from excessive noise.	○	○	○	○	○	○
8. The climate at the work place is comfortable in terms of temperature and humidity and it is free of excessive dust and fumes.	○	○	○	○	○	○

USMC Musculoskeletal Health Questionnaire - Page 7

structions: Indicate on average, how long you do this work on a daily (every day or weekly) asis.



igure A.

Figure B.

Figure C.

Figure D.

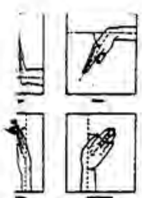


Figure E.

Figure F.

	Task	More than 4 hrs / day	2 - 4 hrs / day	Less than 2 hrs / day	Less than 5 hrs / week	Never
D9.	I work with my hands at or above chest level. (Figure A)	○	○	○	○	○
D10.	To get to or do my work, I must lay on my back or side and work with my arms up.	○	○	○	○	○
D11.	I must hold or carry materials (or large stacks of files) during the course of my work.	○	○	○	○	○
D12.	I force or yank components of work objects in order to complete a task.	○	○	○	○	○
D13.	I reach/hold my arms in front of or behind my body (e.g., using keyboard, filing, handling parts, perform inspection tasks, pushing/pulling carts, etc). (Figure B)	○	○	○	○	○
D14.	My neck is tipped forward or backward when I work. (Figure C)	○	○	○	○	○
D15.	I cradle a phone or other device between my neck and shoulder. (Figure D)	○	○	○	○	○
D16.	My wrists are bent (up, down, to the thumb, or little finger side) while I work. (Figure E)	○	○	○	○	○
D17.	I apply pressure or hold an item/material/tool (e.g., screwdriver, spray gun, mouse, etc. in my hand for longer than 10 seconds at a time).	○	○	○	○	○
D18.	My work requires me to use my hands in a way that is similar to wringing out clothes. (Figure F).	○	○	○	○	○
D19.	I perform a series of repetitive tasks/movements during the normal course of my work (e.g. using keyboard, tightening fasteners, cutting meat, etc).	○	○	○	○	○
D20.	The work surface (e.g., desk, bench, etc.) or tool(s) that I use presses into my palm(s), wrist(s), or against the sides of my fingers leaving red marks on or beneath the skin.	○	○	○	○	○
D21.	I use my hand/palm like a hammer to do aspects of my work.	○	○	○	○	○
D22.	My hands and fingers are cold when I work.	○	○	○	○	○
D23.	I work at a fast pace to keep up with machine production quota or performance incentive.	○	○	○	○	○
D24.	The tool(s) that I use vibrates and/or jerks my hand(s)/arm(s).	○	○	○	○	○
D25.	My work requires that I repeatedly throw or toss items.	○	○	○	○	○
D26.	My work requires me to twist my forearms, such as turning a screwdriver.	○	○	○	○	○

USMC Musculoskeletal Health Questionnaire - Page 8

structions: Indicate on average, how long you do this work on a daily (every day or weekly) sis.

Task		More than 4 hrs / day	2-4 hrs / day	Less than 2 hrs / day	Less than 5 hrs / week	Never
D27.	I wear gloves that are bulky, or reduce my ability to grip.	O	O	O	O	O
D28.	I squeeze or pinch work objects with a force similar to that which is required to open a lid on a new jar.	O	O	O	O	O
D29.	I grip work objects or tools as if I am gripping tightly onto a pencil.	O	O	O	O	O
D30.	When I lift, move components, or do other aspects of my work, my hands are lower than my knees. (Figure G)	O	O	O	O	O
D31.	I lean forward continually when I work (e.g., when sitting, when standing, when pushing carts, etc).	O	O	O	O	O
D32.	The personal protective equipment or clothing that I wear limits or restricts my movement.	O	O	O	O	O
D33.	I repeatedly bend my back (e.g., forward, backward, to the side, or twist) in the course of my work.	O	O	O	O	O
D34.	When I lift, my body is twisted and/or I lift quickly. (Figure H)	O	O	O	O	O
D35.	I can feel vibration through the surface that I stand on, or through my seat.	O	O	O	O	O
D36.	I lift and/or carry items with one hand (Figure I)	O	O	O	O	O
D37.	I lift or handle bulky items.	O	O	O	O	O
D38.	I lift materials that weigh more than 25 pounds.	O	O	O	O	O
D39.	My work requires that I kneel or squat. (Figure J)	O	O	O	O	O
D40.	I must constantly move or apply pressure with one or both feet (e.g. using foot pedals, driving, etc).	O	O	O	O	O
D41.	When I'm sitting, I cannot rest both feet flat on the floor. (Figure K)	O	O	O	O	O
D42.	I stand on hard surfaces.	O	O	O	O	O
D43.	I can see glare on my computer screen or work surface.	O	O	O	O	O
D44.	It is difficult to hear a person on the phone or to concentrate because of other activity, voices, or noise in/near my work area.	O	O	O	O	O
D45.	I must look at the monitor screen constantly so that I do not miss important information (e.g. radar scope).	O	O	O	O	O
D46.	It is difficult to see what I am working with (monitor, paper, parts, etc).	O	O	O	O	

Figure G.

Figure H.

Figure I.

Figure J.

Figure K

USMC Musculoskeletal Health Questionnaire - Page 9

Section E: Work Organization

Instructions: Using the scales below, please answer the following questions about your work situation.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
E1. In my group, people cannot afford to relax.	○	○	○	○	○
E2. In our group, there is constant pressure to keep working.	○	○	○	○	○
E3. In my group, there is a sense of urgency about everything.	○	○	○	○	○
E4. There is adequate time for work breaks given the demands of the job.	○	○	○	○	○
E5. The job does not require shift work or excessive overtime.	○	○	○	○	○
E6. My job requires that I learn new things.	○	○	○	○	○
E7. My job involves a lot of repetitive work.	○	○	○	○	○
E8. My job requires me to be creative.	○	○	○	○	○
E9. My job requires a high level of skill.	○	○	○	○	○
E10. I get to do a variety of different things on my job.	○	○	○	○	○
E11. I have an opportunity to develop my own special abilities.	○	○	○	○	○
E12. My job allows me to make a lot of decisions on my own.	○	○	○	○	○
E13. On my job, I have very little freedom to decide how I do my work.	○	○	○	○	○
E14. I have a lot of say about what happens on my job.	○	○	○	○	○

E15. To what extent does your job require you to work closely with other people?

Very little ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 Very much

E16. To what extent do supervisors or co-workers let you know how well you are doing on your job?

Very little ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 Very much

How accurate are the following statements in describing your job?

E17. The job requires a lot of cooperative work with other people.

Very Inaccurate ○1 ○2 ○3 ○4 ○5 ○6 ○7 Very accurate

E18. The job can be done adequately by a person working alone - without talking or checking with other people.

Very Inaccurate ○1 ○2 ○3 ○4 ○5 ○6 ○7 Very accurate

E19. The supervisors and co-workers on this job almost never give me any "feedback" about how well I am doing in my work.

Very Inaccurate ○1 ○2 ○3 ○4 ○5 ○6 ○7 Very accurate

E20. Supervisors often let me know how well they think I am performing on the job.

Very Inaccurate ○1 ○2 ○3 ○4 ○5 ○6 ○7 Very accurate

How much do your agree with the following statements about your job?

E21. It's hard, on this job, for me to care very much about whether or not the work gets done right.

Disagree Strongly ○1 ○2 ○3 ○4 ○5 ○6 ○7 Agree Strongly

E22. I feel a very high degree of personal responsibility for the work I do on this job.

Disagree Strongly ○1 ○2 ○3 ○4 ○5 ○6 ○7 Agree Strongly

E23. I feel I should personally take credit or blame for the results of my work on this job.

Disagree Strongly ○1 ○2 ○3 ○4 ○5 ○6 ○7 Agree Strongly

E24. Whether or not this job gets done right is clearly my responsibility.

Disagree Strongly ○1 ○2 ○3 ○4 ○5 ○6 ○7 Agree Strongly

E25. Most people on this job feel a great deal of personal responsibility for the work they do.

Disagree Strongly ○1 ○2 ○3 ○4 ○5 ○6 ○7 Agree Strongly

E26. Most people on this job feel that whether or not the job gets done right is clearly their own responsibility.

Disagree Strongly ○1 ○2 ○3 ○4 ○5 ○6 ○7 Agree Strongly

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
E27. I can easily see or hear the information I have to use in my job.	○	○	○	○	○
E28. The information I have to look at or listen to is presented too rapidly.	○	○	○	○	○
E29. The infomation I receive is organized for me in ways that seem natural and easy to deal with.	○	○	○	○	○
E30. My job requires me to make many decisions.	○	○	○	○	○
E31. To do my job well, I have to be able to do a lot of things mentally at the same time.	○	○	○	○	○
E32. My job requires me to remember a great deal of information for brief periods of time.	○	○	○	○	○
E33. I can perform the activities associated with my job without thinking about them.	○	○	○	○	○
E34. My job requires me to think about too many things.	○	○	○	○	○
E35. My job often requires me to learn new procedures.	○	○	○	○	○
E36. Most of the decisions I make are routine and easy to make.	○	○	○	○	○
E37. In my job, there are set rules that I follow over and over again.	○	○	○	○	○
E38. I often feel mentally over-burdened on my job.	○	○	○	○	○
E39. My job requires me to remember many different things.	○	○	○	○	○

	Very Little	A Little	Some	A Lot	A Great Deal
E40. How much do you take part with others in making decisions that affect you?	○	○	○	○	○
E41. How much do you participate with others in helping set the way things are done on your job?	○	○	○	○	○
E42. How much do you decide with others what part of a task you will do?	○	○	○	○	○

USMC Musculoskeletal Health Questionnaire - Page 12

	Somewhat Uncertain	A Little Uncertain	Somewhat Certain	Fairly Certain	Very Certain
E43. How certain are you about what your future career picture looks like?	○	○	○	○	○
E44. How certain are you of the opportunities for promotion and advancement which will exist in the next few years?	○	○	○	○	○
E45. How certain are you about whether your job skills will be of use and value five years from now?	○	○	○	○	○
E46. How certain are you about what your responsibilities will be six months from now?	○	○	○	○	○
E47. If you lost your job, how certain are you that you could support yourself?	○	○	○	○	○
E48. How likely is it that in the next few years your job will be replaced by computers or machines?	○	○	○	○	○

E49. Considering everything, how would you rate your overall satisfaction with your job?

○ Very dissatisfied ○ Dissatisfied ○ Neutral ○ Satisfied ○ Very Satisfied

---

F.

Please rate the extent to which you agree with the following statements regarding your **back** or **upper extremity (hand/wrist/elbow/arm/shoulder/neck)** pain problem.

1. I think I am always going to have a back or upper extremity problem.

(Completely disagree) ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 (Completely agree)

2. I now have to be careful how I do things because of my back or upper extremity problem.

(Completely disagree) ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 (Completely agree)

3. I am not going to take any chances with my back or upper extremities.

(Completely disagree) ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 (Completely agree)

4. Having back or upper extremity pain greatly affects my ability to work and forces me to take time off from work.

(Completely disagree) ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 (Completely agree)

USMC Musculoskeletal Health Questionnaire - Page 13

Section G: SPSI - R

Below are a series of statements that describe how some people might think, feel, and act when faced with important problems in everyday living. We are not talking about the ordinary hassles and pressures that you deal with successfully everyday. In this section, a problem is something important in your life that bothers you a lot but you don't immediately know how to make it better or stop it from bothering you so much. **Read each statement carefully and select one of the choices below that indicates how true the statement is of you.** Consider yourself as you typically think, feel, and act when you are faced with important problems these days. Mark your choice in the bubbles to the right of each question.

	Not at all true of me	Slightly true of me	Moderately true of me	Very true of me	Extremely true of me
I wait to see if a problem will resolve itself first, before trying to solve it myself.	○	○	○	○	○
When a problem occurs in my life, I put off trying to solve it for as long as possible.	○	○	○	○	○
I go out of my way to avoid having to deal with problems in my life.	○	○	○	○	○
I prefer to avoid thinking about the problems in my life instead of trying to solve them.	○	○	○	○	○
I put off solving problems until it is too late to do anything about them.	○	○	○	○	○
I spend more time avoiding my problems than solving them.	○	○	○	○	○
When I am faced with a difficult problem, I go to someone else for help in solving it.	○	○	○	○	○

Thank you for completing this questionnaire. Your participation was very important to this research study.

APPENDIX C

UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES
4301 JONES BRIDGE ROAD
BETHESDA, MARYLAND 20814-4799

November 8, 2000

MEMORANDUM FOR GRANT HUANG, M.S., M.P.H., DEPARTMENT OF MEDICAL AND CLINICAL PSYCHOLOGY

SUBJECT: IRB Approval for Protocol **T072DN-02** Involving Human Subject Use

The protocol entitled ***"The Impact of Work Organization and Ergonomic Factors on Musculoskeletal Disorders in the U.S. Marine Corps"*** received an expedited review and was **APPROVED** by Edmund G. Howe, M.D., J.D., Chairperson, Institutional Review Board on 11/8/2000. This protocol is considered to be not greater than minimal risk in accordance with 32 CFR 219.110 (b)(1) Suppl. 7, and this approval will be reported to the full IRB scheduled to meet on 14 December 2000. *Please note that while this approval letter allows you to begin your study, the IRB can, at its next meeting, decide to hold the study in abeyance if it feels that additional information is required.*

The purpose of this study is to examine musculoskeletal symptoms and work. Subjects who have a self-report of back or upper extremity symptoms will complete a questionnaire which addresses demographic, workplace demand, and symptom data. The IRB understands that all subject identifying information will be coded using a personal study identification number and that only you and your research team will be able to link the study IDs to subject names. The IRB further understands that after data from study questionnaires is entered into the study database, the hard copy of the questionnaires containing personal identifying information will be destroyed.

The consent form approved for use is attached. **Photocopies of this stamped and dated consent form should be used to obtain consent from all enrolled subjects.** ***The original stamped and dated consent form should be maintained in your files.*** It is your responsibility to review and maintain an accurate and accessible file of all consent forms used in this study for each study site. This research study will be reviewed within one year of this date, unless otherwise completed.

Please notify this office of any amendments you wish to propose and of any adverse events that occur in the conduct of this project. If you have any questions regarding human volunteers, please call me at 301-295-3303.

Richard R. Levine, Ph.D.
LTC, MS, USA
Director, Research Programs and
Executive Secretary, IRB

cc: Director, Research Administration

DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
WASHINGTON, D.C. 20380-0001

IN REPLY REFER TO:

5100
SD
21 NOV 2000

MEMORANDUM FOR COMMANDING OFFICERS AND SAFETY MANAGERS

SUBJECT: SUPPORT FOR MUSCULOSKELETAL ILLNESS/INJURY RESEARCH

1. This letter is intended to express the full support of the Safety Division, Headquarters, United States Marine Corps for research proposed by Mr. Grant D. Huang, Senior Graduate Fellow at the Uniformed Services University of the Health Sciences, Bethesda, Maryland. I request your support and assistance in Mr.Huang's research effort.

2. The research study is intended to identify risk factors for musculoskeletal injuries and illnesses and improve musculoskeletal health among our Marines. Information obtained from this project also supports safety and injury prevention goals set forth by the Assistant Commandant of the Marine Corps.

3. Based on preliminary data obtained by Mr. Huang, musculoskeletal disorders are the chief sources of outpatient clinic visits, duty limitations, and lost work days in the Marine Corps. Integral to the design of Mr. Huang's research is his desire to provide practical prevention recommendations for reducing individual and organizational injury burdens associated with selected military occupations. By reducing occupational illnesses and injuries, unit readiness and mission success are enhanced.

4. Please direct further questions to Ms. Freya Arroyo at (703) 614-1202 , e-mail ArroyoFM@hqmc.usmc.mil or to Mr. Huang at (301) 295-9660, e-mail at ghuang@usuhs.mil.

LEIF R. LARSEN
Col USMC

UNITED STATES MARINE CORPS
HEADQUARTERS BATTALION
HEADQUARTERS, U.S. MARINE CORPS
HENDERSON HALL
1555 S. SOUTHGATE RD.
ARLINGTON, VIRGINIA 22214-5000

IN REPLY REFER
5000
Adj
28 Nov

MEMORANDUM FOR DEPUTY COMMANDANTS AND DIRECTORS

Subj: SUPPORT FOR MUSCULOSKELETAL ILLNESS/INJURY RESEARCH

1. This letter is intended to express the full support of Headquarters Battalion, Henderson Hall, Headquarters U. S. Marine Corps, for research proposed by Mr. Grant D. Huang, Senior Graduate Fellow at the Uniform Services University of the Health Sciences, Bethesda, Maryland. I request your support and assistance in Mr. Huang's research effort.

2. The research study is intended to identify garrison risk factors for musculoskeletal injuries and illnesses and improve musculoskeletal health among our Marines. Information obtained from this project also supports safety and injury prevention goals set forth by the Assistant Commandant of the Marine Corps.

3. Based on preliminary data obtained by Mr. Huang, musculoskeletal disorders are the chief sources of outpatient clinic visits, duty limitations, and lost workdays in the Marine Corps. Integral to the design of Mr. Huang's research is his desire to provide practical prevention recommendations for reducing individual and organizational injury burdens associated with selected military occupations. By reducing occupational illnesses and injuries, unit readiness and mission success are enhanced.

4. Please direct further questions to Master Sergeant Barber at (703) 614-2171.

Nancy P. Anderson
NANCY P. ANDERSON
Col USMC
Commanding Officer

DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
3280 RUSSELL ROAD
QUANTICO, VIRGINIA 22134-5103

IN REPLY REFER TO:
5000
M&RA
12 Dec 00

MEMORANDUM FOR MANPOWER AND RESERVE AFFAIRS DEPARTMENT

Subj: SUPPORT FOR MUSCULOSKELETAL ILLNESS/INJURY RESEARCH

1. This letter is intended to express the full support of the Manpower and Reserve Affairs Deparment, Headquarters, U.S. Marine Corps for research proposed by Mr. Grant D. Haung, Senior Graduate Fellow at the Uniformed Services University of the Health Sciences, Bethesda, Maryland. I request your support and assistance in Mr. Huang's research effort.

2. The research study is intended to identify risk factors for musculoskeletal injuries and illnesses and improve musculoskeletal health among our Marines. Information obtained from this project also supports safety and injury preventions goals set forth by the Assistant Commandant of the Marine Corps.

3. Based on preliminary data obtained by Mr. Haung, musculoskeletal disorders are the chief sources of outpatient clinic visits, duty limitations, and lost work days in the Marine Corps. Integral to the design of Mr. Haung's research is his desire to provide practical prevention recommendations for reducing individual and organizational injury burdens associated with selected military occupations. By reducing occupational illnesses and injuries, unit readiness and mission success are enhanced.

4. Please direct further questions to SgtMaj Ouellette at (703) 784-9012, email ouelletteml@manpower.usmc.mil.

J. W. KLIMP

UNITED STATES MARINE CORPS
1st Marine Regiment
1st Marine Division
Box 555402
Camp Pendleton California 92055-5402

5000
FRS
DEC 00

MEMORANDUM

Subj : SUPPORT FOR MUSCULOSKELETAL ILLNESS / INJURY RESEARCH

1. This letter is intended to express the full support of the Regimental Aid Station, 1st Marine Regiment, for research proposed by Mr. Grant D. Huang, Senior Graduate Fellow at the Uniform Services University of the Health Sciences, Bethesda, Maryland. I request your support and assistance in Mr. Huang's research effort.

2. The research study is intended to identify garrison risk factors for musculoskeletal injuries and illnesses and improve musculoskeletal health among our Marines. Information obtained from this project also supports safety and injury prevention goals set forth by the Assistant Commandant of the Marine Corps.

3. Based on preliminary data obtained by Mr. Huang, musculoskeletal disorders are the chief sources of outpatient clinic visits, duty limitations, and lost workdays in the Marine Corps. Integral to the design of Mr. Huang's research is his desire to provide practical prevention recommendations for reducing individual and organizational injury burdens associated with selected military occupations. By reducing occupational illnesses and injuries, unit readiness and mission success are enhanced.

4. Please direct further questions to Lieutenant Commander Sylvia (760) 725-7793 / 7410.

F. R. SYLVIA