

# Occupational Stress and Work-Related Upper Extremity Disorders: Concepts and Models

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**Background** While research has suggested that interventions targeted at occupational stress (job stress) factors may improve clinical and work outcomes related to work-related musculoskeletal disorders, the emerging hypotheses relating occupational stress to work-related upper extremity disorders (WRUEDs) are not particularly well known among occupational health providers and researchers.

**Methods** Generic job stress and health models and multivariable models of WRUEDs were described and evaluated.

**Results** Models on occupational stress and health/WRUEDs offer unique perspectives on the role of occupational stressors on WRUEDs. However, the limited support for the structure and proposed mechanisms of these models suggest that investigations examining and validating proposed biobehavioral pathways are still needed.

**Discussion** Difficulties in conceptualizing occupational stress have, in the past, hindered its systematic incorporation into occupational health research and prevention/intervention strategies. The present paper provides a common basis for researchers and practitioners with diverse backgrounds to understand job stress and its relation to WRUEDs in order to enhance future efforts. Given the present limitations in the field and the need for comprehensive approaches to WRUEDs, there is great potential for occupational health researchers and clinicians to advance knowledge in this area. *Am. J. Ind. Med.* 41:298–314, 2002. © 2002 Wiley-Liss, Inc.

**KEY WORDS:** occupational stress; psychosocial factors; work-related upper extremity disorders; models; work organization

## INTRODUCTION

Occupational health research and practice is focused on the identification, management, and prevention of chemical, biological, physical, and psychological risk factors associated with a number of workplace health and safety problems. While the concept of occupational stress (job stress) and its links with disease has been hypothesized and examined for years [e.g., Rosenman et al., 1964; Syme et al., 1964; Kagan and Levi, 1971; Cooper and Payne, 1978; Fletcher, 1988], there has not been an extensive incorporation of occupational stress factors into research and clinical practice. The lack of emphasis on job stress may be attributed, in part, to difficulties in precisely conceptualizing and measuring the construct and delineating the mechanisms by which it impacts work and health outcomes. Nevertheless,

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data on the effects of individual and organizational interventions that target occupational stress [e.g., International Labour Office, 1992; Hurrell and Murphy, 1996; van der Hek and Plomp, 1997; Sauter et al., 1999] suggest that increased attention to stress in the workplace may lead to improved safety and health outcomes, including the reduction of work-related upper extremity disorders (WRUEDs).<sup>1</sup>

An increasing number of epidemiological investigations have indicated an association between job stress factors and WRUEDs. In a rigorous review, Bongers et al. [2002] (this issue) found that high job demands and higher levels of job stress were among workplace factors that were the most frequently identified as having a positive association with disorders of the upper extremities (i.e., wrist, forearm, elbow, arm, shoulder). Similarly, another review of the epidemiological literature conducted by the US National Institute for Occupational Safety and Health (NIOSH) [Bernard, 1997] indicated there is evidence that perceptions of intensified workload, monotonous work, and low social support all play a role in work-related upper extremity disorders. It was further concluded that, after physical demands are taken into account, psychosocial factors have an effect on such disorders either partially or completely independent of physical factors [Bernard, 1997]. The National Research Council [NRC, 2001] noted that, although the majority of studies were cross-sectional in nature, high perceived job stress and high job demands were factors more frequently found to be positively associated with symptoms and disorders in all upper extremity sites. In the NRC analysis of the literature, work-related exposures had risk ratios that ranged from 1.4 to 4.4 and attributable fractions suggesting that modifying occupational stress and high job demands could potentially reduce WRUED risks by 33–58%. Also, reports by the European Agency for Safety and Health at Work, a joint effort established in 1996 by the member nations of the European Union to “encourage improvements in the working environment,” have highlighted the need to address occupational psychosocial factors in epidemiological and intervention efforts for work-related low back and upper extremity disorders [Buckle and Devereux, 1999; DeBeeck and Hermans, 2000].

Considering the evidence linking occupational stress and WRUEDs, and the potential for acting on this knowledge to develop effective prevention and control methods, it is important that researchers and clinicians from diverse backgrounds possess a common understanding of the stress process. The goals of the present paper are to: (1) put forth a framework for understanding occupational stress and its sources; (2) to discuss various theoretical approaches to occupational stress; and (3) to examine the integration of job

stress factors in multivariable models of work-related upper extremity disorders. More specifically, this paper provides a conceptualization of occupational stress based on a review of the literature that utilized a NIOSH description of occupational factors as the basis for the search and describes and reviews models of job stress and WRUEDs. The discussion then concludes by identifying future directions for improving our understanding of the nature of job stress and its association with WRUEDs.

## **OCCUPATIONAL STRESS: CONCEPTS AND DEFINITIONS**

Occupational factors that give rise to stress can be quite diverse and have often been discussed in terms of “occupational psychosocial factors.” More recently, these factors have been expressed as “work organization factors” in reference to task- and/or organizational-level aspects of the work process that give rise to stress and potential adverse health outcomes. Work organization has been broadly described as “the way work processes are structured and managed” [NIOSH, 1996; Rosenstock, 1997; Amick et al., 1999]. Hagberg et al. [1995] define work organization as the manner work is organized, supervised, and carried out. Sauter et al. [1999] include management and supervisory practices, production practices, and their influence on the way tasks are performed in their definition of work organization. Although some investigators have defined occupational psychosocial factors in terms of subjectively experienced qualities of the organizational environment, in contrast to work organization factors which represent more concrete structural aspects of the work process [see Carayon and Smith, 2000], distinctions and definitions of this nature have not received widespread acceptance. Nevertheless, in noting the complexity of this area in general, some excellent recent reviews of job stress and its measurement [Hurrell et al., 1998; Kasl, 1998; Landsbergis and Theorell, 2000] have emphasized the need to make distinctions between the structural (objective) characteristics of work and those that are more subjective such as worker perceptions of such characteristics, particularly in efforts that involve the assessment of these factors.

In the US National Occupational Research Agenda (NORA) [NIOSH, 1996], work organization is discussed as comprised of six major components. These components are: scheduling (e.g., work-rest schedules, hours of work, shift work); job design (e.g., task complexity, required skill/effort, worker control); interpersonal (e.g., relationships with supervisors and coworkers); career concerns (e.g., job security, growth opportunities); management style (e.g., participatory management practices, teamwork); and organizational characteristics (e.g., climate, culture). These categories closely resemble stressors proposed in the early model by Cooper and Marshall [1976] on the dynamics of

<sup>1</sup> These disorders typically affect the muscle/tendons, nerves, or vasculature in the hand, wrist, arm, elbow, shoulder, and/or neck regions and include diagnoses such as carpal tunnel syndrome, tendinitis, and epicondylitis [Rempel et al., 1992; Pilgian et al., 2000].

work stress. In the Cooper and Marshall 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 defining 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 would provide a detailed listing of these variables that have been used to delineate the broad domain of work organization/job stress. 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 where 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.

Table I lists the work organization terms previously used by NIOSH [1996], the variables and constructs identified in the literature search, and the category in which these variables and constructs were placed. The results of this review illustrate the extent to which work organization factors have been investigated in occupational stress research, and serve to define in more specific terms for the occupational health community what is meant when the terms “job stressors” and “work organization factors” are used.

## MODELS OF OCCUPATIONAL STRESS AND HEALTH

As there is a need for the occupational health field to utilize more concrete terms (e.g., work organization, worker perceptions) when referring to job stressors, there is also a need to understand the theories and models that link such factors to occupational health. Early work by Cannon [1932], Selye [1956], Lazarus [1966], and Levi [1972], among others, have given rise to a number of general theories and models of job stress. These theories and models have various features in common. For example, they all posit that the stress process originates, at least in part, with exposure to environmental agents that are generally referred to as “stressors.” These stressors can trigger an acute response that typically includes a cascade of physiological and psychological changes. If these changes are persistent or recurrent, the onset of symptoms and subsequent illness may occur. However, current theories and models of job stress are also distinguished by major theoretical differences. For instance, “transactional” models of occupational stress [Cox, 1978; European Agency for Safety and Health at Work, 2000] focus less on environmental stressors in assessing risk, and more on the interaction of environmental stressors with worker attributes, coping style, and resources within the work environment. This approach derives from the Lazarus [1966] model of stress that emphasizes the role of individual cognitive and coping factors in determining the outcome of exposure to stressors in the environment. “Person-environment” fit models [French et al., 1982] and the more contemporary “effort-reward” theory [Siegrist, 1996] are examples of transactional models of occupational stress wherein the potential for stress and illness result from a mismatch between job requirements and the capacities, needs or expectations of individuals. In contrast to the transactional models of occupational stress, models such as the Karasek “control-demand” model of job stress [Karasek, 1979; Karasek and Theorell, 1990] give primary attention to the role of the occupational psychosocial environment. This model focuses on the role of psychological demands, decision latitude (control), and social support at work. Other theoretical approaches, such as that used by NIOSH build upon the Levi [1972] model of job stress [see Hurrell and McLaney, 1988]. While the NIOSH approach acknowledges the contribution of individual attributes such as coping styles, prior learning, and personality traits to the stress process, these factors are not viewed as primary determinants of stress risk but rather as moderators of occupational exposures.

As a preface to discussing how work organization and stress may influence risk of WRUEDs, three representative generic job stress models [Karasek, 1979; Hurrell and McLaney, 1988 [NIOSH]; Siegrist, 1998] are presented to more fully describe conceptual approaches to occupational stress and health in general. As will be seen, these models

**TABLE I.** Job Stress Items by NORA [NIOSH, 1996] Work Organization Categories

<b>NORA category</b>	<b>Scheduling</b>	<b>Job design</b>	<b>Interpersonal</b>	<b>Career concerns</b>	<b>Management style</b>	<b>Organizational characteristics</b>
NORA terms	<ul style="list-style-type: none"> <li>● Work-rest schedules</li> <li>● Hours</li> <li>● Shift work</li> </ul>	<ul style="list-style-type: none"> <li>● Complexity</li> <li>● Skill/effort</li> <li>● Control/decision latitude</li> </ul>	<ul style="list-style-type: none"> <li>● Relationships with supervisors/co-workers</li> </ul>	<ul style="list-style-type: none"> <li>● Job security</li> <li>● Growth opportunities</li> </ul>	<ul style="list-style-type: none"> <li>● Participatory management style</li> <li>● Teamwork</li> </ul>	<ul style="list-style-type: none"> <li>● Climate</li> <li>● Culture</li> <li>● Communications</li> </ul>
Literature search terms	<ul style="list-style-type: none"> <li>● Cycle</li> <li>● Flexibility</li> <li>● Piece work</li> <li>● Rest/breaks</li> </ul>	<ul style="list-style-type: none"> <li>● Activity</li> <li>● Autonomy</li> <li>● Constraints</li> <li>● Content/task</li> <li>● Cycle regulation</li> <li>● Demands/loads</li> <li>● Division of labor</li> <li>● Job strain</li> <li>● Job stress</li> <li>● Monotony</li> <li>● Nature</li> <li>● Pace</li> <li>● Policies/procedures/rules</li> <li>● Practices</li> <li>● Pressure</li> <li>● Process</li> <li>● Production standards</li> <li>● Role ambiguity</li> <li>● Role conflict</li> <li>● Rotation</li> <li>● Structure</li> <li>● Technology/mechanization/automation</li> <li>● Variation</li> <li>● Work distribution</li> </ul>	<ul style="list-style-type: none"> <li>● Conflict</li> <li>● Groups</li> <li>● Openness</li> <li>● Resources</li> <li>● Socialization</li> <li>● Support</li> <li>● Teams</li> <li>● Units</li> </ul>	<ul style="list-style-type: none"> <li>● Achievement</li> <li>● Advancement</li> <li>● Challenge</li> <li>● Change</li> <li>● Competence</li> <li>● Downsizing</li> <li>● Effectiveness</li> <li>● Engagement</li> <li>● Enrichment</li> <li>● Future</li> <li>● Performance</li> <li>● Rewards</li> <li>● Satisfaction</li> <li>● Skill level</li> <li>● Stage</li> <li>● Status</li> <li>● Stimulation</li> <li>● Training/education</li> <li>● Wages/salary</li> </ul>	<ul style="list-style-type: none"> <li>● Administration</li> <li>● Authority</li> <li>● Bureaucratization</li> <li>● Discrimination</li> <li>● Hierarchy</li> <li>● Institutionalization</li> <li>● Planning</li> <li>● Process</li> <li>● Skill</li> <li>● Subordination</li> <li>● Superior</li> <li>● Supervisory</li> <li>● Treatment</li> </ul>	<ul style="list-style-type: none"> <li>● Attitudes</li> <li>● Commitment</li> <li>● Confidence</li> <li>● Environment</li> <li>● Esteem</li> <li>● Goals</li> <li>● Identification</li> <li>● Morale</li> <li>● Size</li> <li>● Strategy</li> </ul>
Number of terms	7	33	9	23	15	13

acknowledge to varying degrees the contribution of both work organization factors and individual attributes to the stress process.

**Siegrist Model of Effort-Reward Imbalance at Work**

The model of effort-reward imbalance [Siegrist, 1998] centers around the assumption that the work role provides

individuals with opportunities to perform, make contributions, be rewarded or valued, and/or have a sense of belonging to a particular group (i.e., status control). In the context of the workplace, efforts are expended with the expectation that rewards such as status control, esteem, or financial rewards will be forthcoming. According to the model, when costs outweigh gains and an imbalance between efforts and rewards exists, a state of emotional distress arises and physiological strain reactions including

autonomic nervous system arousal may occur [Siegrist, 1996].

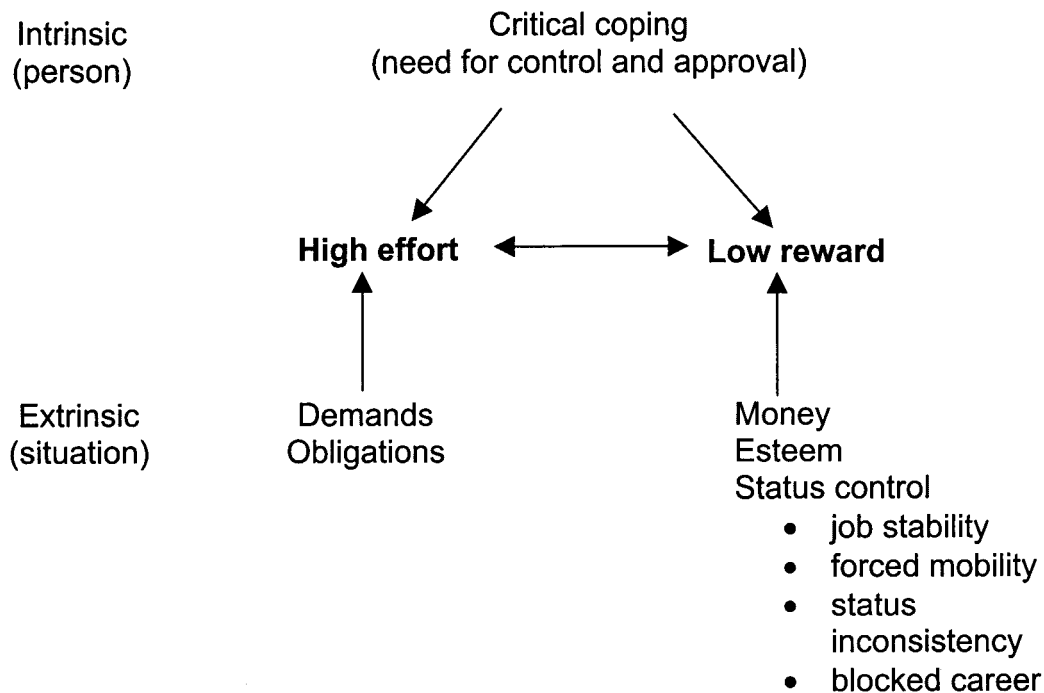
Siegrist [1998] describes two sources from which high efforts at work may come. One source is labeled “extrinsic” and involves the demands and obligations of the job. The other source is called “intrinsic” and comes from the motivations of an individual worker in a given work situation (see Fig. 1). This intrinsic source results from a pattern of coping termed “need for control” [Siegrist, 1998]. A coping style that is rooted in a need for control may result in expenditure of energy or immersion in work that exceeds the rewards that are obtained. While it may appear that maintaining such a coping style for extended periods of time would be difficult, Siegrist [1998] argues that possible costs from abandoning this approach (e.g., being laid off, downward mobility) may explain the sustained efforts on the part of the worker.

The concentration placed on individual coping patterns is the reason this model is considered as more of a “person-centered” or “transactional” than an “environment-centered” conceptualization of occupational stress. This model has been examined in etiologic studies where it has proven successful in predicting stress-related outcomes, including cardiovascular effects [e.g., Siegrist et al., 1997; Siegrist, 1998], and suggests that interventions targeting coping style, need for control, social skills, and/or beliefs/cognitions about rewards may reduce the experience of job stress. However, it has received far less investigation than either the Karasek model or more generic formulations resembling the

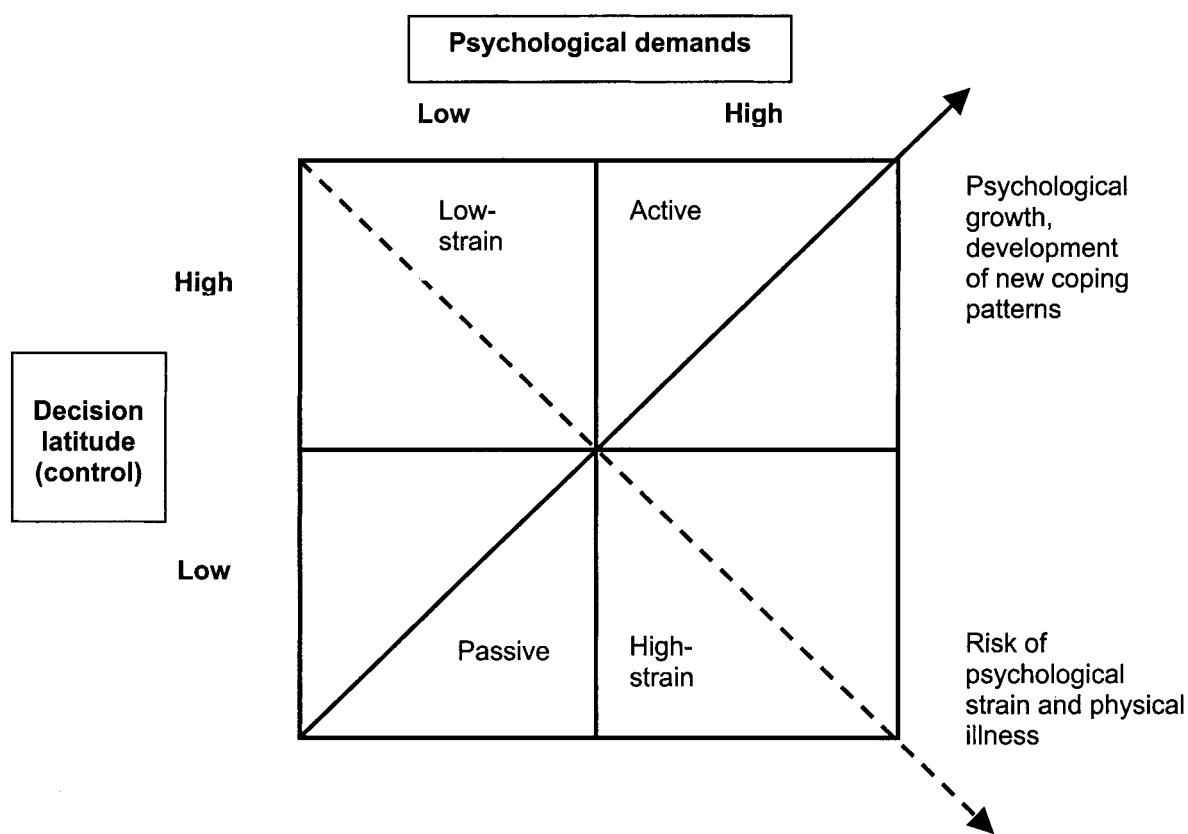
NIOSH stress model and has not yet been applied to the study of musculoskeletal-related outcomes. Additionally, the effort-reward imbalance model does not discuss how physical stressors play a role in health outcomes such as WRUEDs.

### Demand/Decision Latitude Model

The psychological demand/decision latitude model [Karasek, 1979] illustrated in Figure 2, also referred to as the “job strain” model, is perhaps the most widely recognized contemporary model of job stress and health. According to this model, the interaction between the levels of psychological demands and the worker’s level of decision latitude (i.e., control) defines the level of stress risk. From these two components, four types of exposures are possible: passive, active, low-strain, and high strain. 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, in the “active” situation, high levels of psychological demands coupled with high levels of control results in psychological growth and the development of new coping patterns. The “low-strain” situation involves the combination of low demands and high levels of decision latitude. In the fourth combination, a “high-strain” situation, workers experience high levels of psychological demands but low levels of control. It is hypothesized



**FIGURE 1.** Model of effort-reward imbalance at work [Siegrist, 1998]. From Theories of Occupational Stress. In: Cooper CL (2000). Reprinted by permission of Oxford University Press.



**FIGURE 2.** Psychological demand/decision latitude model [Karasek, 1979]. Reprinted from 'Job demands, job decision latitude, and mental strain: Implications for job redesign' by RA Karasek published in the *Administrative Science Quarterly*, Vol. 24, by permission of *Administrative Science Quarterly* © 1979 by Cornell University.

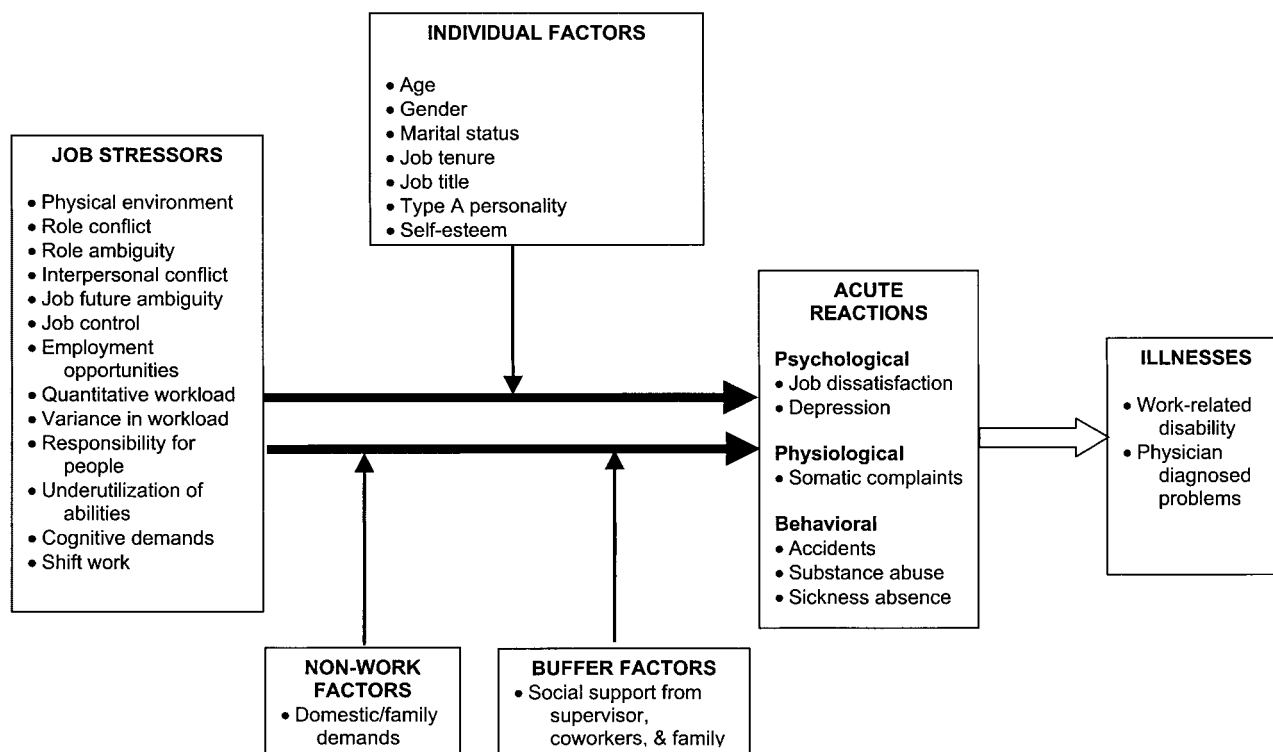
that this high-strain situation places the individual at the greatest risk for psychological strain and physical illness. Occupations that fall into this sector include telephone operators, garment stitchers, freight handlers, and assemblers (e.g., electronics manufacturing) [Karasek and Theorell, 1990].

The job strain model has been successful in predicting health outcomes in working populations. Studies have found, for example, that lower levels of decision latitude are associated with: myocardial infarction [Karasek et al., 1988; Theorell et al., 1998]; smoking [Cohen et al., 1991]; lower pain thresholds [Theorell et al., 1993], sleep disturbances [Theorell et al., 1988], and work-related upper extremity disorders [Bernard et al., 1994; Faucett and Rempel, 1994]. Furthermore, job strain (referring to the combination of high demands and low decision latitude) has been repeatedly associated with increased risk of cardiovascular disease [Schnall et al., 2000]. However, there is uncertainty about whether job demands and decision latitude combine additively or interactively to affect health. Additionally, 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. Karasek's

psychological demand and decision latitude measures (i.e., Job Content Questionnaire, [Karasek et al., 1998]) have been applied perhaps more than any other metric in studies to investigate the effects of stress on musculoskeletal outcomes. However, it is interesting to note that in the review by Bongers et al. [2002, this issue] decision latitude was associated with a greater number of studies with negative findings than positive findings in relation to WRUEDs.

### Model of Job Stress and Health

The NIOSH model of job stress and health (see Fig. 3), initially proposed by Hurrell and McLaney [1988], is similar to earlier formulations by Kagan and Levi [1971], Levi [1972], and Cooper and Marhsall [1976] and provides an overarching framework for understanding how adverse health outcomes may be tied to work-related factors. Based on evidence from the occupational stress literature, the model identifies multiple sources of stress in the work environment (physical environment, role conflict, role ambiguity, job control, interpersonal conflict, work load, responsibility for people, underutilization of abilities, cog-



**FIGURE 3.** Model of job stress and health [Hurrell and McLaney, 1988].

nitive demands, and shift work). Accordingly, this model is distinguished from the Siegrist [1998] and Karasek [1979] models which are more restrictive in their consideration of work-related stressors. Another unique aspect of this model is the recognition that exposure to physically threatening or hazardous situations can also be a source of stress to workers. As with other occupational stress models, it is proposed that exposure to work-related stressors contributes to acute psychological, physiological, and/or behavioral reactions, referred to as “strains.” These short-term reactions are believed to have the capacity to manifest themselves later as longer-term physical and/or psychological disorders or disability.

Individual factors such as personality and coping, as well as non-work factors (e.g., domestic/family demands) and “buffer” factors (e.g., work and non-work-related social support), are also integrated into the model as moderators of the relationship between job stressors and acute and chronic reactions. Therefore, like the Siegrist [1998] and other transactional models of occupational stress [e.g., French et al., 1982], the NIOSH model acknowledges the contribution of individual attributes to the stress process; however, like the Karasek [1979] model and consistent with the public health philosophy emphasizing primary prevention by protecting individuals from exposure to hazardous environments, the model gives primacy to the role of workplace factors in the etiology of job stress.

## MULTIVARIABLE MODELS OF WORK-RELATED MUSCULOSKELETAL SYMPTOMS/DISORDERS

While generic models of job stress are helpful in providing an overall conceptualization of how occupational psychosocial factors may influence health in general, such models were not intended to specifically delineate the relationship between occupational stress and WRUEDs. A review of various models that propose to address this relationship follows below. These formulations are examined in the context of a set of criteria that represent critical features of explanatory models. These criteria include the following:

1. Models must be testable. Pathways should be well specified such that proposed linkages can be evaluated empirically. The validity of the model should also be testable in relation to outcomes such as symptoms, function, health care utilization, productivity, and worker well-being.
2. The model should possess well-defined constructs of exposure(s) and response(s). Measures of constructs should have demonstrated reliability and validity. In the event that “off-the-shelf” measures of the constructs of interest are not available, the constructs

should be sufficiently detailed to facilitate efficient development and validation of new measures.

- Given results of studies of psychosocial factors and WRUEDs reported in the epidemiological literature thus far, the models should be multivariable in scope and consider both psychosocial and physical risk factors. These models should address the exposures, modifiers, and their potential interactions in a manner that is consistent with the empirical research [Bongers et al., 2002, issue; Bernard, 1997; National Research Council, 2001].

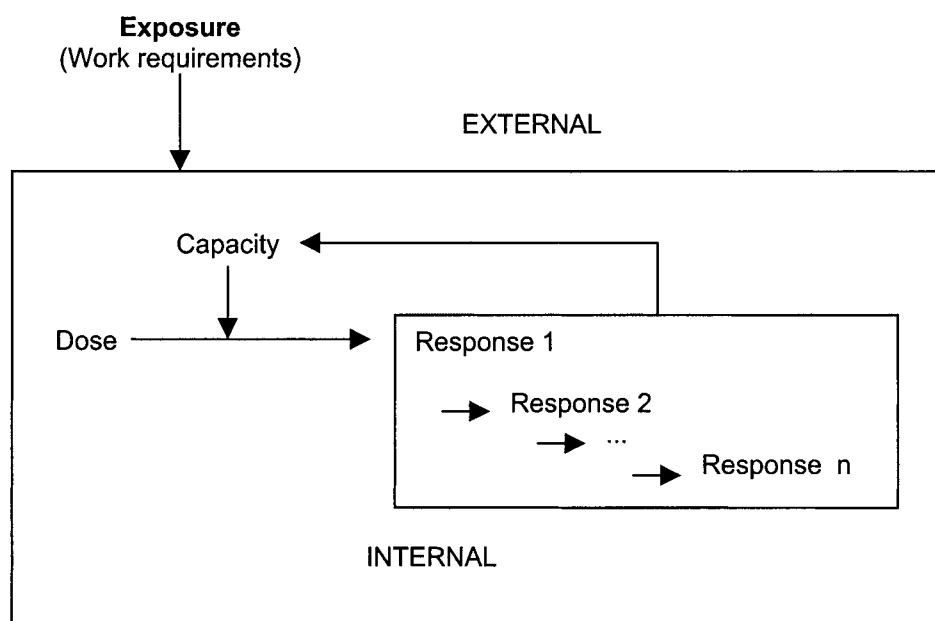
### Dose-Response Model for Work-Related Neck and Upper-Limb Musculoskeletal Disorders

A dose-response model developed by Armstrong et al. [1993] highlights the importance of mechanical and physiological factors in work-related musculoskeletal disorders. A schematic of this model is shown in Figure 4. In this model, external exposure to work requirements can result in an “internal dose” such as tissue loads and metabolic demands. Mechanical, physiological or psychological changes, called internal “disturbances,” are hypothesized to result from these internal doses. Such internal disturbances may involve tissue deformation or changes in cellular processes in the body. When repeated or sustained doses occur, a worker’s ability to adapt to the internal changes may be either improved or compromised. When the capability for adapting to these changes is compromised, then muscle, tendon, or nerve-related disorders can result.

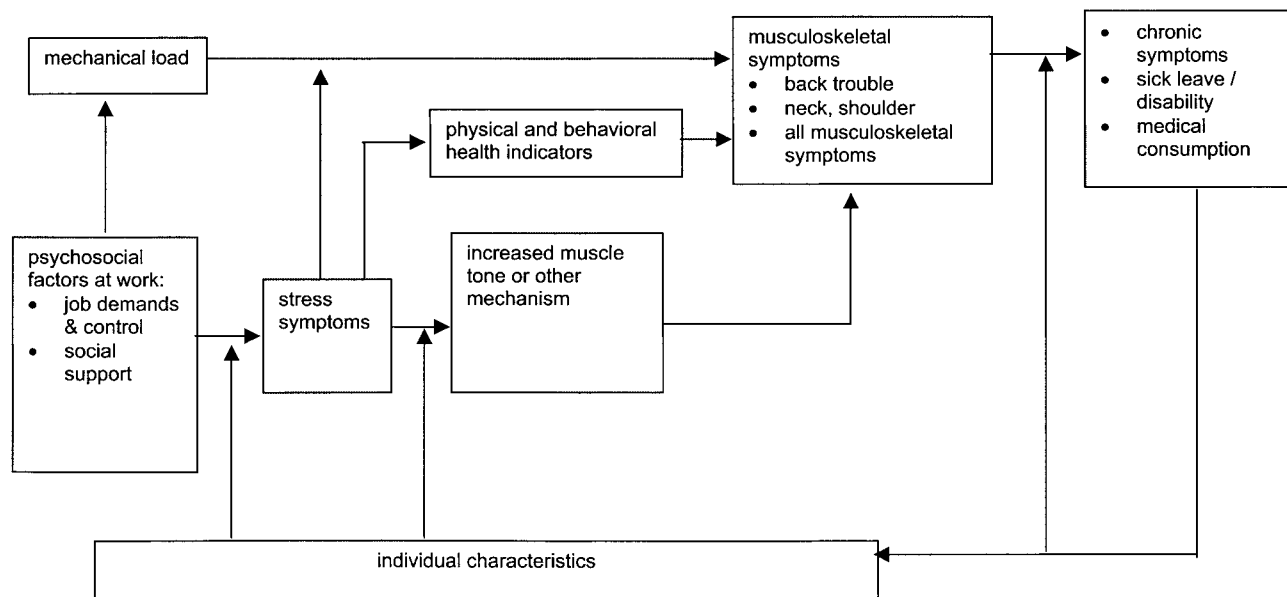
One strength of this model is the use of the dose-response relationship concept between exposure to biomechanical factors and a musculoskeletal outcome. This concept is viewed as a necessary prerequisite for determining the plausibility of an exposure—outcome relationship. However, the lack of specific attention to job stress exposures limits the model’s ability to provide a comprehensive perspective on how both physical and psychosocial/work organization factors might interact to influence musculoskeletal outcomes.

### Epidemiological Model of Musculoskeletal Disorders

An earlier model described by Bongers et al. [1993] was developed based upon epidemiological studies on the etiology of musculoskeletal disorders. Their model, illustrated in Figure 5, also incorporates concepts from research on stress and health and the psychological dimensions of chronic pain (i.e., back pain) patients. Consistent with the basic job stress model, it is hypothesized that work-related psychosocial factors, in conjunction with coping ability, influences work-related stress. Workplace stress, in turn, influences muscle activity and/or moderates the relationship between mechanical load and the perception of musculoskeletal symptoms. In the case of increased muscle activity, musculoskeletal symptoms may arise via a specific physiological mechanism such as a neuroendocrine pathway. While this pathway was not described in greater detail, research has indicated that elevations in epinephrine, norepinephrine, and cortisol levels result in response to



**FIGURE 4.** Dose-response model for work-related neck and upper limb musculoskeletal disorders [Armstrong et al., 1993]. Reprinted with permission.



**FIGURE 5.** Epidemiological model of musculoskeletal disorders [Bongers et al., 1993]. Reprinted with permission.

psychosocial stressors such as mental demands and low job control [Frankenhaeuser, 1979; Frankenhaeuser and Lundberg, 1982]. Bongers et al. [1993] also postulate that musculoskeletal symptoms may be produced as a result of an enhanced perception of symptoms and/or a reduced ability to cope with these symptoms in the presence of stressful working conditions. Regardless of the pathway by which musculoskeletal symptoms occur, it is further hypothesized that these symptoms can subsequently become chronic and lead to disability and/or increased health care utilization.

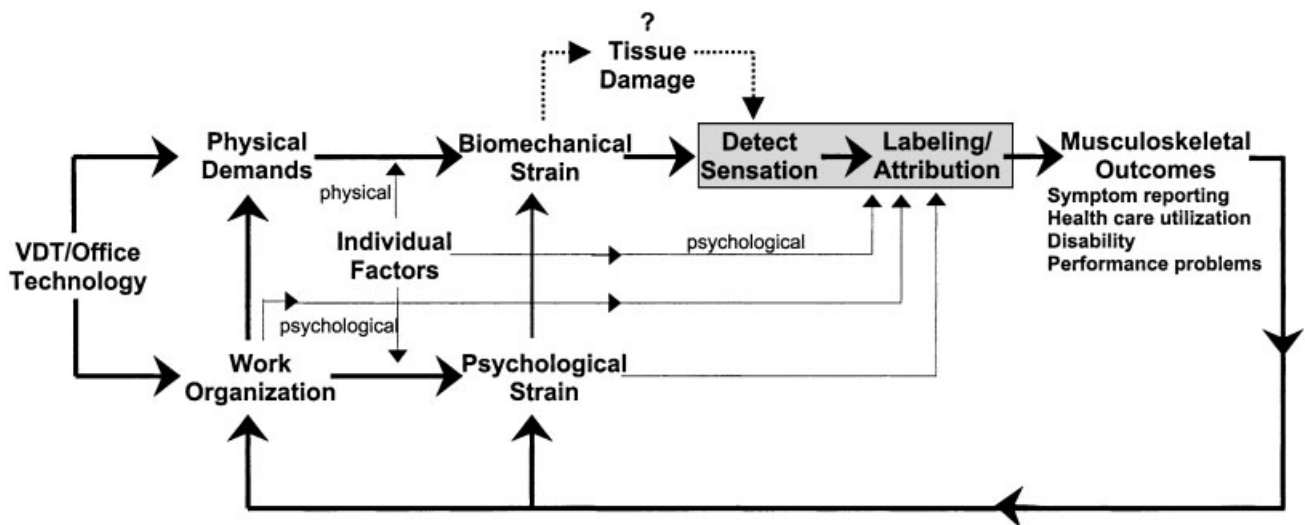
One difference between the Bongers et al. model and other musculoskeletal models is its presentation in the context of a comprehensive, systematic evidenced-based literature review. Based on the results of the review, specific variables (i.e., monotonous work, time pressure, and perceived high work load) 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 certain studies that measured stress symptoms before the development of musculoskeletal symptoms. While Bongers et al. did not intend for the model to be explanatory, but rather a framework for understanding the literature, the criteria used in the literature review helped to provide empirical support for the associations/mechanisms they proposed. However, the limitations in the literature as noted by Bongers et al. highlight the need for caution. The importance of longitudinal studies to further elaborate on

the proposed associations in the model was evident at the time of her earlier review and the situation on these types of investigations has not improved regarding WRUEDs [see Bongers et al., 2002, this issue].

### Ecological Model of Musculoskeletal Disorders

Sauter and Swanson [1996] ecological model incorporates psychosocial, biomechanical, and cognitive factors in explaining musculoskeletal outcomes as illustrated in Figure 6. The model is specific to work involving visual display terminals/office technology and was designed to help explain the etiology of work-related upper extremity symptoms/disorders. The model has been recently tested and primary pathways partially validated through empirical research and path analyses [Amick et al., 1999].

The ecological model has multiple components. The biomechanical component involves physical demands leading to biomechanical strain, which is proposed to be the primary mechanism by which musculoskeletal symptoms occur. The psychosocial/work organization/stress and cognitive components (i.e., somatic interpretation) of this model play moderating roles. The psychosocial/work organization/stress component involves the interplay of work organization factors with individual factors and is a primary source of psychological strain. Psychological strain can subsequently impact biomechanical strain via influence on muscle tension, and also moderates the relationship between biomechanical strain and outcomes such as symptom attributions and reporting, health care utilization, and disability. The manner in which psychological strain



**FIGURE 6.** Ecological model of musculoskeletal disorders [Sauter and Swanson, 1996].

moderates the relationship between biomechanical strain and musculoskeletal outcomes has yet to be examined in research on WRUEDs. However, based on past studies, Sauter and Swanson [1996] suggest that mood disturbances, increased worries, and fatigue may affect the detection, labeling, and attribution of sensations arising as the result of biomechanical strain as well as the behavioral response to symptoms (e.g., reporting, sickness absence, transition from short-term to long-term disability). Work organization can also affect the physical demands that a worker experiences by directly influencing how job tasks are performed (i.e., work method) and, thereby, increase ergonomic exposures. In this sense, work organization is proposed to play an indirect role in the causal mechanism for a musculoskeletal outcome.

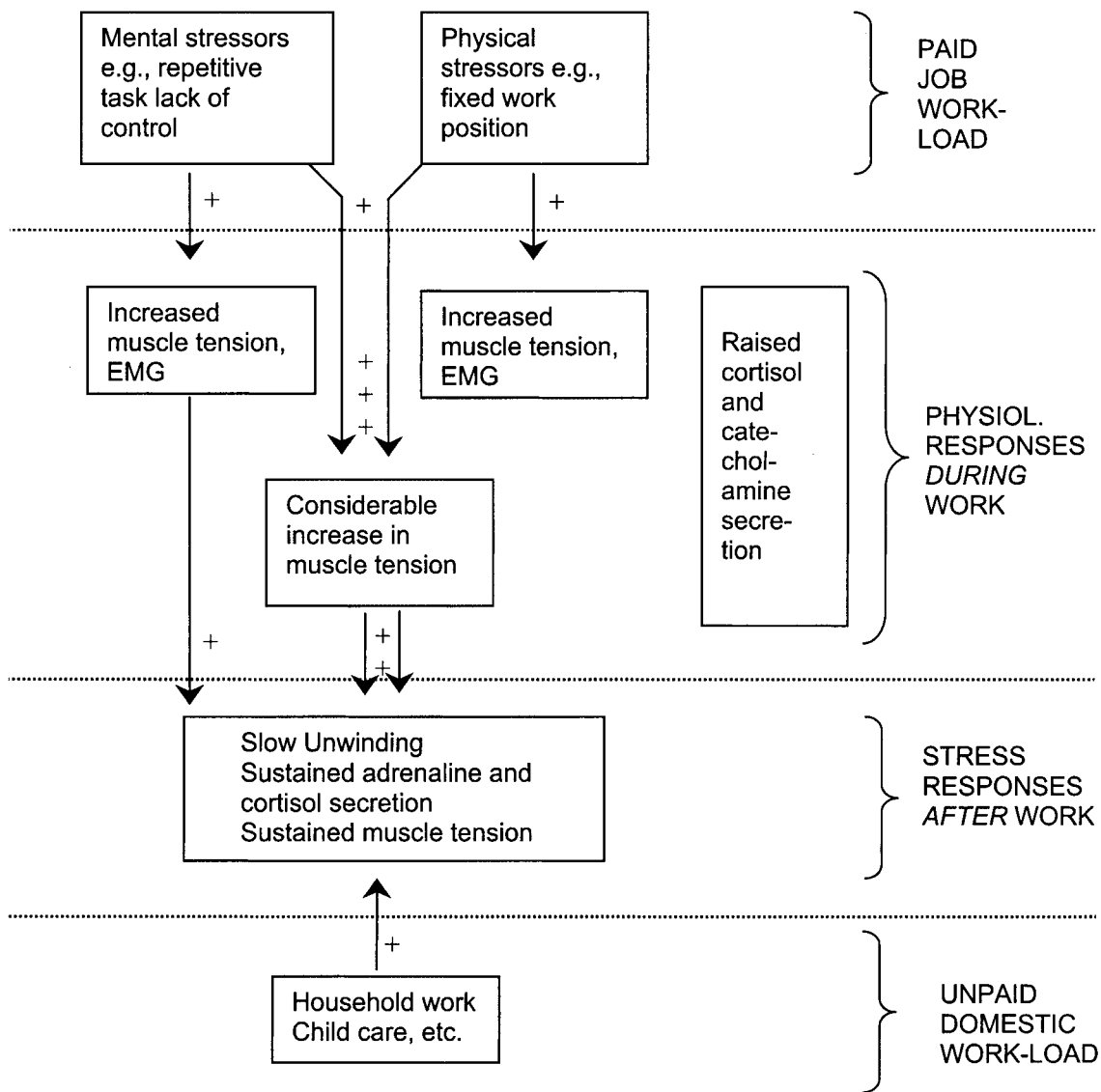
The cognitive component of this model is a unique aspect. According to attribution theory and related propositions in social psychology, individuals are psychologically uncomfortable when they cannot explain bodily sensations [Cioffi, 1996]. Furthermore, contextual factors play a role in detecting, labeling, and attributing the source of these sensations, particularly when such sensations cannot be readily explained by other factors. By implication then, the level of stress in the workplace may influence (raise or lower) the threshold for nociception, the labeling of sensations as symptoms or illness, and the attribution of symptoms and illness to either the workplace or other sources. However, while this mechanism has been demonstrated in basic research in social and health psychology [Pennebaker and Hall, 1982; Cioffi, 1996], it has not been examined in research on psychosocial factors and musculoskeletal disorders.

In summary, this model postulates multiple plausible pathways between psychosocial factors and WRUEDs that

are similar to pathways described in both Bongers et al. [1993] and Carayon et al. [1999] models and also postulates new mechanisms. But as with these alternate models, further research is needed to disentangle and validate the multiple casual pathways that are proposed.

### Biopsychosocial Model of Job Stress

According to a biopsychosocial stress model developed by Frankenhaeuser [1991], psychological stress may result from both overload (i.e., demands that can exceed an individual's ability to deal with them) and underload (i.e., demands that are too low (e.g., monotonous work situations) that do not sufficiently challenge the individual. Melin and Lundberg [1997] applied this model to explain the relationship among mental and physical stressors and hormonal stress responses and muscle tension (see Fig. 7). The Melin and Lundberg model proposed that mental and physical stressors related to workloads produce physiological responses while at work. Although delineating the array of specific stressors was not a primary objective in the model, stressors such as monotonous and repetitive work tasks, high workplace, and low job satisfaction were cited. While mental or physical demands could each separately result in increased muscle tension as well as increased cortisol and catecholamine activity, it was proposed that the combination of both types of demands would produce an even greater increase in these responses [Melin and Lundberg, 1997]. A special feature of this model is that it also addresses post-work activity when it is generally assumed that the stress response associated with exposure to work tasks and/or the work environment subsides. The model proposes that a full recovery of the stress response to levels prior to the exposure to workplace stressors may not occur quickly. That is, after



**FIGURE 7.** Biopsychosocial model of job stress [Melin and Lundberg, 1997]. Reprinted with permission.

work, the stress response may continue in the form of sustained muscle tension and/or secretion of stress hormones such as adrenaline and cortisol. Furthermore, should the individual be exposed to other workloads such as household work or child-care, the recovery may be further affected. As the physiological stress response persists over time, a worker may be placed at greater risk for a musculoskeletal disorder. (See Lundberg, 2002, [this issue] for further elaboration of this process).

This model is unique in considering the potential contribution of family-related factors in musculoskeletal symptoms and draws attention to how stress responses from work may be maintained and/or exacerbated when an individual is away from the workplace. This notion is especially important because of the difficulty in separating work and home/family experiences in today's economy.

Research on visual display terminal workers [Bergqvist et al., 1995] has indicated that women with children at home were at greater risk for upper extremity disorders. Among dental hygienists, the risk for work-related musculoskeletal disorders in the upper body and arms increased with higher levels of family overload [Ylipaa et al., 1999].

By suggesting the concept of "total workload" (i.e., work and home factors), this model represents an important addition to the emerging models used to help explain the link between job stress and WRUEDs. However, at present, the model tends to focus more on the potential physiological processes in response to stress than on identification of specific dimensions of the workplace or home environment that might contribute to excessive levels of stress or the lack of physiological recovery following work. Further work to

identify and distinguish these two classes of stressors and their relative effects is needed.

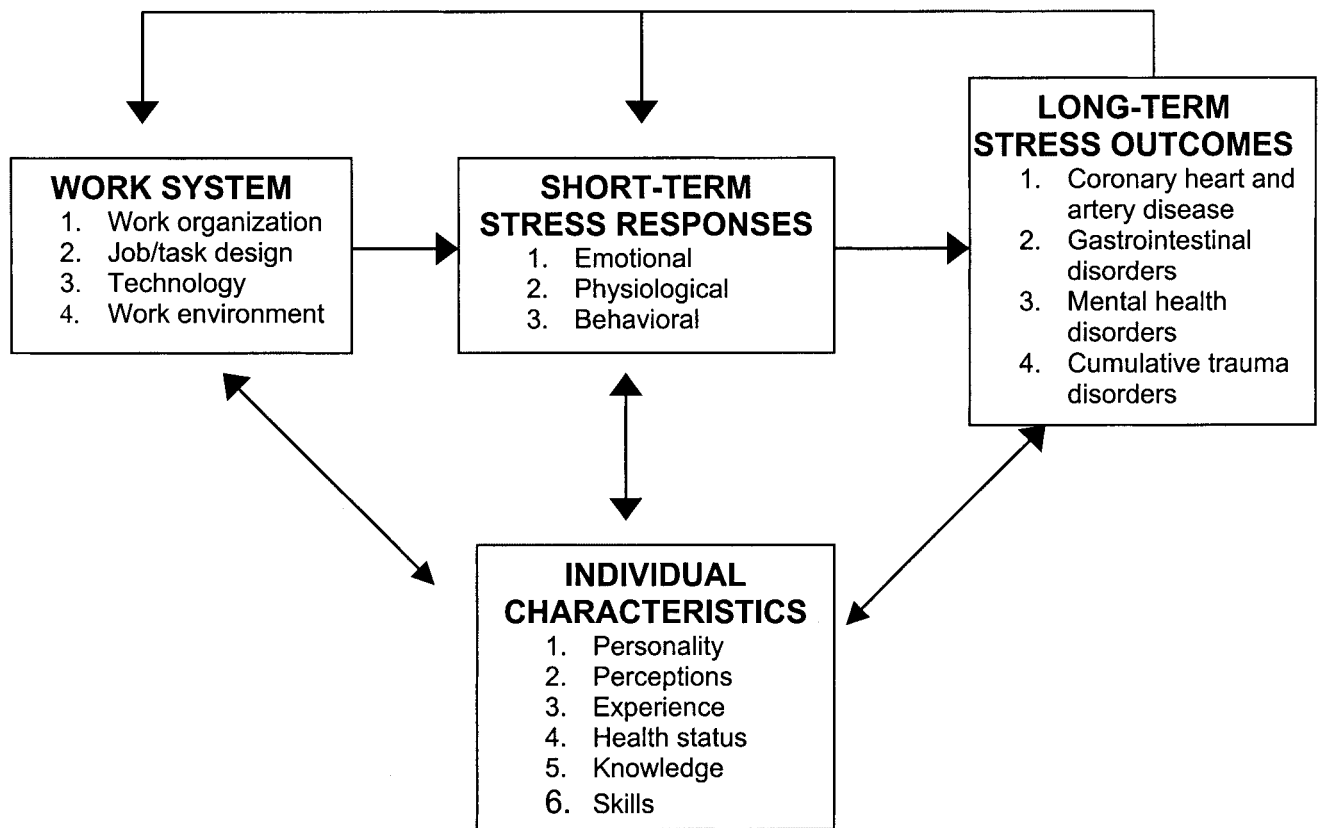
**Balance Theory of Job Design and Stress**

Carayon et al. [1999] have proposed a comprehensive job stress model (Fig. 8) that incorporates WRUEDs among a variety of health outcomes. This model is integrated within a broader theoretical formulation of job design and stress referred to as “balance theory” [Smith and Carayon-Sainfort, 1989; Smith and Carayon, 1996]. Balance theory postulates that stress results from loads that arise from imbalance between various elements of a work system. In addition to the worker, these elements include technological, organizational, task, and environmental factors. Although balance theory and the nature and effects of imbalance are discussed only in conceptual terms, the subsidiary stress model is more specific with hypothesized relationships between psychosocial factors and WRUEDs that are supported by research.

As illustrated in Figure 8, this stress model is conceptually similar to the NIOSH [Hurrell and McLaney, 1988], Cooper and Marshall [1976], and Kagan and Levi [1971] stress models, and to the earlier models of psychosocial/work organization factors and musculoskeletal dis-

orders by Bongers et al. [1993] and Sauter and Swanson [1996]. In this model, work organization factors present as stressors in the workplace and also impact ergonomic demands. In turn, these factors give rise to various stress-related disorders, including musculoskeletal disorders, either directly or as mediated by acute stress reactions. This causal sequence is moderated by individual characteristics, including personality, coping, perceptions, and experience. Like the NIOSH stress model and later elaborations of the Kagan and Levi model [see European Commission, 2000], this model suggests that health outcomes feed back to influence both work organization and the nature of stress reactions.

Within this model, Carayon et al. [1999] describe various mechanisms linking work organization factors to musculoskeletal outcomes, including psychobiological, psychological, and behavioral processes. Examples of the former include the effects of stress-induced changes in blood pressure, peripheral neurotransmitters, stress hormones, and muscle tension on muscle function. Psychological and behavioral mechanisms include effects of stressful working conditions on workstyle, coping style, and motivation to report injury or seek treatment. It is perhaps this comprehensive consideration of psychobiological, psychological, and behavioral mechanisms which sets this model apart from others models of stress and muscu-



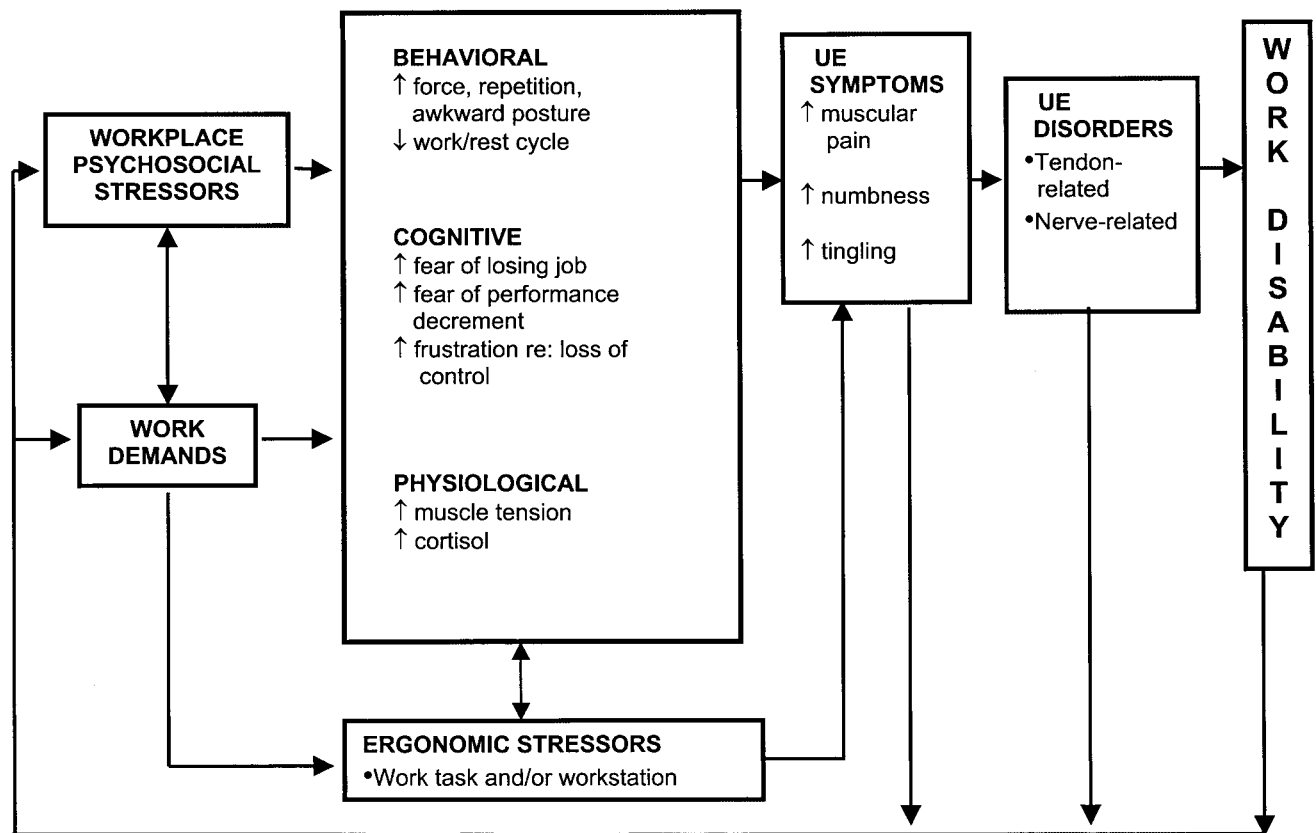
**FIGURE 8.** Balance theory of job design and stress [Carayon et al., 1999]. Reprinted with permission from Human Factors, Vol. 41, No. 4, 1999. Copyright 1999 by the Human Factors and Ergonomic Society. All rights reserved.

loskeletal disorders. It is important to note, however, that many of these mechanisms are speculative, lack detail on specific biological processes, and require further research to support or refute such processes. Finally, as with the Bongers et al. [1993] and Sauter and Swanson [1996] models, Carayon et al. [1999] postulate direct effects of work organization factors on ergonomic exposures such as the degree of repetition or duration of exposure. Yet, at present, the empirical evidence for the combined effects of these suspected risk factors is limited.

### Workstyle Model

The workstyle construct was initially based upon a review of the literature related to work technique and musculoskeletal symptoms and anecdotal observations of patients and workers performing various job tasks. The concept was operationally defined and placed in the context of a broader model to help explain why workers exposed to identical work tasks vary in the development and exacerbation of work-related upper extremity symptoms. The workstyle construct [Feuerstein, 1996, Feuerstein et al.,

1999] has been defined as an individual pattern of cognitions, behaviors, and physiological reactivity that co-occur while performing job tasks. It has been proposed that a workstyle response involving cognitive and behavioral reactions 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 and/or perceived work demands. Based on this construct, a multidimensional model has been developed that incorporates workplace psychosocial stressors, work demands, and ergonomic stressors (Fig. 9). In this model, workplace psychosocial stressors in combination with work demands and ergonomic stressors can trigger a high-risk workstyle response that, in turn, can lead to the musculoskeletal hazard chain (i.e., symptoms, disorders, disability). The experience of musculoskeletal symptoms, disorders or disability, can subsequently increase the negative impact of workplace psychosocial stressors and work demands by increasing the likelihood that the worker will sustain a high-risk workstyle in order to accommodate the demands. When



**FIGURE 9.** Workstyle model [Feuerstein, 1996; Feuerstein et al., 1999]. Reprinted with permission. Source: Feuerstein M. 1996. Workstyle: Definition, empirical support and implications for prevention, evaluation and rehabilitation of occupational upper extremity disorders. In: Moon SD, Sauter SL, editors, "Beyond Biomechanics: Psychosocial Influences on Cumulative Trauma Disorders in Office Workers." Bristol, PA: Taylor and Francis, p191.

this high-risk workstyle is maintained, negative health and work outcomes can persist.

Preliminary evidence exists to indicate that, among office workers, certain dimensions of a high-risk workstyle (i.e., “tendency to work in a way that contributes to pain to insure high quality”) have been associated with upper extremity symptoms and functional limitations [Hauffler et al., 2000]. In addition, sign language interpreters who report the occurrence of certain features of a high-risk workstyle (i.e., “tendency to work in a way that contributes to pain to insure high quality,” “pressure at work”) also reported increased levels of symptoms and functional limitations [Feuerstein et al., 1997]. Behavioral characteristics of a potentially high-risk workstyle, such as taking fewer rest breaks or exerting greater force on a keyboard during standard work tasks have also been observed in symptomatic workers [e.g., Feuerstein and Fitzgerald, 1992; Feuerstein et al., 1997].

The model provides a framework to help explain how occupational stress and ergonomic exposures might interact to contribute to UE symptoms, disorders and disability. For example, a worker with a high-risk workstyle who is concerned about completing a deadline may be more likely to take fewer breaks, exert greater force on his/her keyboard, and sustain prolonged awkward postures, thereby increasing exposure to suspected ergonomic risk factors. Also, time pressure in this case can be a work demand and/or psychosocial stressor and can by itself trigger higher levels of muscle activity and the release of stress hormones [e.g., Birch et al., 2000]. The combined effect can set the stage for the expression of symptoms of fatigue and pain.

This model generates options for interventions directed at both individual and organizational levels that focus on reducing ergonomic and work organization risk factors although such approaches require empirical support. While the model proposes that workplace psychosocial stressors and work demands impact behavioral, cognitive, and physiological responses of the worker, it does not detail the exact dimensions of these components. Similar to the models by Bongers et al. [1993] and Carayon et al. [1999], the Workstyle model needs to specify the underlying biological processes linking exposure to pain in greater detail. The workstyle construct also requires further validation in terms of the association between high-risk work style and symptom severity and functional limitations. Additionally, in such validation efforts, it is important to determine the unique contribution of workstyle independent of traditional measures of job stress.

## **SUMMARY AND FUTURE DIRECTIONS**

This paper has two inter-related objectives. First, it challenges the conventional view among many in the occupational health field that stress is an elusive concept, rooted

in individual psychological characteristics, and therefore difficult to integrate into occupational safety and health research and practice. In this regard, organizational sources of stress are described to illustrate the broad range of task-level and organizational-level factors contributing to stress at work. Prominent models of occupational stress are also reviewed to provide the footing for discussion and future investigation of occupational stress as a risk factor for WRUEDs. Secondly, the paper explores multivariable models of WRUEDs that incorporate work organization and other stress factors as etiologic agents. These models provide a rich theoretical context for understanding the influence of psychosocial factors (referring to work, non-work, and individual factors that may contribute to the stress process) on WRUEDs, and a general understanding of how these factors operate. For example, most of these models suggest that work organization can influence musculoskeletal outcomes by directly affecting ergonomic exposures and biomechanical loads. At the same time, most models acknowledge that organizational factors may contribute to stress responses (physiological, psychological, and behavioral) that impact the relationship between ergonomic exposures and musculoskeletal outcomes. It is also possible that exposure to occupational stress can independently exert a direct effect on symptom expression. Finally, a number of these models propose that individual factors, such as coping and personality, intersect with organizational factors and serve as co-determinants of stress responses and their effects on WRUEDs.

While there exist similarities among the general frameworks of these models, each model also makes unique contributions to understanding psychosocial risk factors for musculoskeletal disorders. Carayon et al. [1999], for example, highlight the role of psychophysiological mechanisms (e.g., possible effects of stress hormones on fluid retention and changes in regional blood flow) not specified in other models; Melin and Lundberg [1997] underscore the influence of demands outside the workplace; workstyle is featured in the Feuerstein [1996] model; and Sauter and Swanson [1996] call attention to the effects of work organization factors on symptom perception.

But notwithstanding the high degree of theoretical sophistication witnessed in these models of job stress and musculoskeletal disorders, it is important to note that empirical support for their architecture is still rather primitive and presents a number of challenges for researchers and clinicians. Examination of this research reveals various limitations that have been alluded to in the preceding sections. First, few of the psychological, psychophysiological, and behavioral mechanisms integral to the models have been empirically substantiated. For example, of the numerous psychophysiological mechanisms postulated by Melin and Lundberg [1997] and Carayon et al. [1999], only the effects of psychologically demanding work on muscle loads

and catecholamine activity have been verified empirically. Additionally, study designs in epidemiology have not allowed researchers to disentangle multiple causal pathways presumed to exist between work organization factors and musculoskeletal disorders, nor has this been a pursuit in epidemiologic research on this topic. Whereas the weight of evidence suggests that work organization factors contribute to musculoskeletal disorders [Bongers et al., 1993; NRC, 2001; Bongers et al., 2002, this issue], the experimental control and analytical methods (e.g., structural analysis) essential to isolating effects of work organization factors and specifying pathways along which they operate in conjunction with biomechanical/ergonomic factors are beyond the extent of conventional epidemiologic methods. In this regard, the complexity of theoretical frameworks linking work organization factors and musculoskeletal outcomes may defy the design of stand-alone studies to examine their internal structure. Moreover, findings indicating that workplace physical and psychosocial stressors share a common variance [e.g., MacDonald et al., 2001] may further complicate approaches toward specific identification of work organization effects in validating proposed pathways. Alternative research paradigms, relying perhaps on investigations that decompose these models and systematically examine their constituent elements under well-controlled field and laboratory conditions, may be the critical next step in advancing our knowledge of work organizational aspects of work-related musculoskeletal disorders.

In pursuing directions that assist with our understanding of specific mechanisms for work-related musculoskeletal disorders, the need for intervention/prevention strategies and evaluating their effectiveness should not be overlooked. Although it would be ideal to apply attained research findings on WRUED pathways in developing intervention strategies, it is not feasible to wait until that information is available. Furthermore, existing data on risk factors provide an empirical basis for a multifaceted prevention approach that is aimed at reducing both ergonomic/biomechanical and work organization stressors.

The field of occupational health is presented with an opportunity for expanding the scope of its traditional focus with regard to WRUEDs. It is hoped that serious consideration of occupational stress will produce meaningful new knowledge that can be used to help reduce the impact of these exposures on affected workers and those at increased risk. This knowledge should, in turn, improve efforts at prevention and management.

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