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Evaluation of an Ecological Model for Work-Related Musculoskeletal Disorders

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Work-related musculoskeletal disorder is a major occupational health problem worldwide. The ecological model by Sauter and Swanson proposes a way in which psychosocial factors can influence musculoskeletal disorders. Employing Chinn and Kramer's framework, we evaluated the ecological model and found it had a specific scope for the working populations and clear concepts. This model also demonstrated high clarity, consistency, generalizability, and accessibility aligning with a nursing metaparadigm. Empirical evidence supports the applicability of the ecological model in nursing research and practices, but more research is needed for nursing-specific application. **Key words:** *conceptual model*, *ecological model*, *framework*, *theory description*, *theory evaluation*, *work-related musculoskeletal disorders*

MUSCULOSKELETAL DISORDERS (MSDs) are defined as soft-tissue injuries caused by sudden or sustained exposure to repetitive motion, force, vibration, and awkward positions,[1] which account for the single largest category of occupational health problems and lead to a temporary or permanent disability.[2] In the United States, approximately 2.4 million workers have musculoskeletal conditions annually, which indicates 25.4 per 10 000 person-years.[3] The European Agency for Safety and Health at Work pointed out that, considering the effect of demographic aging, MSDs are not limited to an occupational health challenge, but extend to a public health challenge.[4] As a major contributor to disability, MSDs significantly limit the dexterity and mobility of workers, resulting in absenteeism, early retirement from work, and reduced quality of life.[5] Nursing is an occupation that is particularly subject to MSDs as it involves physically demanding tasks such as manual patient handling. Nursing also involves emotionally demanding components as nurses are required to suppress their own emotional reaction while assuaging the fear and distress of their patients, all of which may cause mental stress and increase the risk of MSDs.[6]

For MSDs that are caused or exacerbated by work itself or by the circumstances of work performance, it is referred to as work-related musculoskeletal disorders (WRMSDs).[7] The term "work-related" is more appropriate because it takes more risk factors into account than "occupational," where a single factor is understood to cause the disease.[8] Reflecting on multiple risk factors and the interconnection between WRMSDs, many theorists have attempted to conceptualize the etiology of WRMSDs. Biomechanical

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Statements of Significance

What is known or assumed to be true about this topic?

Work-related musculoskeletal disorder is a complex concept in terms of its multiple risk factors. Many theories have been developed to address this phenomenon. Sauter and Swanson introduced the ecological model for musculoskeletal outcomes incorporating psychosocial factors into their model along with physical work factors. This model is also distinguished from other models by focusing on cognitive processes and expanded musculoskeletal outcomes. Despite a wide use of the ecological model by Sauter and Swanson, the critical analysis of the theory has yet to be published.

What this article adds:

This article provides the description and evaluation of Sauter and Swanson's ecological model for musculoskeletal outcomes employing Chinn and Kramer's framework. The ecological model showed coherent content throughout the theory within a specific scope for working population and clear concept definition. Also, the ecological model is demonstrated high clarity, consistency, generalizability, and accessibility aligning with the nursing metaparadigm. Based on the empirical evidence, the ecological model has the potential to apply in nursing research and practices.

models postulate that exceeding mechanical loads over one's internal tolerance leads to WRMSDs.[9] In pathomechanisms, MSDs are induced by muscular imbalance, impaired neural mechanisms, and overburden of small motor units due to awkward or repetitive postures.[10] While these models have focused primarily on physical work factors and biophysiological responses, extensive research has also identified the significant role of psychosocial factors in the etiology of WRMSDs. This line of research is basically built on the stress paradigm that stress, as a highly individualized and subjective phenomenon, triggers physiological and psychological changes resulting in illnesses.[11]

Sauter and Swanson[12] proposed to incorporate psychological strain into their ecological model for WRMSDs in addition to biomechanical load (see the Figure). The primary goal of the ecological model was to propose how work organization factors—any work-related risk factors for job stress such as supervisor support, job demand, and job control—may elicit psychological strain, which in turn are connected to WRMSDs.[12] Although Sauter and Swanson developed the ecological model for office workers, many studies provided evidence for its relevance in nursing field. Based on the ecological model, Eatough et al[13] found that work organization factors such as role conflict, job control, and lack of safety-focused leadership were positively related to WRMSDs among US workers including nurses, after controlling for physical job demands. Chang et al[14] also reported nurses who perceived higher imbalance between the social support they have to provide to and the support they can receive from their coworkers were more likely to have WRMSDs via psychological strain. Many other studies showed further evidence that work organization factors contribute to WRMSDs among nurses after controlling for exposure to physical demands.[14-16]

In this context, the ecological model of WRMSDs focusing on work organization can be a useful theoretical framework for nursing research and practices to understand and prevent WRMSDs among nurses. Despite its potential value, to date, very limited studies have analyzed or tested the ecological model. Therefore, the purpose of this article is to evaluate the ecological model by Sauter and Swanson, employing Chinn and Kramer's framework to determine its appropriateness and usefulness for research and practices on WRMSDs among nurses. Chinn and Kramer's framework focuses on

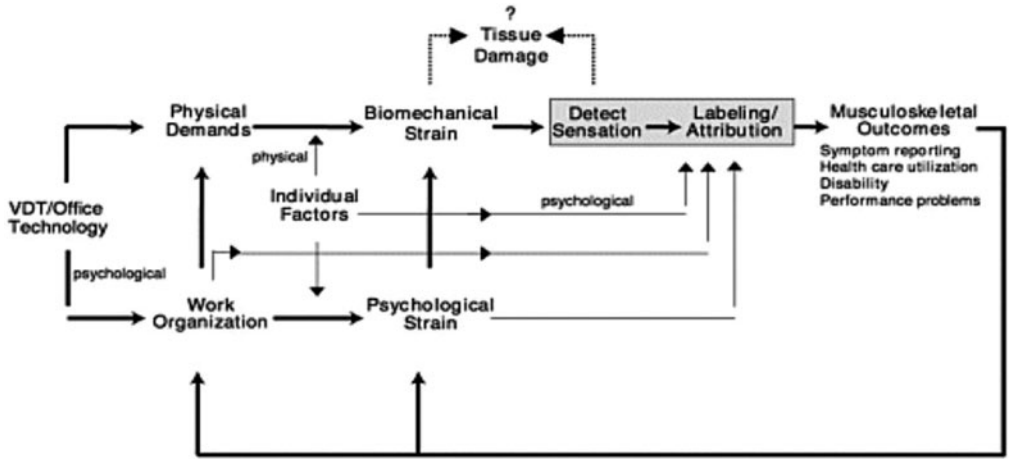

Figure. Ecological model by Sauter and Swanson.[12]

2 components that are appropriate for analysis and evaluation of a theory in detail: description and critical reflection. Description includes theory's purpose, concepts, definition, assumptions, structure, and relationships, and critical reflection assesses the theory's clarity, simplicity, generality, accessibility, and importance.

THEORY DESCRIPTION

Purpose and scope

The purpose of the ecological model is to present a holistic pathway through which psychosocial factors at work, alongside physical factors, can contribute to WRMSD progression for office workers.[12] Considering that the concept and proposition of this model are relatively specific and can be directly converted into measures for testing, it is appropriate to consider the ecological model as a middle-range theory.

Concept and definition

Chinn and Kramer[17] defined concepts as structured ideas within a theory, and definition as implied meanings. In general, the term "psychosocial factors" at work broadly encompasses nonphysical elements of the work environment and is often used interchangeably with the term "work organization."[12] Sauter and Swanson, however, attempted to distinguish between psychosocial factors and work organization factors. In the ecological model, work organization represents any work or organizational factors of job stress, whereas psychosocial factors refer to both job and individual attributes that affect job stress. Sauter and Swanson postulated that there are common work factors causing strain, although the magnitude of the response may vary in person to person. In this model, specific individual factors and work organization factors feed the stress process. The individual factors include genetic factors, acquired aspects, and dispositional factors such as personality and attitudes.[12] Sauter and Swanson also elaborated on several dimensions of the work organization factors: (1) physical aspects of work (eg, physical environmental conditions including physical ergonomic demands such as lifting requirements); (2) temporal aspects of the job (eg, hours of work and work-rest schedule, work shift, and work pace); (3) job content (eg, scope and repetitiveness of tasks, use of skills, vigilance/mental workload demands, participation in decision-making, work roles, and clarity of demands); (4) interpersonal relationships (eg, group cohesion,

supportiveness of peers and supervisors, and the availability of feedback); (5) organizational aspects (eg, vertical/horizontal organizational structure, associated bureaucratic characteristics, values, communication styles, training, and career development opportunities); (6) financial/economic aspects (eg, salary and benefits); and (7) community/societal aspects (eg, status/prestige associated with the job).[12] In addition, work technology is a comprehensive concept that embraces the nature of work and the work system. In their model for office workers, Sauter and Swanson[12] designated mechanized or automated information work within the nature of work and visual display technology or computers as a main work system.

Relationship and structure

According to Chinn and Kramer,[17] relationships refer to the linkages among and between concepts, and structure is the overall form of the relationships. Within a theory, structure reflects on perspective of the relationship between an individual and the environment, and assumptions enable theoretical reasoning, as the accepted truths held by theorists.[17] The Figure shows how the concepts of the ecological model are interconnected. Sauter and Swanson suggest that work technology, as the ultimate cause of the musculoskeletal mechanism, directly links to physical demands or work organization. The ecological model comprises biomechanical, psychosocial, and cognitive structures—all of which are components of the pathways from work technology to musculoskeletal outcomes. In the biomechanical structure, physical demands have a direct path to biomechanical strain, which, in turn, is connected to musculoskeletal outcomes, and this process is mediated by cognitive structures. In the psychosocial structure, work organization induces psychological strain, affects physical demands leading biomechanical, and moderates the relationship between biomechanical strain and the appearance of musculoskeletal symptoms. Cognitive structure is the process of detection and labeling symptoms, which is affected by psychological strain, individual attributes, and work organization. Sauter and Swanson suggested that work organization factors, such as the safety climate defined as workers' perceptions regarding the safety aspects of their organization,[18] may have directly contributed for workers to detect and interpret their somatic symptoms, regardless of the accompanying stress. The detection, labeling, and attribution of sensations may also be affected by psychological strain such as increased mood disturbance, worries, and fatigue. Finally, musculoskeletal outcomes such as symptom reporting, health care utilization, disability, and performance problems are hypothesized to generate a feedback loop to work organization factors and psychological strain.[12] According to the ecological model, the individual is a part of the environment within the linkage among 3 structural frameworks (biomechanical, psychosocial, and cognitive)—rather than a feature separate from the environment. The reciprocal interactions among persons, environment, and health are aligned with the nursing metaparadigm.

Assumptions

While the ecological model did not provide its assumptions, a couple of assumptions can be explored. Primarily, Sauter and Swanson assumed that stress plays a crucial role in creating musculoskeletal outcomes and WRMSDs result from the interrelationships of multiple factors including biomechanical, psychosocial, and cognitive processes. Another assumption is that symptom detection and labeling are a complex cognitive process that is supposed to be interpreted in a social context and personal experience. Sauter and Swanson put forth a holistic approach, borrowing from all the above assumptions about various associated factors.

CRITICAL REFLECTION

Clarity and consistency can be classified into 2 parts by the characteristics of a theory:

the semantic part and the structural part. Semantic clarity and consistency help us examine how well the concepts are defined for their intended purpose and whether the meaning of the concepts is maintained in the same way.[17] Structural clarity and consistency refer to how discernible and relevant the connections are and whether structural forms are used consistently throughout a theory.[17] Simplicity—defined as using a minimal number of elements—is determined by the intended purpose of the theory.[17] In the framework, while the breadth of scope and purposes of a theory determine a theory's generality, a clear concept and purpose can enhance the theory's accessibility, which refers to the ability to be empirically identified. For example, without clear definition in the ecological model of WRMSDs, the term "work organization" could have conveyed many dimensions of meaning, but Sauter and Swanson set a clear definition of work organization so that it can be empirically accessible to measure. Increasing the complexity of a theory often increases its empiric accessibility by showing more detailed pathways.[17] The importance of a theory can be determined by its clinical significance or practical value, reflecting the professional and personal values of the person who proposes the theory.[17]

Semantic clarity and consistency

The semantic clarity of WRMSD frameworks can be hampered by the very broad use of the nonspecific term "psychosocial" in occupational health. To enhance the clarity and consistency, Sauter and Swanson make a distinction between the concept "work organization" and "psychosocial factors" and use the term "work organization" only in their model. Further, they provide specific examples for work organization and the pathway from the work organization to the psychological strain that is moderated by individual attributes. An appropriate and wise use of definitions and examples in the ecological model accomplishes a high level of conceptual clarity. The ecological model also shows semantic consistency, as it coherently delivers the same meaning of the main concept throughout the theory.

Structural clarity and consistency

Based on the clear and coherent concepts in the ecological model, as described previously, the relationships between concepts are transparently and consistently presented with diagram. The ecological model depicts the pathways from work technology to musculoskeletal outcomes via 2 routes: physical demands causing biomechanical strain and work organization causing psychological strain. Sauter and Swanson also emphasize the roles of work organization and psychological strain, which affect the physical demands and biomechanical strain. Overall, the structure of the ecological model reaches a high degree of clarity and consistency.

Simplicity or complexity

The ecological model comprises 3 components: (1) visual display technology/office technology as a primary workplace system-level factor affecting the physical and psychosocial work environment and conditions (physical demands and work organization); (2) 3 structures (biomechanical, psychosocial, and cognitive structure) leading to musculoskeletal outcomes; and (3) musculoskeletal outcomes including symptom reporting, health care utilization, disability, and performance problems. The model proposes pathways and interrelations among these components; such multiple concepts and compositions of relationships may induce some complexity. On the other hand, Sauter and Swanson reduce the complexity of the model by not including a detailed physiological response pathway to biomechanical and psychological strain. When strain occurs, a response with adaptive or degenerative changes can subsequently reproduce the observed pathologies. Overall, the ecological model by Sauter and Swanson appears to be complex but fails to include some important factors such as physiological response.

Generality

Sauter and Swanson's ecological model was developed primarily for office workers who are subject to a sedentary work environment using computers. In their original model, Sauter and Swanson focused on upper extremity MSDs, but their model serves as a general theoretical framework for MSDs including other body regions.[13,19] The model has also been applied to various type of work settings. To investigate the generality of their theory, we performed a database search using PubMed, CINAHL, and Google Scholar with the key terms "ecological model" and "musculoskeletal disorders" and located studies conducted after 1996 (the theory development year). As shown in the Table, 9 studies were found to be relevant.[13,14,19-25] All studies except for Haukka et al[19] tested the main pathways in the ecological model (associations among work technology/work organization, psychological strain, and musculoskeletal outcomes); their findings were empirically supportive of the theory. One study performed a randomized controlled trial to examine the efficacy of a participatory ergonomics intervention in preventing MSDs based on Sauter and Swanson's ecological model but failed to find supportive evidence.[19] Of these, 4 studies[13,14,19,20] targeted various workers other than office workers such as nurses, kitchen workers, and manufacturing workers and found the supportive evidence for Sauter and Swanson's ecological model. The geographical spread of the studies using the ecological model was global, including England, Finland, Malaysia, Sweden, and United States. Based on the broad application of this theory to different work settings in different countries, the ecological model appears to possess a high degree of generality.

Accessibility

The complexity and conceptual clarity for the ecological model yield empirically identifiable phenomena. MSDs and work organization have been measured using validated scales. Based on the data search for assessing the generality of Sauter and Swanson's ecological model, most of the studies summarized in the Table used a standardized questionnaire for musculoskeletal symptoms, such as the Nordic Musculoskeletal Questionnaire (NMQ)[13,14,25] and the National Institute for Occupational Safety and Health (NIOSH) survey for musculoskeletal symptoms.[21-23] For work organization, many studies included job demand, job decision latitude, social support, and role conflict in work organization factors[13,14,20,23-25] and used the Job Content Questionnaire or Effort-Reward Imbalance questionnaire.[13,14,20,24] Given this evidence, the ecological model serves as an accessible tool for advancing research.

Importance

As depicted in the Table, the ecological model demonstrates its significance in WRMSD research within various settings. Although Haukka et al[19] failed to find evidence for the efficacy of the ergonomic intervention in preventing WRMSDs among kitchen workers, Swanson and Sauter[23] supported the relationships for keyboard condition and WRMSD symptoms, keyboard condition and work organization, and work organization and stress among office workers using longitudinal study design. For the utility of the ecological model pertaining to nursing personnel, Chang et al[14] showed the potential of the ecological model to apply in nursing field, as they found the association between work organization and nurses' WRMSDs via psychological strain. The ecological model was developed for upper extremity WRMSDs, but it is also verified for various WRMSDs in different body regions. Sauter and Swanson's model emphasizes that work organization factors, along with physical demands, play a pivotal role in the development and progression of WRMSDs. For intervention to prevent WRMSDs, Sauter and Swanson highlight the importance of organizational practices in terms of commitment to workers' safety and health or more supportive policies to

Table. Application of the Ecological Model in the Research

Author(s)	Purpose	Design and Sample	Concepts and Instruments	Empirical Findings
Amick et al[20]	To test pathways proposed by the ecological model	Design: cross-sectional Sample: 1779 workers at a large aerospace manufacturing company in the United States	1. Physical demand: observation 2. Work organization: JCQ 3. Psychological strain: nonspecific psychosocial measure 4. Individual: demographics 5. Labeling/attribution: Crowne-Marlowe measure 6. Musculoskeletal outcomes: self-formulated questionnaire	The study found the effect work organization on both psychological strain and MS symptoms
Swanson and Sauter[23]	To test pathways between physical, work organization, psychosocial stress, and MS symptom based on the ecological model	Design: longitudinal Sample: 189 office-workers in the United States	1. Psychosocial aspects: NIOSH job stress questionnaire 2. Musculoskeletal symptoms: NIOSH symptom survey 3. Work technology: keyboards	The study provided partial support for the tested pathways: significant relationships for keyboard condition and MS symptoms, keyboard condition and work organization, and work organization and stress were found.
Conway[21]	To examine the relationship between psychosocial factors of work, mental strain, personal factors, and MS discomfort based on the ecological model	Design: cross-sectional Sample: 214 office-workers in the United States	1. Psychosocial work aspects: NIOSH job stress questionnaire 2. Psychological stress: Profile of Mood States-short version 3. Individual factors: demographics 4. Musculoskeletal symptoms: NIOSH symptom survey	The study demonstrated the significance of total mood disturbance on MS discomfort for employees performing intensive data entry work

(*continues*)

Table. Application of the Ecological Model in the Research (*Continued*)

Author(s)	Purpose	Design and Sample	Concepts and Instruments	Empirical Findings
Devereux[22]	To examine the pathway between perceived work-related mental stress and recurrent hand/wrist problems based on the ecological model	Design: cross-sectional Sample: 2084 office-workers in England	1. Individual: demographics 2. Physical work factors: self-formulated questionnaire 3. Psychosocial stress: self-formulated questionnaire 4. Musculoskeletal symptoms: NIOSH symptom survey	The study found that physical strain from performing more than 4 hours of keyboard work per day and perceiving the job to be mentally stressful mediates the exposure-effect relationship between keyboard work and recurrent hand/wrist problems
Zakerian and Subramaniam[25]	To examine the association among 3 factors (psychosocial work factors, work stress, and musculoskeletal discomfort) based on the ecological model	Design: cross-sectional Sample: 30 office-workers in Malaysia	1. Psychosocial work factors: University of Wisconsin Madison Office Worker Survey 2. Musculoskeletal discomfort: the standardized NMQ	The study reported a significant relationship among psychosocial work factors, work stress, and MS discomfort
Wahlstrom et al[24]	To investigate whether perceived muscular tension, psychological demands, and stress are associated with physical load or working technique during VDU work	Design: cross-sectional Sample: 57 VDU office-workers in Sweden	1. Psychological demands: JCQ 2. Emotional stress: self-formulated questionnaire 3. Perceived muscular tension: self-formulated questionnaire 4. Working technique: observation 5. Muscle activity: commercial electromyography system 6. Wrist movements: electrogoniometers 7. MS symptoms: self-formulated questionnaire	The study found perceived muscular tension and emotional stress were associated with physical load, in terms of muscle activity in the trapezius muscles, during VDU work in ordinary occupational settings, which is aligned with hypotheses of the ecological model

(*continues*)

Table. Application of the Ecological Model in the Research (*Continued*)

Author(s)	Purpose	Design and Sample	Concepts and Instruments	Empirical Findings
Haukka et al[19]	To examine the efficacy of an ergonomic intervention in preventing MSDs among kitchen workers	Design: RCT Sample: 504 kitchen workers in Finland	1. Ergonomic intervention: ergonomic change 2. MS symptoms: self-formulated questionnaire	The study failed to find evidence for the efficacy of the intervention in preventing MSDs
Eatough et al[13]	To test the ecological model, a stress-based model that links psychosocial work stressor, strain, and MS symptoms	Design: cross-sectional Sample: 277 a wide range of employees (retail/services, nurse, teacher, and computer programmer) in the United States	1. Psychosocial work factors: JCQ 2. Psychological stress: the Brief Symptom Inventory-18 3. Individual: demographics 4. MS symptoms: the standardized NMQ	The study demonstrated the link between psychosocial work stressors (low safety leadership, low job control, and high role conflict) and MS symptoms. This study also found a partial mediation by strain between psychosocial work stressors and MS symptoms
Chang et al[14]	To examine the association among 3 factors (psychosocial work factors, psychological strain, and musculoskeletal symptoms) based on the ecological model	Design: cross-sectional Sample: 410 nurses in the United States	1. Psychosocial work factors: Social Burden Scale, Social Support Scale, Social Support Questionnaire for Transactions 2. Psychological stress: Emotional Strain Scale 3. MS symptoms: the standardized NMQ	The study reported a significant association among imbalance in perceived social support, anger, and MS symptoms in low back and upper limbs

Abbreviations: JCQ, Job Content Questionnaire; MS, musculoskeletal; MSDs, musculoskeletal disorders; NIOSH, National Institute for Occupational Safety and Health; NMQ, Nordic Musculoskeletal Questionnaire; RCT, randomized controlled trial; VDU, visual display unit.

decrease work disability rates and to facilitate work reintegration and retention after WRMSDs. According to previous studies, educations or training in proper body mechanics for nurses does not prevent their WRMSDs due to the cumulative effect of patient handling tasks and work organization factors such as limited staffing, lack of policies, time constraint, and lack of management support work as a barrier for nurses to the use of assistive devices in patient handling.[26] Considering that intervention programs focusing only on individual behaviors and physical factors are not effective, the ecological model integrating the important role of work organization can be useful for nursing practices and effective intervention programs.

CONCLUSION

Sauter and Swanson's ecological model shows a specific scope for working populations and clear concepts. This model demonstrates great clarity, consistency, and generalizability. This model also provides a comprehensive understanding of WRMSDs by showing multiple potential pathways to WRMSDs. Incorporating work organization into the model for WRMSDs, the ecological model emphasizes the 3 structures of biomechanical, psychosocial, and cognitive processes—all of which can be important factors for prevention and management of WRMSDs. The key strength of this model is highlighting person-environment interactions. Sauter and Swanson addressed why the progression of WRMSDs varies from person to person even under the same circumstances, by describing how environment factors in workplace affect physical health via strain that is highly personal and contextual in the model. In the ecological model, WRMSDs, as a dynamic process, are influenced by the environment through individual responses and the reciprocal interactions of the model are consistent with the discipline of the nursing metaparadigm. Overall, Sauter and Swanson's ecological model can serve as a useful theoretical framework for both nursing research and practices where both physical factors and work organization factors must be considered to prevent WRMSDs. More research using Sauter and Swanson's ecological model for WRMSDs among nurses would provide further evidence on the utility of the model.

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