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An Ecological Model of Musculoskeletal Disorders in Office Work[1]

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Introduction

There is increasing recognition that so-called "psychosocial" factors in the workplace are somehow involved in the etiology of work-related musculoskeletal disorders, especially in the context of office work involving video display terminals (VDTs). In an expansive review of the epidemiologic literature on psychosocial factors and musculoskeletal disorders, Bongers and de Winter (1992) concluded that monotonous work, high perceived workload, time pressure, and low control and social support were all related to musculoskeletal symptoms among workers. This relationship is captured in a metaphor by Hocking (1990) which likens work-related disease to an iceberg floating in a social sea (workplace psychosocial environment). Disease is more or less manifest as the iceberg floats higher or lower as a function of conditions in the psychosocial sea.

Despite the mounting evidence, the notion that psychosocial factors affect musculoskeletal disorders has met with some uncertainty. As we see it, the problem is two-fold, having to do with 1) confusion regarding the concept of psychosocial factors, and 2) questions regarding possible causal mechanisms linking psychosocial factors and musculoskeletal disorders. These uncertainties are elaborated further as follows.

The expression "psychosocial factors" is a nonspecific term and involves a vernacular that is unfamiliar outside the stress arena. In its general usage in occupational health, the term has served as a catch basin in reference to nonphysical elements of the job/work environment, including organizational climate or culture, aspects of work organization such as the complexity of tasks, and even psychological attributes of workers such as job attitudes (e.g., job satisfaction) and personality traits. Such breadth is not inappropriate (International Labor Office, 1986; Theorell, this volume), but it likely contributes to confusion in interpreting what is meant when we speak of psychosocial factors in relation to health problems.

A related issue is that psychosocial factors, such as organizational climate, can be difficult to measure as objectively as many physical workplace hazards such as lifting requirements or the presence of toxic agents. Information on workplace psychosocial factors is usually subjective, obtained through surveys or other self-report techniques. Further, some theorists place greater emphasis on individual appraisals (perceptions) of the environment, in contrast to the objective environment, in determining health risks (e.g., Lazarus, 1966). This subjectivity can create uncertainty in interpreting whether self-reports of workplace psychosocial conditions represent attributes of the environment or whether they are highly individualized perceptions, which leads to uncertainty in ascribing risks associated with workplace psychosocial factors to the job or to the individual.

Uncertainty results also from the absence of a satisfactory or widely accepted framework for explaining causal linkages between psychosocial factors and musculoskeletal disorders. Concepts of disease in western culture are dominated by the biomedical model, involving biological determinism or mediation of disease processes. Some investigators have proposed that muscle tension secondary to stress may account, in part, for the relationship between psychosocial factors and musculoskeletal disorders (Ursin, Endressen, Svebak, Tellnes and Mykletun, 1993; Ursin, Endresen and Ursin, 1988; Waersted, Bjorklund and Westgaard, 1991; Westgaard and Bjorklund, 1987). But, with this exception, there has been limited discussion or evidence of biological mediation between psychosocial factors and musculoskeletal disorders.

In the wake of the repetition strain injury (RSI) epidemic which engulfed Australia during the 1980s (see Hocking, 1987a, for an overview), mechanisms involving psychological mediation of the relationship between psychosocial factors and musculoskeletal disorders have been proposed. However, this type of explanation has had mixed reception. Within a biomedical paradigm, the implication of psychological processes in the etiology of disease may create the impression that the disease is not "real" (see Skelton, this volume, for a broader discussion of this issue). Various Australian explanations for RSI have emphasized psychiatric mechanisms or other abnormalistic processes (see Bammer and Martin, 1988; Mullaly and Grigg, 1988; Spillane and Deves, 1987), which probably serves to

exacerbate this effect. Further, implication of psychological mechanisms may be seen by some as "victim blaming," in that it appears to shift the etiologic focus toward the worker and away from the job.

The present discussion attempts to address some of these areas of uncertainty. The primary goal is to suggest ways in which workplace psychosocial factors can influence musculoskeletal disorders. The intent is not to diminish the importance of physical ergonomic factors and biomechanical mechanisms in the etiology of work-related musculoskeletal disorders but, rather, to suggest a more holistic framework which incorporates both psychosocial and physical ergonomic components.

We begin with an attempt to shed further light on the concept of psychosocial factors. Then a hypothetical model of workplace psychosocial factors and musculoskeletal disorders is presented. An important feature of the model is that psychological mediation of musculoskeletal disorders is discussed in terms of normal psychological processes which are well understood in social and health psychology. Finally, research supporting constituent pathways in the model is presented with an emphasis on studies of VDT work.

Psychosocial Factors

Few explicit definitions of the expression "psychosocial factors" can be found in the literature. In the context of work, definition is often by reference to specific conditions such as lack of autonomy, increased work pressure, difficult interpersonal relationships at work (e.g., see National Occupational Health and Safety Commission, 1986). Other definitions simply distinguish physical and non-physical aspects of the job. Evans, Johansson and Carrere (1994, p.2) define the psychosocial environment at work as "...the way production of goods and services is organized and....the social climate of the setting produced by the activities of the organization and the people in it," in contrast to physical factors which refer to "...inanimate components of the work setting". A similar distinction is made by the World Health Organization (WHO), European Office in a 1989 report on psychosocial and health aspects of VDT work (WHO, 1989).

Imbedded in these approaches to psychosocial factors is the notion of psychological salience; i.e., psychosocial factors have some kind of psychological representation, meaning or valence within the individual. For example, in defining psychosocial stressors, Van Harrison (1983) emphasizes the "symbolic meaning" of actions and conditions in the workplace.

The International Labor Office (ILO) and WHO carry this concept a step further.

In a joint report, ILO/WHO define psychosocial factors as aspects of the work environment, the extra-work environment and of the individual which interact to affect well-being (and performance), with an emphasis on psychological effects (ILO, 1986). In effect, this is a simple expression of an occupational stress model or process. In this approach, psychosocial factors can be understood as any factor or condition, whether individual or work related, that contributes to the stress process.

Although it's a significant over-generalization, it can be said that all theories of stress/occupational stress (e.g., Caplan, Cobb, French, Van Harrison, and Pinneau, 1975; Hurrell and Murphy, 1992 ; Kagan and Levi, 1971; Karasek and Theorell, 1990; Matteson and Ivancevich, 1989; McGrath, 1970; Smith and Carayon-Sainfort, 1989) can be reduced to a common theme: psychological stress is understood as a process involving the interaction of environmental demands with individual attributes (needs, expectations, resources, etc), which leads to acute psychological, behavioral, and physiological reactions and ultimately affects physical health. This core feature is illustrated in Figure 1, which shows a generic or simplified version of the Kagan and Levi (1971) and other (e.g., Cooper and Marshall, 1976; Hurrell and Murphy; 1992) psychosocial stress models. In this type of model, individual factors are usually considered as intervening variables which serve to modify the relationship between environmental demands (stressors) and stress responses (strains/ill health); i.e., the model gives primacy to

environmental factors in determining health outcomes. (Other models such as Caplan et al., 1975 posit more direct effects of individual factors, placing stronger emphasis on the actual fit or balance between environmental demands and individual resources as a determinant of stress.)

Figure 1 about here

Not shown in this model is the appraisal process postulated by Lazarus (1966) which occurs at the intersection of environmental demands and individual variables. As described by Lazarus, appraisal is a multistage cognitive process in which the individual first evaluates the threat potential of the environmental stimulus, and then the availability of individual coping resources. In this schema, stress is regarded as a highly individualized and subjective or intrapsychic phenomenon and, thus, the etiological and prevention focus shifts away from environmental conditions toward individual factors. While not denying individual variability in appraisal, critics of Lazarus assert that there are certain environment/job conditions which most workers appraise as threatening most of the time, which argues more for an environmental emphasis (see Brief and George, 1991).

Reviews and studies of job stress provide insight to specific individual factors and working conditions that feed the stress process, and help to provide a more concrete understanding of psychosocial factors. With regard to individual factors, Payne (1988) identified three classes of variables corresponding to 1) genetic factors (e.g., intelligence), 2) acquired aspects (e.g., social class, culture, educational attainment) and 3) dispositional factors (e.g., personality characteristics or attitudes such as job satisfaction). The latter two classes of variables are of special significance to the present discussion. Cultural factors are seen as potent psychosocial determinants of musculoskeletal and other occupational health disorders (Hocking,1987a; 1987b, Mechanic, 1972). Also, negative affectivity, a dispositional factor characterized by undifferentiated subjective distress, is increasingly associated with elevated levels of somatic complaints (Cohen, Doyle, Fireman, Gwaltney, and Newsom, 1994; Watson and Pennebaker, 1989). Bergquist, Wolgast, Nilsson and Voss (in press, a), for example, have shown that negative affectivity is associated with increased neck-shoulder discomfort in VDT users.[1]

The stress literature also suggests specific classes of psychosocial factors pertaining to working conditions (Cooper and Marshall, 1976; Evans, 1994, ILO, 1986; Matteson and Ivancevitch, 1989). The ILO/WHO taxonomy (ILO, 1986), for example, categorized work-related psychosocial factors into 1) physical environmental conditions, 2) factors intrinsic to the job (e.g., workload

and design of tasks), 3) arrangement of work time (e.g., hours of work and shift schedule), 4) management/operating practices (e.g., workers' roles, participative management, relationships at work) and 5) technological change.

Kasl (1992) has attempted to dimensionalize working conditions as risk factors for mental health in a way that may also prove useful for understanding work-related psychosocial factors. Elements in the Kasl (1992) taxonomy are summarized as follows:

- Physical aspects of work: Physical environmental conditions at work (e.g., heat or chemical exposure) including physical ergonomic demands such as lifting requirements.

- Temporal aspects of the job: Hours of work and work-rest schedule, work shift, work pace, etc.

- Job content: Scope and repetitiveness of tasks, use of skills, vigilance/mental workload demands, participation in decision-making, clarity of demands, etc.

- Interpersonal relationships: Group cohesion, supportiveness of peers and supervisors, availability of feedback, etc.

- Organizational aspects: Tall/flat organizational structure and associated bureaucratic characteristics.

- Financial/economic aspects: Pay methods, benefits, etc.

- Community/societal aspects: Status/prestige associated with the job.

Like ILO (1986) Kasl also adds "change in the work setting" as a separate psychosocial dimension, particularly in regard to potential for promotion, demotion, job loss, etc. Additional dimensions, which might be considered for this list based on their prominence in prior and current stress research, include "work roles" (clarity, conflict and number), "human resource systems" (training, career development opportunities, etc.) and "organizational climate" (values, communications styles, etc., in the organization). However, there is a considerable degree of arbitrariness here, and there is no single classification scheme which predominates in the organizational psychology or stress literature.

Both ILO (1986) and Kasl (1992) include physical environmental conditions as a psychosocial hazard. However, although it may be a fine point, the following distinction can be made. Unlike other dimensions, the immediate or direct effect of physical environmental conditions (except for aesthetic aspects of the environment) are somatic, not psychological. Psychological effects occur only as a

secondary phenomenon following from the experience of somatic symptoms or disorders resulting from the physical exposure. This argues against the inclusion of physical environmental factors as primary psychosocial factors.

As a group, these dimensions of work are often referred to as job design or work organization factors because, to a large extent, they derive from the way work systems are designed or organized. In subsequent discussion, the expression "work organization" is used broadly in reference to any work-related risk factor for job stress, whereas the expression "psychosocial factors" refers to attributes of both the job and the individual which contribute to job stress.

Psychosocial Pathways to Musculoskeletal Disorders

Three types of explanations for the association between work-related psychosocial factors and musculoskeletal disorders seem especially plausible. In a report on VDT work and musculoskeletal disorders in news editors, the National Institute for Occupational Safety and Health (NIOSH) postulated that 1) psychosocial demands and job stress may produce increased muscle tension and exacerbate task-related biomechanical strain, 2) psychosocial demands may affect awareness and reporting of musculoskeletal symptoms, or affect perceptions of their cause, or 3) the association may be related to a causal or correlational relationship between psychosocial and physical demands (NIOSH, 1993). These types of mechanisms

have been suggested by several investigators (Bergquist, 1984; Bongers and de Winter, 1992; Bongers, de Winter, Kompier and Hildebrandt, 1993; Sauter, Gottlieb, Jones, Dodson and Rohrer, 1983a; Sauter, Gottlieb, Rohrer and Dodson, 1983b; Ursin, Endresen, and Ursin, 1988).

The present paper incorporates all of these pathways into a formal causal model, which builds on earlier efforts by the authors to model the relationship between psychosocial factors and musculoskeletal disorders in office work (Sauter, 1991; Sauter and Swanson, 1993; Sauter et al, 1983a; Sauter et al, 1983b). This model, shown in Figure 2, represents an integration of the generic psychosocial stress process illustrated in Figure 1 into the traditional biomechanical model of

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Figure 2 about here

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musculoskeletal disorders. This integration can be seen in Figure 3, which decomposes the present model into biomechanical, psychosocial and cognitive components.

Figure 3 about here

Recently, researchers from the TNO Institute of Preventive Health Care in the Netherlands have described a generic model of workplace psychosocial factors and musculoskeletal disease with pathways similar to those depicted in Figures 2 and 3 (Bongers and deWinter, 1992; Bongers et al, 1993).[2] However, an important distinguishing feature of the present model is the attention to cognitive processes, described below, which mediate between biomechanical strain and the development of musculoskeletal disorders (i.e., the shaded area in Fig. 2 and the "cognitive" component in Fig. 3).

According to the present model (Fig. 2) musculoskeletal disorders can be traced ultimately to the nature of work technology, which includes both the nature of tools and work systems. In the case of office or VDT work the chief tool is the VDT/computer, and the nature of work can be defined as mechanized or automated information work. As shown in the model, work technology has a direct path to physical demands, as defined by the physical coupling between the worker and the tool (i.e., workstation ergonomics), and also a direct path to work organization. The influence of industrialization/mechanization on the specialization of job tasks, recognized since Adam Smith (1776), is an example of the latter.

The pathway from work organization to physical demands suggests that the physical demands of work are exacerbated by organizational demands; for example, increased specialization leads to increased repetition.

The present model also shows a direct path between work organization and psychosocial strain (stress) which, in turn, influences musculoskeletal outcomes via two routes. First, psychological strain is hypothesized to produce muscle tension, and possibly other autonomic effects, which compound biomechanical strain induced by task-related physical demands. This effect is depicted by the arrow between psychological strain and biomechanical strain in Figure 2. Second, psychological strain is hypothesized to moderate the relationship between biomechanical strain and the appearance of symptoms. (Moderating effects are denoted by faint arrows in Figure 2.)

The model also suggests that the relationship between biomechanical strains (i.e., internal physiological events) and development of musculoskeletal symptoms is mediated by a complex of cognitive processes (denoted by the shaded area in Figure 2), which involves the detection and labeling/attribution of somatic information (symptoms). As discussed by Cioffi (this volume), development of symptoms is not a direct or predetermined response to some internal physical event. Rather, it is a highly malleable, interpretive process which is subject to influence by contextual and experiential factors. Unfortunately, however, the

rather extensive psychological literature on the perception and attribution of symptoms (see Cioffi, this volume; Cioffi, 1991; Pennebaker and Hall, 1982) has received little or no attention in ergonomics and occupational health.

With regard to the perception of symptoms, Figure 2 shows that the connection between biomechanical strain and musculoskeletal outcomes is influenced not only by psychological strain, but also by individual and work organization factors apart from the contribution of these factors to psychological strain. Factors such as organizational safety climate, for example, may have a direct influence on how workers detect, interpret and respond to physical (somatic) sensations, regardless of whether safety climate actually results in stress.

For ease of presentation, multiple effects are combined in Figures 2 and 3 under the rubric of "musculoskeletal outcomes." As shown in Figure 4, it would be more appropriate to describe these effects in terms of a continuum of events involving first the development of symptoms, then symptom reporting and health care utilization, then sick leave utilization and disability, etc., and it can be postulated that psychological factors as discussed above are instrumental in the evolution of each stage.

Figure 4 about here

Figure 2 also shows a pathway from biomechanical strain to tissue damage to somatic interpretation. The broken lines comprising this pathway indicate that physical damage or disease is not necessarily integral to the model; i.e., all that is essential are conditions that give rise to musculoskeletal symptoms.

Finally, the model suggests that the experience of musculoskeletal disorders feeds back to influence stress at work (this is the pathway between physical environmental factors and stress mentioned in the preceding discussion of psychosocial factors), and it is likely that these disorders also prompt work redesign. It is because of these closed system properties, as well as the fact that the model incorporates inputs from both the physical and psychosocial work environment, that we refer to the model as an "ecological" model of musculoskeletal disorders.

Evidence for the Model

There are insufficient data to fully substantiate the pathways between work organization and musculoskeletal disorders illustrated in Figure 2. Key problems in

the extant literature, as pointed out by Bongers and deWinter (1992), include inadequate exposure assessment for the physical or psychosocial factors, and failure to effectively disentangle the effects of these two sets of variables. Further, while many studies link work organization and musculoskeletal outcomes, the effect sizes are often quite small. Also, few studies establish intermediary effects, which is essential to identify specific pathways. Finally, most of the pertinent studies are characterized by cross-sectional designs which limit causal inferences, including direction of causation between psychosocial and musculoskeletal measures. These deficiencies not withstanding, we believe that select studies offer circumstantial support for several of the pathways in Figure 2. These studies are discussed below, with the emphasis on investigations of musculoskeletal disorders in office/VDT workers.

The Path from Office Technology to Work Organization

The mechanization of office work, which was associated the introduction of the typewriter at the turn of the century, produced changes in the organization of office work not unlike the effects of mechanization in manufacturing processes. As described by Guiliano (1982), the mechanized or "industrial" office resulted in the standardization of office jobs and fragmentation of tasks and responsibilities characteristic of assembly-line work. VDT (computer) technology offers promise for reversal of these effects through enlargement of tasks and skills in office work (e.g., see Johansson and Aronsson, 1984). However, the indication is that some

types of VDT work are still stuck in the industrial age (Stellman, Klitzman, Gordon and Snow, 1987), or may even exacerbate the adverse organizational aspects of office mechanization. For example, a 1981 NIOSH investigation of clerical workers who used VDTs and their counterparts who did not work with VDTs found that VDT users reported significantly less autonomy and role clarity, and greater work pressure and management control over work processes (Smith et al., 1981). Identical findings were obtained in a subsequent NIOSH investigation of VDT users and non-users in Wisconsin (Sauter et al., 1983a; 1983b). A much larger 1987 study at Columbia University (Stellman et al., 1987) compared all-day VDT users with part-time users and several groups of typists and clerical workers. In contrast to all other study participants, the all-day VDT users reported significantly higher levels of workload demand and repetition, and lower levels of decision latitude, ability to learn new things on the job, and understanding of the overall work process.

Many additional studies have investigated organizational aspects of VDT work, but strict comparisons with non-computerized workplaces has been difficult in recent years because VDTs have become ubiquitous and, thus, suitable comparison groups are unavailable. Still, review of this work suggests a pattern of effects consistent with the reduction of tasks, skills, and autonomy, etc., as discussed above (see WHO, 1989).

Pathways from Work Organization to Musculoskeletal Outcomes

An impressive number of studies in the last decade have linked workplace organizational factors to upper extremity musculoskeletal signs and symptoms among VDT/keyboard users (Bergquist et al., in press, a; in press, b; Gomer, Silverstein, Berg and Lassiter, 1987; Canadian Labour Congress, 1982; Green and Briggs, 1990; Hales, Sauter, Peterson, Fine, Putz-Anderson, Schleifer, Ochs and Bernard, 1994; Hopkins, 1990; Lim and Carayon, 1993; Linton and Kamwendo, 1989; NIOSH 1992; NIOSH 1993; Pot, Padmos and Brouwers, 1986; Ryan and Bampton, 1988; Sauter et al., 1983a; 1983b; Spillane and Deves, 1988; Westgaard, Jensen and Hansen, 1993). Factors predictive of musculoskeletal outcomes in these studies include limited rest pauses, routine tasks, uncertain job future, highly variable workload, time pressure and heavy workload demands, high mental workload, low coworker and supervisory support, low worker autonomy, and low work group cohesion. Several of these factors (e.g., heavy workload demands and low autonomy, low supervisory support, and low peer group cohesion) were predictive of musculoskeletal problems in multiple studies.

Figure 2 shows two principal pathways from work organization factors to musculoskeletal disease; one mediated by psychological strain and one mediated by increased physical demand. With regard to the latter, it is evident that the VDT itself imposes musculoskeletal demands relating to the posture required to view the display and operate the keyboard, etc. However, it is intuitive that extent of

exposure to these demands, as well as exposure to other generic risk factors such as repetitive motion (e.g., excessive keying), is influenced by work organization factors such as the complexity of tasks (which would affect cycle time). At least two studies have shown a relationship between organizational and physical stressors in VDT work (Sauter et al.,1983a; Stellman et al., 1987), with correlations as high as 0.38 reported between these two classes of variables (Sauter et al.,1983b). Although an artifactual relationship (resulting from the effect of technology on both work organization and physical demands) cannot be ruled out, data by Lim and Carayon (1993) argue for a causal link. Using path analysis to explore the relationship between organizational factors, ergonomic demands and psychological stress, these authors reported a direct path from organizational factors to ergonomic (physical) demands.

Research support for linkages in the pathway between work organization and musculoskeletal disorders which is mediated by psychological strain is also available. Using structural analysis methods, Sauter et al. (1983b), found that factors such as job future certainty, social support and workload demands influenced somatic symptoms in VDT users by way of an intermediary effect on mood disturbances. A study of keyboard operators performing postal letter sorting tasks (Gomer et al., 1987) linked every element in the pathway mediated by psychological strain in Figure 3. Specifically, tasks involving increased visual search and memory demand were associated with reports of increased mental

demand, spectral changes in the forearm electromyogram (EMG) and increased forearm tremor, and increased musculoskeletal discomfort. Similar multilink associations were reported by investigators from the Karolinska Institute (Theorell, Harms-Ringdahl, Ahlberg-Hulten, and Westin, 1991), although the study population did not include office workers. Increased psychological demands at work were associated with increased worry, fatigue and sleep problems which, in turn, were associated with behavioral indicators of muscle tension, which were associated with increased back, neck, and shoulder discomfort.

Other studies address specific links within the psychologically-mediated pathway. Lim and Carayon (1993) and Bergquist et al., (in press, a) reported associations between indicators of psychological strain (fatigue and stomach reactions, respectively) and upper extremity musculoskeletal symptoms (Lim and Carayon, 1993; Bergquist et al., in press, a) and diagnosed disorders of the upper extremities (Bergquist et al., in press, a).

As early as 1951, Lundervold (1951) demonstrated effects of psychological demands on muscle tension in keyboard operators, supporting the link between psychological strain and biomechanical strain in the present model. More recently, Waersted, Bjorklund and Westgaard (1987; 1991) investigated static muscle loading as a possible mechanism linking work organization, psychological strain and musculoskeletal disorders among VDT users. Consistent with extensive prior

research showing effects of psychological demands on muscle tension (see Ursin, Endresen, and Ursin, 1988, and Waersted et al., 1991 for a review), increases in low level muscle tension in the trapezius were induced by increasing the complexity and attentional requirements in VDT tasks. Although the overall group effects were modest, averaging about 0.5%-1.0% of maximum voluntary contraction (MVC), considerable interindividual variability was seen, with some subjects producing sustained loads up to 6.0% MVC. The latter level is within the range thought by Jonsson (1978) to pose risk for musculoskeletal disease with chronic exposure. In this regard, it is notable that Kogi (1982) reported Japanese research showing sustained muscle loads in the range of 20%-30% in the forearm extensors among office machine operators (although a possible linkage to psychosocial demands was not discussed).

It is plausible that the direct, neurogenic effects of psychological demand on muscle tension and ensuing biomechanical strain are complemented by stress-related endocrine effects on musculoskeletal function; for example, an effect of catecholamines on the vigor of keying action (Lim and Carayon, 1993; Theorell et al, 1991). However, there has been little empirical study of such mechanisms.

Despite the evidence supporting the bold pathway in Figure 2 from organizational factors to musculoskeletal outcomes via psychological strain, it is difficult to rule out a competing pathway involving direct effects of organizational factors or

psychological strain on the perception and attribution of symptoms (i.e., the pathway denoted by the faint arrows from work organization and psychological strain in Figure 2). (This effect is examined in the discussion on somatic interpretation below.) But a more fundamental issue is whether effects attributed to the pathway from work organization through psychological strain are possibly confounded by physical effects related to 1) the path from work organization through physical demands, or 2) the covariation of physical and organizational demands resulting from the effects of technology on both of these classes of variables.

Two lines of evidence can be raised against the confounding hypothesis. First, for several types of variables found to predict musculoskeletal outcomes among VDT users, a significant effect on physical demand would seem unlikely. Examples of these types of variables include low group cohesion, work clarity, and staff support, which were predictive of RSI cases in the study by Ryan and Bampton (1988), or uncertainty regarding job future and reduced supervisory support which were predictive of musculoskeletal symptoms in a NIOSH study of telecommunications workers (NIOSH, 1992). Unlike organizational variables such as time pressure or repetitive work, it is difficult to see how changes in these conditions could elicit changes in physical workload demands (i.e., the pathway from organizational demands to physical demands would not seem to be operative).

More compelling are the results of studies which statistically separated effects relating to physical and psychosocial factors and, thus, are able to demonstrate effects unique to the psychological pathway.[3] Using multiple regression methods, Sauter et al., (1983a; 1983b) reported a significant association between worker autonomy and musculoskeletal symptoms in VDT users after adjusting for a wide variety of variables denoting physical stressors. Similarly, NIOSH (1993) found an association between supervisory support and hand/wrist symptoms in news editors after adjusting for the amount of time spent typing. Additionally, Bergquist et al., (in press, a), Lim and Carayon (1993) and Ryan and Bampton (1988) all were able to separate, to some extent, the effects of physical and organizational factors in predicting musculoskeletal problems in VDT users.

Similar evidence of effects uniquely attributable to psychosocial variables comes from Arndt (1987), Linton (1990) and Theorell et al. (1991), although none of these studies employed VDT users. The Arndt (1987) and Theorell et al. (1991) studies are of particular interest. Arndt found increased electromyographic activity in assembly workers who were implored to speed up, but who were unable to respond with increased work speed (virtually eliminating any possibility of a confound with physical factors). Like several VDT studies, Theorell et al. (1991) found effects of psychological demands on back, neck and shoulder symptoms after adjusting for physical demands (lifting demands, awkward postures, etc.). Similar to Gomer et al. (1987), the Theorell et al. (1991) study was also able to

demonstrate intermediate linkages of psychosocial demands to psychological strain, muscle tension (self-reported only) and, ultimately to musculoskeletal discomfort.

Finally, inherent limitations of cross-sectional studies, which is the predominant methodolgy in VDT health research, poses a potential problem. The cited associations between organizational factors and musculoskeletal disorders might result from an influence of symptoms on job perceptions, not the reverse. Two studies, however, tend to discount this possibility. Hopkins (1990) studied the organizational environment in workplaces with high and low prevalences of RSI. However, ratings of organizational factors were obtained from asymptomatic workers only (thereby eliminating the possibility of a symptom influence on job perceptions). Almost without exception, ratings of organizational factors were more negative in the high (RSI) prevalence workplaces. Similar findings are reported by Hales et al. (1994) who observed an association between fear of job loss and neck, shoulder, and elbow symptoms in directory assistance operators. Fear of job loss ratings within job sites were rescored based on values obtained from asymptomatic workers, and then associations with musculoskeletal symptoms were re-examined. The results showed symptoms levels were still positively associated with fear ratings; i.e., higher in units with higher fear ratings.

Psychological Mediation of the Path from Biomechanical Strain to Musculoskeletal Outcomes

Thus far, it has been suggested that psychosocial factors might contribute to musculoskeletal disorders via two paths: one involving effects on physical workplace demands, and a second involving stress-related effects on muscle function. A third possible mechanism bears some similarity to what has been referred to as an "iatrogenic" process (deriving from the Greek "iatros," meaning physician, and "genesis").

The iatrogenic hypothesis has been heavily promoted as a partial explanation for the surge in upper extremity musculoskeletal disorders witnessed internationally in the last decade. According to this hypothesis, musculoskeletal discomfort and fatigue are endemic in VDT work. Environmental forces, including not only medical practitioners, but also social and cultural factors, legal-compensation systems, and workplace industrial relations then encourage the interpretation of discomfort as signals of underlying injury and promote the development of sick roles and disability (Bell, 1989; Cleland, 1987; Hadler, 1986; 1990). Although the iatrogenic hypothesis has not been empirically tested in the context of VDT work, this type of explanation finds support in the medical anthropologic and sociologic literature which identifies significant cultural variations in response to somatic symptoms (see, for example, Hocking, 1987b; Mechanic, 1972).

The iatrogenic hypothesis converges to some extent with an extensive area of investigation in psychology which offers a theoretically deeper and richer formulation for explaining iatrogenic-like effects on musculoskeletal disorders. Extensive research in social and cognitive psychology in the last two decades has sought to explain how people interpret internal somatic information such as sensations associated with emotional response or illness. Space does not permit more than the briefest summary of this work (see Cioffi, this volume; Cioffi, 1991; Pennebaker and Hall, 1982 for excellent reviews), but the theory and findings suggest that response to somatic signals involves a multistage attributional process which is governed by cognitive and environmental factors.

First, as in the perception of any stimulus, whether or not an event is even noticed depends upon factors such as the degree of arousal of the individual and the salience of competing stimuli (which could mask the somatic stimulus). Second, once detected, explanations for the sensation are sought, which involves labeling the sensation and then deducing its cause. Social psychological research has shown that this inferential process is highly influenced by situational and experiential factors. In the classic studies in this area, subjects were injected with epinephrine to induce psychological and physiological arousal, but were uninformed about the effects. It was then demonstrated that self-labeling of the arousal state as euphoria or anger could be readily manipulated by exposure of the subjects to euphoric or angry confederates (Schacter and Singer, 1962). Importantly, this

attributional process is understood to be a natural, probably hard-wired, and lawful process that has survival value for the organism (Cioffi, this volume; Pennebaker and Hall, 1982); i.e., it is normal to seek causal explanations for events in and around us, and to rely on contextual cues when the stimuli are ambiguous, which is often the case with somatic sensations.

In the current model of musculoskeletal disorders, it is suggested that somatic interpretation processes as discussed here (shaded area in Fig. 2) mediate between biomechanical strain and musculoskeletal outcomes, and that these processes are influenced by various psychosocial factors (faint parallel inputs to the shaded processes in Fig. 2). Within this framework, several effects of stress and psychosocial factors on musculoskeletal disorders seem plausible, although studies to confirm these effects have not been undertaken.

With regard to the detection of symptoms, it is possible that stress-related arousal may sharpen sensitivity to normally sub-threshold musculoskeletal stimuli. Work organization might similarly influence the detection of musculoskeletal signals. For example, competition for attention to musculoskeletal stimuli may be considerably reduced in dull routine tasks in comparison to more varied, challenging tasks providing richer environmental stimulation. This may help to explain, for example, why clerical-level VDT jobs are associated with increased musculoskeletal symptoms in several studies (e.g., Canadian Labour Congress,

1982; Sauter et al, 1983a; Sauter et al, 1983b; Smith et al. 1981), or why monotonous work was associated with neck symptoms in a Swedish working population (Linton, 1990). Ironically, as discussed by Pennebaker and Hall (1982), this mechanism might also increase the health risk for workers in more challenging, engrossing tasks by reducing their relative awareness to somatic danger signals. Could such a suppression phenomenon partially explain, for example, the reportedly high prevalence of musculoskeletal disorders among news editors (NIOSH, 1989; 1993)?

It is also possible to suggest ways in which psychosocial conditions might influence the labeling and attribution of musculoskeletal sensations. Assuming that people hold implicit hypotheses that stress promotes disease, it is predictable that musculoskeletal sensations arising in the context of stressful working conditions might be interpreted as signals of injury or disease. Further, attribution of these symptoms to the job might seem natural in the presence of adverse organizational conditions such as a negative safety climate. NIOSH (1993) found, for example, that perceived lack of management support for ergonomic programs nearly doubled the odds for neck symptoms among news editors.

Effects of personality or dispositional factors on musculoskeletal disorders in office work (Bergquist et al., in press, a; Spillane and Deves, 1988) and in other occupations (Bigos, Battie, Spengler, Fisher, Fordyce, Hansson, Nachemson and

Wortley, 1991; Ursin et al., 1988) might also be explained within the somatic interpretation framework. It is possible, for example, that negative affectivity, shown by Bergquist et al. (in press, a) to predict neck and shoulder discomfort among VDT users, colors the labeling of sensations in negative (disease) terms. (Self-reports of working conditions might be similarly influenced adversely by negative affectivity, which would tend to inflate associations of organizational factors and musculoskeletal outcomes.)

Although the current model highlights somatic interpretation, it is important to emphasize that this process has not been investigated in the context of work-related musculoskeletal disorders, and thus the significance of this mechanism in comparison with other mechanisms suggested in the current model is unkown. It is very doubtful that this mechanism alone could fully explain the relationship between psychosocial factors and musculoskeletal disorders seen in the extant literature. Several studies have demonstrated significant associations between workplace psychosocial factors and more objective indices of musculoskeletal disorders involving clinical evaluation (Bergquist, in press, a; Hales et al, 1994; Leino, 1989; NIOSH, 1992; Ryan and Bampton, 1988; Toomingas, 1992). Use of more objective methods for assessment of musculoskeletal disorders obviates, to a considerable extent, the influence of cognitive processes which are integral to the somatic interpretation explanation.

Feedback effects

Finally, the current model shows reciprocal effects of musculoskeletal disorders on psychological strain and work organization. This pathway is highly intuitive. For example, adjustments in job tasks such as assignment to "light duty" or other forms of work redesign are commonly made for injured or symptomatic workers. With regard to effects on psychological strain, Ghiringhelli (1980) reported fear of health impairment to be an important source of stress among VDT users. However, evidence supporting such effects is quite limited. Sauter et al. (1983b) conducted a series of analyses showing interdependencies illness symptoms and mood states in a sample of office workers, including VDT users. One other study, with a longitudinal design permitting stronger causal inference, reported this type of effect in a sample of office and production workers. Leino (1989) found that 1973-1978 stress symptom scores predicted rheumatic symptoms and clinically-defined musculoskeletal disorders upon follow-up in 1983. However, among male workers, rheumatic symptoms and musculoskeletal disorders in 1973-1978 also predicted stress symptoms in 1983.

Summary and Direction

A theoretical model suggesting multiple causal linkages between workplace psychosocial factors and musculoskeletal disorders in VDT work is discussed. This model and its linkages do not diminish the importance of physical

environmental/ergonomic factors in the etiology of musculoskeletal disorders which is supported in prior research (Hunting, Laubli and Grandjean, 1981; Sauter, Schleifer and Knutson, 1991); rather, psychosocial effects are depicted as complementary to and interactive with effects of physical workplace demands. Further, the psychological mechanisms linking or mediating between psychosocial factors and musculoskeletal disorders are discussed as normal psychological processes, in contrast to clinical or abnormalistic characterizations by others (e.g., Luciere, 1986; Spillane and Deves, 1987).

Evidence presented in support of the psychosocial pathways suggested in these models is neither perfect nor complete. More powerful study methods employing longitudinal designs, improved exposure (to both psychosocial and ergonomic demands) and health assessment, and improved analytical schemes such as structural analysis would be useful in substantiating and isolating the effects of psychosocial factors. Further, research is needed to evaluate the strength of specific pathways postulated in the model. For example, to our knowledge, studies have not looked at the magnitude of static muscle loads during actual workplace exposure to known psychosocial stressors (e.g., deadline work, electronic monitoring, etc.). Thus, the need for further analytic study is evident.

But, from a prevention imperative, an additional course of investigation is worth consideration. Specifically, case study of <u>organizational interventions</u> to prevent

musculoskeletal disorders in VDT work suggest rather powerful effects of psychosocial factors. According to Westin (1990), for example, the Federal Express Corporation has been able to maintain high levels of productivity with minimal experience of musculoskeletal disorders among VDT users by adopting a "people-technology" philosophy that gives priority to improving job design to minimize monotony, by adoption of participative management practices, and by improved employee education among other measures.

Intervention studies often do not permit the type of control or manipulation needed to define specific mechanisms or pathways of effect. Further, naturalistic interventions are not always pure enough to isolate specific causal factors. Indeed, the people-technology philosophy at Federal Express also included a commitment to improved ergonomics. Still, these types of studies have a high degree of ecological validity and can be much more powerful motivators of preventive actions than the more molecular investigations which have been examined in this paper.

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Footnotes

[1]Although negative affectivity is commonly discussed as an individual or personality characteristic (e.g., see Watson and Pennebaker, 1989), it is plausible that, like job attitudes such as job dissatisfaction, negative affectivity could be shaped by chronic exposure to stressful working conditions. These two perspectives would have different implications (i.e., in terms of focussing on the person or the job) in attributing the cause of health outcomes associated with negative affectivity and in the design of interventions.

[2]It should be noted, however, that the authors were reluctant to represent this model as an "explanatory" model. Rather they describe it as a vehicle for their extensive review of studies exploring associations between psychosocial factors and musculoskeletal disease.

[3]However, this counterargument to the confounding hypothesis rests in part on the adequacy of the exposure assessment for physical demands, which has been a difficult issue and may be problematic in many studies.

Figure Legends:

Figure 1. The psychosocial stress process.

Figure 2. An ecological model of musculoskeletal disorders in VDT work.

Figure 3. Components of the ecological model.

Figure 5. Moderating effects of psychosocial factors on musculoskeletal outcomes.

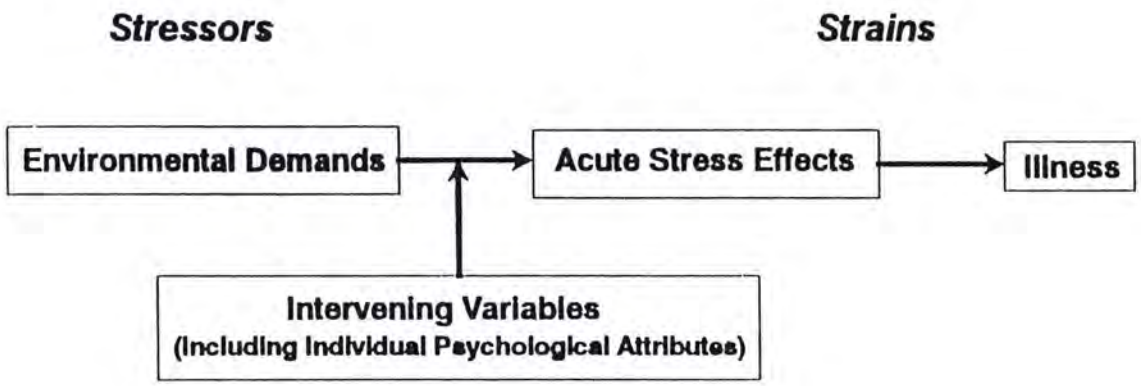
Stressors
Strains
Environmental Demands
Acute Stress Effects
Illness
Intervening Variables
(Including Individual Psychological Attributes)

Fig. 1.

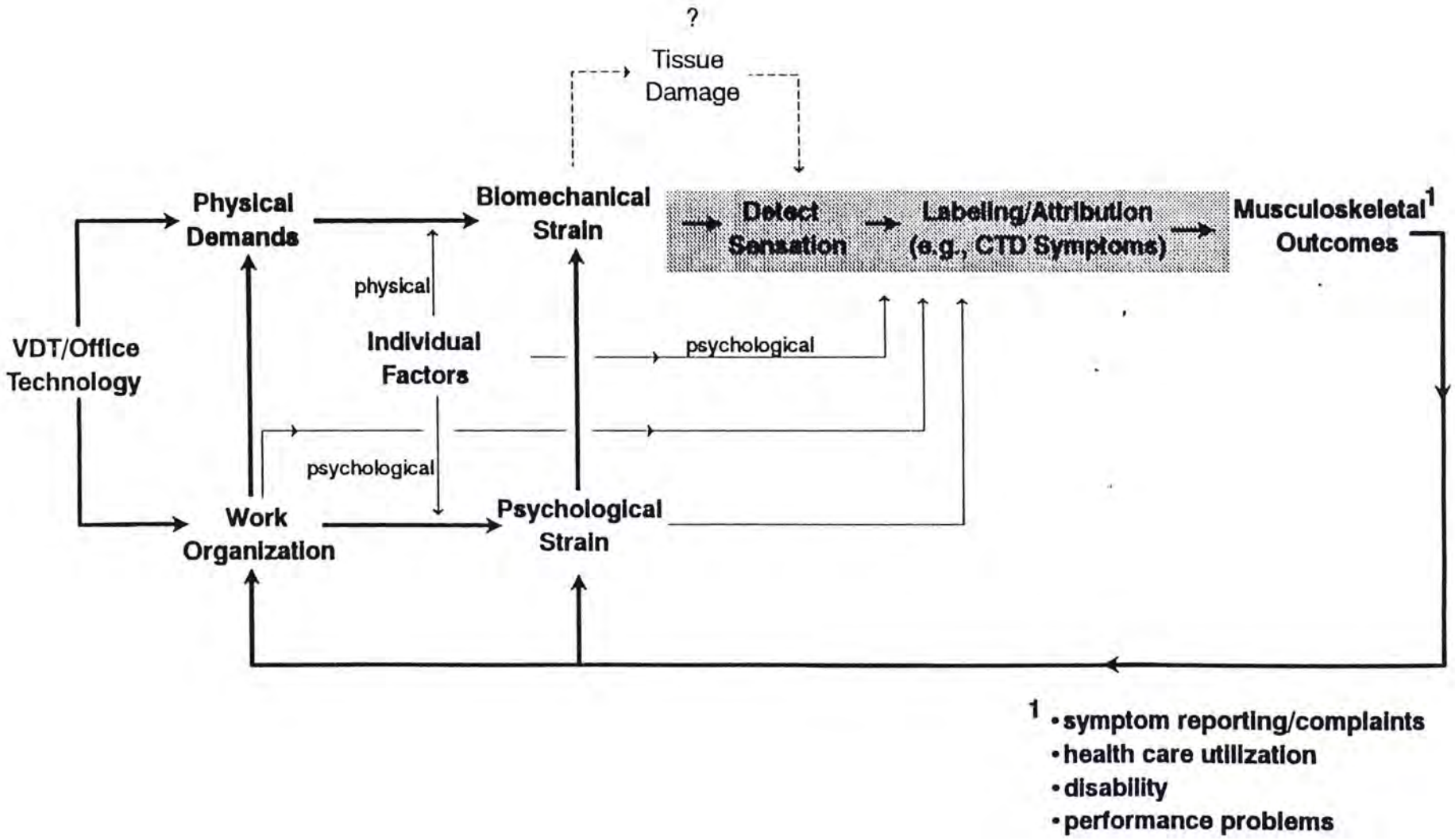
?
Tissue Damage
Physical Demands
Biomechanical Strain
Detect Sensation
Labeling/Attribution (e.g., CTD Symptoms)
Musculoskeletal Outcomes
1
physical
VDT/Office Technology
Individual Factors
psychological
psychological
Work Organization
Psychological Strain
1 • symptom reporting/complaints
• health care utilization
• disability
• performance problems

Fig. 2.

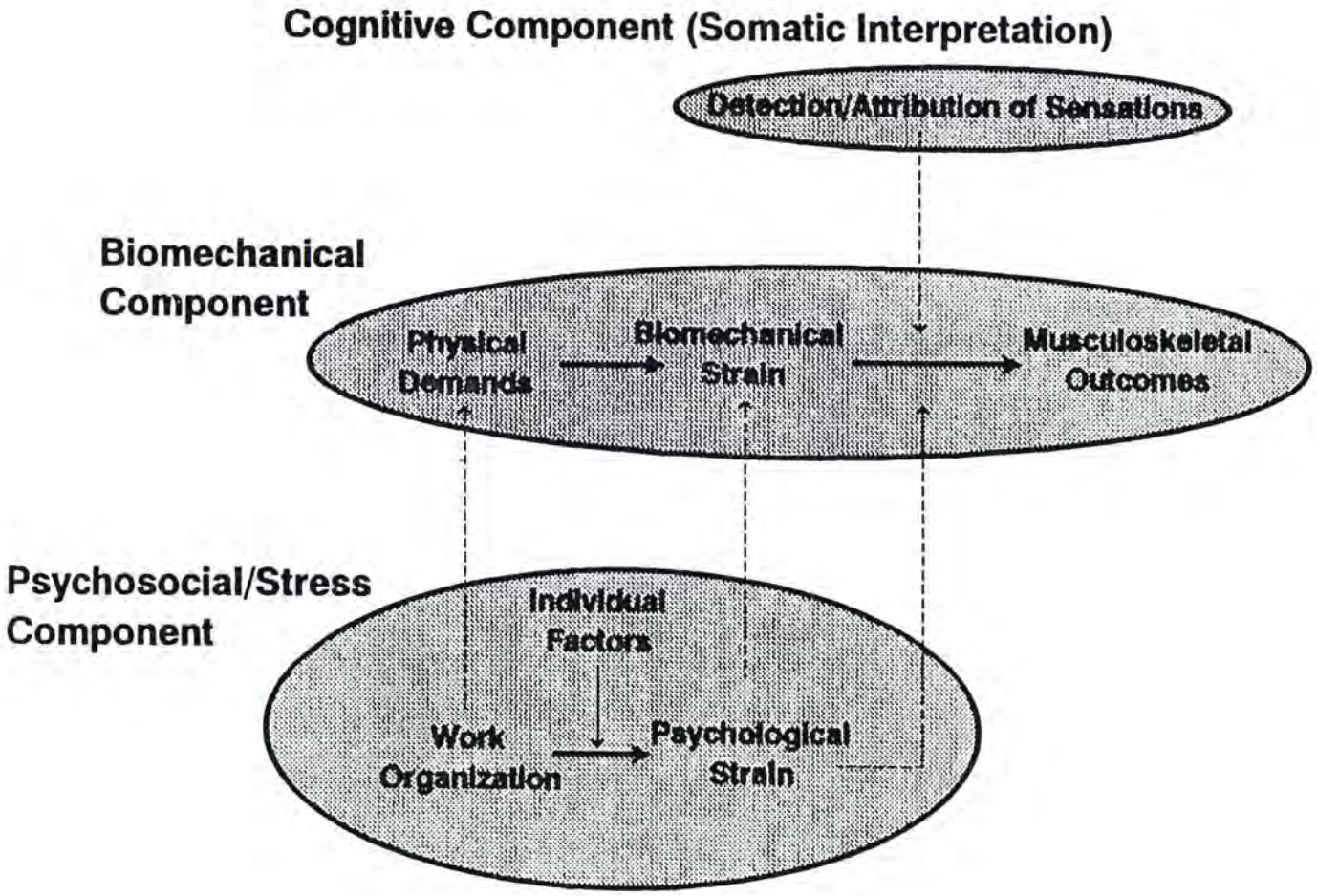
Cognitive Component (Somatic Interpretation)
Detection/Attribution of Sensations
Biomechanical Component
Physical Demands
Biomechanical Strain
Musculoskeletal Outcomes
Psychosocial/Stress Component
Individual Factors
Work Organization
Psychological Strain

Fig. 3.

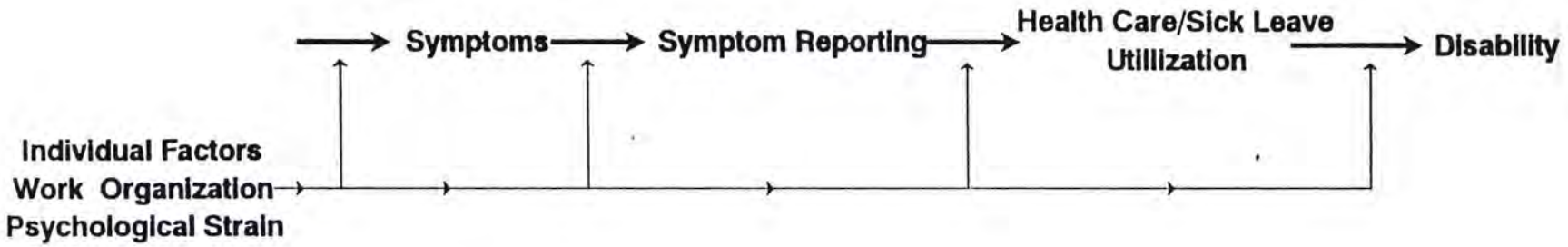
Symptoms
Symptom Reporting
Health Care/Sick Leave
Utillization
Disability
Individual Factors
Work Organization
Psychological Strain

Fig. 4