Stress and Work-Related Musculoskeletal Disorders of the upper extremities

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Work-related musculoskeletal disorders of the upper extremities (WRMSDue) are one of the main causes of work-related illnesses in Europe. This catch-all term refers to both a wide array of disorders and the fact that work-related stresses are causal in their development. So, biomechanical (repetitive motions, effort, extreme joint postures) and psychosocial risk factors have been demonstrated. The role of stress and work-related psychosocial factors in the development of WRMSDue is still poorly understood and there is still no consensus on the epidemiological data. However, it seems likely that the body responds to stress factors through four systems – central nervous, autonomic nervous, endocrine and immune – which are constantly interacting as a complex network. Whether or not, the fact that we do not understand the specific mechanics of the associations between stress and WRMSDue is no reason not to put in place preventive measures which include organizational and psychosocial factors because there is sufficiently compelling scientific evidence to bear out the effectiveness of a holistic approach to work situations.

An EU survey of working conditions carried out in 2000 [1] revealed that the most common health problems included :

- back pain, reported by 33% of workers;
- stress, reported by 28% of workers;
- muscle pain (neck and shoulders), reported by 23% of workers.

According to the survey's authors, this rising tide of health problems is to do with poor working conditions, in particular working in painful positions, the carrying of heavy loads, and intensification of work. The survey findings clearly show, therefore, that whole-body MSD and stress are the most frequently encountered complaints among the workers interviewed.

Work-related musculoskeletal disorders of the upper extremities (WRMSDue) affect the soft tissues of the locomotor system. Many authors [2,3] regard the acronym WRMSDue not as a diagnosis but as a "catch-all term" which covers a wide array of disorders (carpal tunnel syndrome, epicondylitis, rotator cuff syndrome, myalgia, etc.) resulting from physical activities which put the locomotor system under strain. Whole-locomotor system MSD are regarded as the main cause of care demand, disability and sickness absence [4]. In the United States and Canada, WRMSDue is the cause of the fastest-rising disability rate since the mid-90s [5]. The current consensus is that work is an undeniable risk factor for WRMSDue [5,6].

Stress has been the focus of much scientific study. A summary report written for the European Agency for Safety and Health at Work [7] defines stress as "*a psychological state which is part of and reflects a wider process of interaction between the person and their work environment... stress may be experienced as a result of exposure to a wide range of work demands and, in turn, contribute to an equally wide range of health outcomes*".

The issue of a possible link between WRMSDue and stress was brought to the fore some years ago by epidemiological research [8,9] demonstrating a causal association between the 2 disorders. The question of a link between stress and WRMSDue is therefore both one of causation – what is instrumental in what – and biological likelihood – how does it happen?

This article briefly reviews what WRMSDue and stress are, then rehearses the arguments for a credible link between stress and WRMSDue.

A general explanatory model for WRMSDue

In 1999, the European Agency for Safety and Health at Work published a report on WRMSDue [6]. The report's authors state that "*there is a substantial evidence within the EU member states that neck and upper limb musculoskeletal disorders are a significant problem with respect of ill health and associated costs within the workplace. It is likely that the size of*

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the problem will increase as exposure to work-related risk factors for these conditions is increasing within the European Union". They argue that "*the scientific reports, using defined criteria for causality, established a strong positive relationship between the occurrence of some neck and upper limb musculoskeletal disorders and the performance of work, especially where high levels of exposure to work risk factors were present*". The NIOSH [5] (US National Institute for Occupational Safety and Health) published a report in 1997 giving a detailed review of the epidemiologic evidence for the work-relatedness of MSDue. The authors state that "*A substantial body of credible epidemiologic research provides strong evidence of an association between MSDs and certain work-related physical factors...*". Table 1 shows the risk-relatedness of biomechanical factors to WRMSDue [5], but refers only to evidence of relatedness between biomechanical or physical risk factors and whole-body MSD. Finally, a series of models are suggested to explain the complex relationships between work risk factors and WRMSDue [6].

The INRS [10] has developed an explanatory model (cf. Figure 1, p.52) which demonstrates how the links between categories of risk factor and WRMSDue are organized, and shows that work-related WRMSDue must be regarded as multifactorial disorders. The risk of contracting them results from the indivisibly systemic nature of risk factors which clinical examinations cannot reveal.

Stress

There is an extensive body of research on work-related stress[1], and the corpus of knowledge is reasonably certain. Stress is a set of physiological, behavioural and emotional responses that occur in reaction to situations which are potentially harmful to the individual's physical or psychological health. A model developed by Cooper as amended by Fox [7] (cf. Figure 2, p.52) gives a summary depiction of the relation between the stressors which are also called psychosocial factors (Table 2), the symptoms of stress and the illnesses which may result from a state of stress. Chronic stress is what is most often encountered in the work environment. So, when physical, organizational, psychosocial, etc. changes occur in the human organism's work environment, the body mobilizes its metabolic and "psychological" resources to respond to the changed environment. Two situations may then arise depending on whether the *challenge* can be satisfactorily met or not (Figure 3, p.52).

Table 1 : Relevancy of biomechanical-WRMSDue risk factor relationships [5]

Anatomical region Risk factor	Cogent evidence (+++)	Epidemiological evidence (++)	Insufficient evidence (+/0)
Neck and cervicobrachial			
Repetitive motions		✘	
Strain		✘	
Range of motion	✘		
Vibration			✘
Shoulder			
Repetitive motions		✘	
Strain			✘
Range of motion		✘	
Vibration			✘
Elbow			
Repetitive motions			✘
Strain		✘	
Range of motion			✘
Combination*	✘		
Hand/Wrist			
Carpal Tunnel Syndrome			
Repetitive motions		✘	
Strain		✘	
Range of motion			✘
Vibration		✘	
Combination	✘		
Tendinitis			
Repetitive motions		✘	
Strain		✘	
Range of motion		✘	
Combination	✘		

* *Combination* = At least 2 risk factors present

Table 2 : Psychosocial factors of work-related stress

In the modern approach to stress, stressors include the controllability, predictability, loss of control, hazards, etc., of the work social environment. This makes it possible to draw up a list (non-comprehensive, and not in order of importance) of the main psychosocial factors of chronic work-related stress.

- Loss of job
- Change at work (transfer, retraining, change in job content/requirements, retirement...)
- Change in work responsibilities
- Husband/wife starting new job/leaving job
- Relationships within the organization (superiors/colleagues) (role conflict/ambiguity)
- Changes in working hours (rotating shift work, shift work)
- Length and method of daily commute
- Working conditions (social work, care for patients and people with disabilities...)
- Empowerment/control over how the work is performed
- Working to tight deadlines
- Job content (poor --> underload, over-demanding --> mental overload)
- Organization (rigid structures, no communication between organizational levels)

In the first, the person is energized and motivated; the challenge then becomes a key ingredient of quality, productive work bringing satisfaction to the worker. This is often mislabeled "good stress", which perpetuates the confusion over what stress is. In the second, the person feels (cognitive appraisal) that their physiological, psychological and emotional

[1] The Bilbao-based European Agency's report gives a detailed, cogently-argued review of the current state of knowledge [7].

Figure 1 : WRMSDue risk factors : a dynamic model

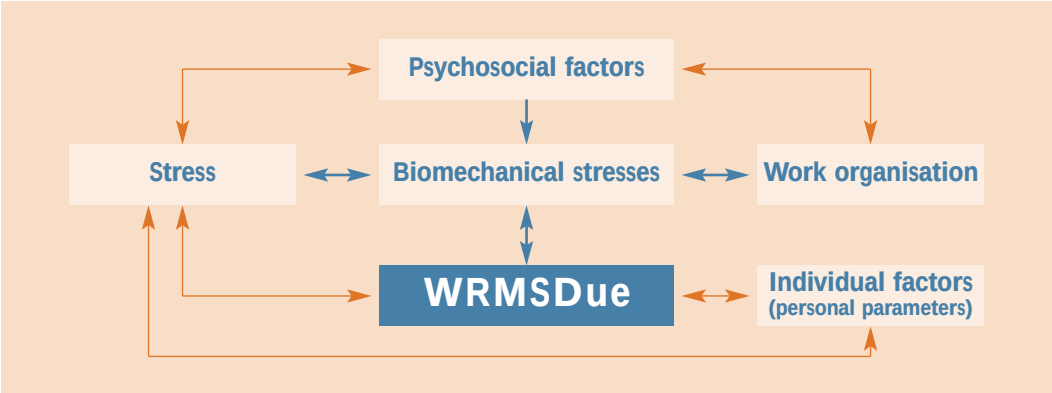


Figure 2 : Cooper's model of the dynamic of work stress*

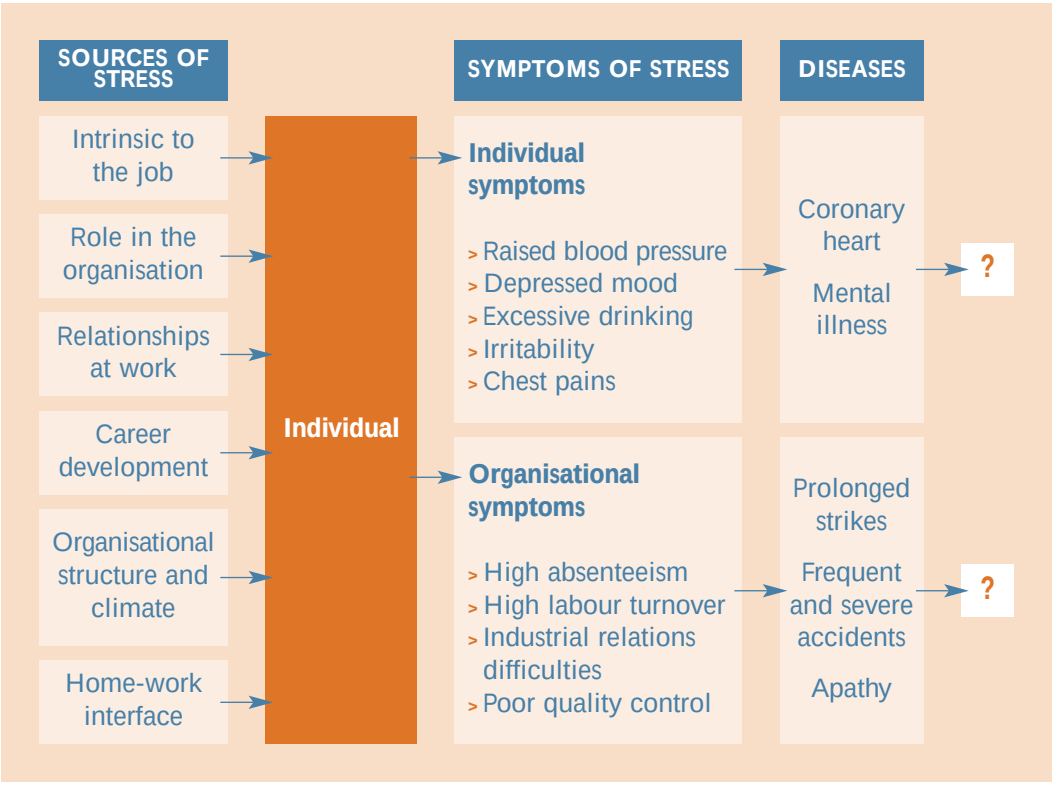
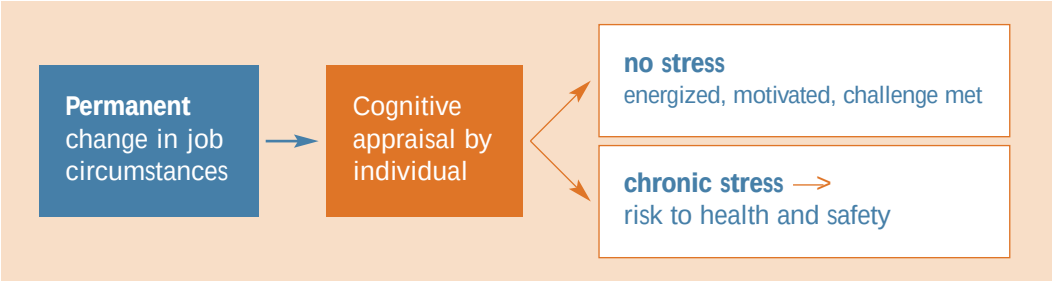


Figure 3 : Impact of the sources of stress on the state of stress



The concept of "acute" stress is not included in this figure as it relates to a temporary change in job circumstances.

*Adapted from Cooper & Marshall (1976), from Fox, *in Research on work-related stress* (2000) [7]

resources are unable to cope with the challenge; they are stressed. The body's natural equilibrium is upset, its ability to respond is diminished, and its immune defences are less effective. The conditions are then ripe for physical or psychosomatic disorders (raised blood pressure, gastrointestinal disorders, disturbed sleep patterns, infections, etc.) or accidents and neuropsychological disorders (depression, neurosis, loss of appetite...) to occur.

The origin of work-related stress is multifactorial, which puts it in the same realm of probabilistic causation as WRMSDue. The consensus view divides identified working environment stressors into physical factors (noise, cold, heat, vibrations...), psychosocial factors (Table 2) and organizational factors.

The general context to the concept of stress comprises :
- the circumstances that the individual considers as threatening;
- the stressed person (evidence and symptoms of stress);
- the interaction between one or more stressors and the individual's resilience to them.

Relations between stress and WRMSDue

The role of work-related stress and psychosocial factors in the occurrence of WRMSDue is still poorly understood and there is still no consensus on the epidemiological data [7,8,9,11]. So, NIOSH argues that [5], "*the epidemiologic studies of upper extremity disorders suggest that certain psychosocial factors have a positive association with these disorders*", but qualifies this with the assertion that "*these factors, while statistically significant in some studies, generally have only modest strength*".

There may be several explanations for this conclusion :
- the association between psychosocial factors, stress and WRMSDue is difficult to establish, because there is a limitless number of risk factors;
- the diversity of findings may be explained by the lack of a consensus on the methods and tools of scientific investigation. Also, the objective evidencing of processes and their associations is made still more difficult by the lack of objective measures of psychosocial factors.

A great deal more research is therefore needed into establishing causal inferences in the chain of events linking psychosocial factors, stress symptoms and illnesses as depicted in the model developed by Cooper *et al*. (cf. Figure 2) or that developed by the US National Academy of Sciences [see 6, page 32]. However, recent discoveries about the mechanisms used by a stressed individual's body allow credible propositions to be advanced about the links between stress and WRMSDue (Figure 4, p.55).

These propositions are not given in order of importance, as the precise relative contribution of each in the etiopathology of WRMSDue and stress cannot yet be told. Figure 4 simply illustrates the complexity of the mechanisms in play, shows the number of physiological functions involved, and reminds us that the body is a psycho-sensori-motor whole. The response to stress involves four systems: the central nervous system, the autonomic nervous system, the endocrine system and the immune system. These systems continually interact as a network, allowing the organism to maintain its wholeness and homeostasis. The response mechanisms that psycho-neuro-immunology [12] seeks to evidence are a chain of nervous, hormonal and mood reactions generally controlled by feedback loops. These feedback loops will not be described in this article so as not to further complicate the physiopathological picture; but their existence ought still to be borne in mind.

Activation of the central nervous system

Stress produces activation of the central nervous system, which increases activity ("tone") in the reticular formation. This in turn, increases muscle tone which itself increases muscle and tendon "biomechanical load", thereby contributing to an increased risk of WRMSDue.

Activation of the catecholaminergic pathway

Stress produces activation of the autonomic nervous system, which triggers the secretion of catecholamines (adrenalin and noradrenalin). These are released in the blood and elicit, among other things, increased reticular formation tone (see above), a raised heart rate, and arteriolar vasoconstriction. This leads to raised blood pressure and, in the long term, the risk of coronary heart disease. Where WRMSDue are concerned, restriction of muscle and tendon microcirculation (the latter generally displaying poor vascularisation) both reduces nutrient delivery to the tendons, thus hampering self-healing of the microlesions caused to the tendinous fibres by the excessive biomechanical strain ("ergonomic" factors), and encourages the development of chronic muscle fatigue and muscle pain.

Activation of the adrenal cortex

Stress produces activation of the central nervous system which, via the hypothalamus activates the pituitary gland, which among other things, triggers the release of corticosteroids from the adrenal cortex. These corticosteroids (corticosterone, cortisol) act

on the kidneys and may disrupt the body's fluid and mineral balance, the most visible sign of which is oedema. As regards WRMSDue, oedema may cause "tunnel syndromes" as oedematized adjacent tissues (tendons, etc.) cause local compression of the nerves.

Activation of cytokine secretion

Stress produces activation of the central nervous system, which in turn activates the production and release of cytokines (molecules secreted by immune system cells). Some of these cytokines, like interleukins (IL-1, IL-2, IL-10, etc.) are pro-inflammatory, and may possibly be instrumental in or cause WRMSDue (inflammation of tendons). This has been indirectly borne out by the findings of a study on the side effects of a triple therapy cancer treatment [13] associating two specific drugs with IL-2. The patients treated developed carpal tunnel syndrome just three weeks into the treatment. Crossover studies in complete bed rest patients, whose wrists were therefore not subject to any particular biomechanical strains, confirmed that IL-2 was indeed the sole cause of carpal tunnel syndrome.

Summary

There is, then, a sufficient body of persuasive scientific evidence to prove a credible biological relationship between stress and WRMSDue. That relationship forms part of a self-consistent biological model based on the wholeness and complexity of the living organism. That scientific evidence is wholly consistent with a psychosocial approach in which human beings are continuously interacting with their environment, especially their work environment. Far from calling into question the social dimension of working life, it adds to its relevance and more than ever argues in favour of a systemic approach to preventive measures in the work environment.

Figure 5, developed by Claudon and Cnockaert [14] summarizes (and amplifies certain points of) the foregoing propositions. Beyond the purposely over-simplified not to say simplistic approach to the stress-WRMSDue relationship that it portrays, it does hint at the complexity of the mechanisms involved. It also gives some insight into, if it does not explain, inter-individual (faced with the same circumstances, some people are stressed, others not) and intra-individual (faced with the same circumstances, the same person may be stressed or not according to when the circumstances arise) variability.

From this, it can be deduced that :

- stress is a WRMSDue risk factor : it damages employees by impairing their working efficiency. This is a conclusion shared by Smith and Carayon [15], who argue that stress and biomechanical strains (effort, repetitive motions and extreme joint postures) are "intermediate variables" between organizational, ergonomic and psychosocial risk factors (cf. Figure 1);
- stress is also potentially a form of illness in itself;
- by acting on the organizational and psychosocial factors, it is possible to prevent both stress and WRMSDue at once. Figure 1 shows that stress and WRMSDue result from new patterns of work organization (cf. European Foundation for the Improvement of Living and Working Conditions' report). It is therefore a shared problem with which all actors in prevention must feel concerned.

How this knowledge impacts the prevention of WRMSDue and stress

A study reported by the Dublin-based European Foundation for the Improvement of Living and Working Conditions was carried out in a major Swedish industrial group (over 30 000 workers) manufacturing electrical equipments. It showed that action on psychosocial factors brought not just financial, turn-over, absenteeism, productivity and other benefits, but also very significantly reduced the incidence of WRMSDue (255 cases a year in 1988 to 10 in 1994). This bears out the proposition that prevention of WRMSDue also involves counting in and getting a grip on the psychosocial factors and stress which are instrumental in the development of WRMSDue.

The right prevention response is to take a holistic approach to jobs, in the workshop, in piecing together the WRMSDue risk factors through a rounded and transparent participatory ergonomic intervention as part of a project approach run by the business manager, enlisting expertise (ergonomists, methods and procedures officers, occupational health nurse, occupational health doctor, etc.) and worker representatives [16]. It is fundamentally in line with the available scientific evidence, and the only way to reduce WRMSDue risks. The economic, financial, health and social consequences that WRMSD create for firms mean that there is no alternative to preventive measures. That is also the belief of the authors of the European report on WRMSDue [6], who say "*the report concludes that existing scientific knowledge could be used in the development of preventative strategies for WRMSDue. These will be acceptable to many of those interested in prevention and are practical for implementation*". ■

Figure 4 : Relations between stress and WRMSDue (Propositions)

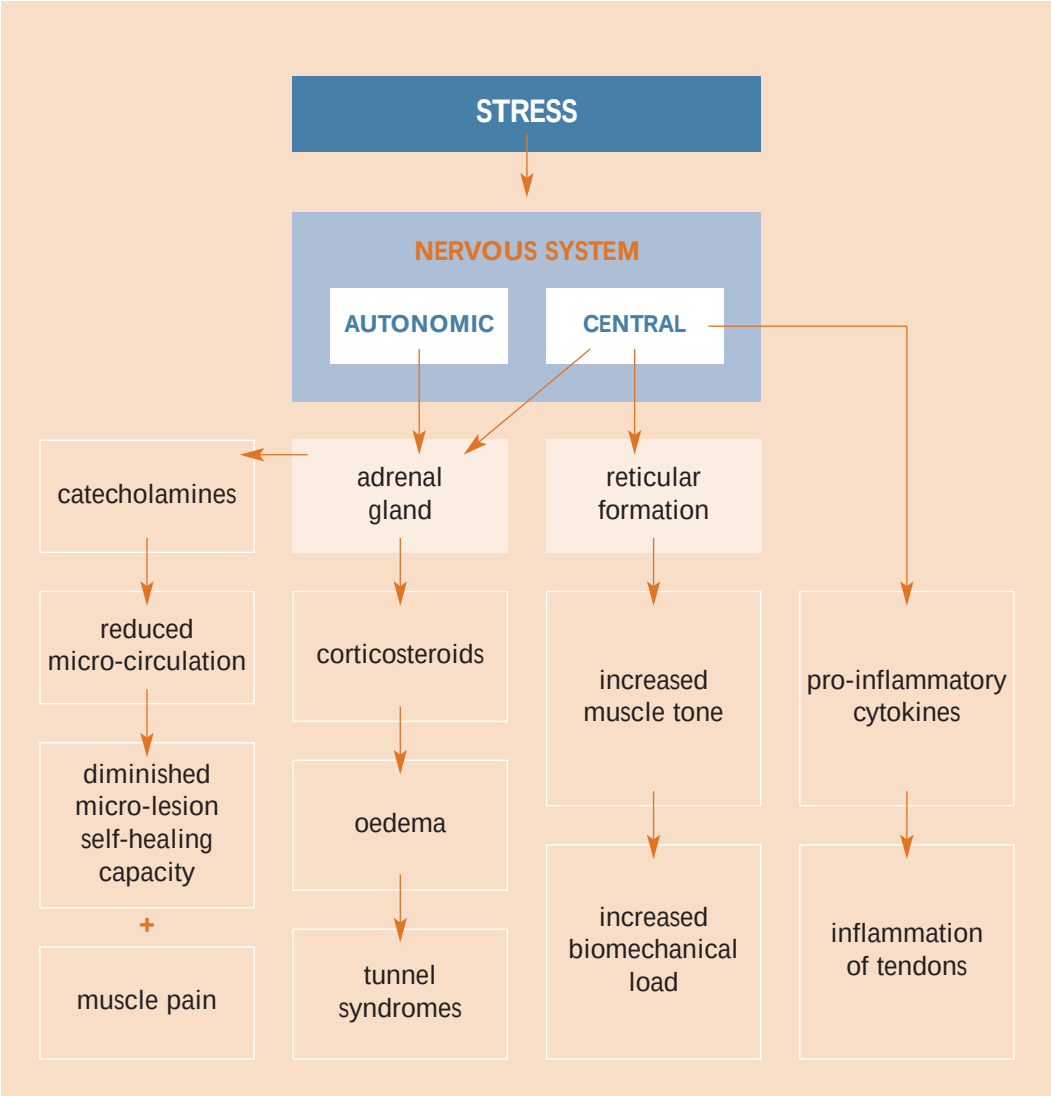
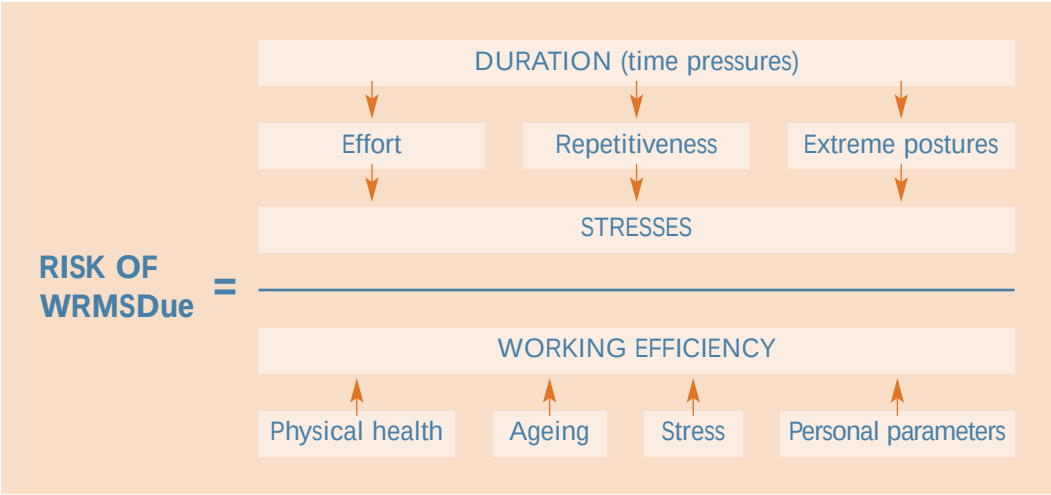


Figure 5 : WRMSDue risk factors : a dynamic model



References

1) Merllié, D., Paoli, P., *Ten Years of Working Conditions in the European Union* (Summary), European Foundation for the Improvement of Living and Working Conditions, Dublin, 2000, 12 p.

2) Miller, MH., Topliss, DJ., *Chronic upper limb pain syndrome (Repetitive Strain Injury) in the Australian workforce: a systematic cross sectional rheumatological study of 229 patients*, J. Rhum, 1988 ; 15(11): 1705-1712.

3) Yassi, A., *Repetitive Strain injuries*, Lancet 1997; 349: 943-947.

4) Sluter, *et al., Case definitions and criteria for upper extremity musculoskeletal disorders*, Scand. J. Environ. Health, 2001 ; 27 suppl. 1 : 3-73.

5) Bernard, BP., *et al., Musculoskeletal disorders and workplace factors: a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back*, Cincinnati (OH): United States Department services: 1997.

6) Buckle, P., Devereux, J., *Work-related neck and upper muskuloskeletal disorders*, European Agency for Safety and Health at Work, Office for Official Publications of the EU, Luxembourg, 1999.

7) Fox, T., Griffiths, A., Rial-Gonzalez, E., *Research on work-related stress*, European Agency for Safety and Health at Work, Office for Official Publications of the EU, Luxembourg, 2000.

8) Bongers, PM., Winter, CR., Kompier, MAJ., Hildebrandt, VH., *Psychosocial factor at work and musculoskeletal disease*, Scand. J. Work Environ. Health, 1993; 19: 297–312.

9) Hootman, ILD., Bonger, PM., Smulders, PGW., Kompier, MAJ., *Psychosocial stressors at work and musculoskeletal problems*, Scand. J. Work Environ., 1994; 20 : 139-145.

10) Aublet-Cuvelier, A., "Evaluation des facteurs de risque directs et indirects de TMS dans une blanchisserie hospitalière", *Notes Scientifiques* 195, INRS éditeur; Paris:2000.

11) Vergracht, S., Cock, N., Malchaire, J., *Troubles musculosquelettiques des membres supérieurs et de la nuque : rôle des caractères psychologiques des travailleurs*, Arch. Mal. Prof. 2000; 7: 499-505.

12) Adler, R., Fleten, D.L., Cohen, N., *Psycho-Neuro-immunology*, 2ed., Academic Press, San Diego, 1996.

13) Puduvalli, VK., Sella, A., Austin, SG., Forman, AD., *Carpal tunnel syndrome associated with interleukin-2 theraphy*, Cancer 1996, Mar 15:77(6): 1189-1192.

14) Claudon, L., Cnockaert. JC., "Biomécanique des tissus mous : modèles biomécaniques d'analyse des contraintes au poste de travail dans le contexte des troubles musculosquelettiques", *Document pour le médecin du travail*, 1994; 58(tc49): 140-148.

15) Smith, M., Carayon, P., "Work organization, stress and cumulative disorders", in Moon, S., and Sauter, S., *Beyond biomechanics - Psychosocial aspects of musculoskeletal disorders in office work*, Taylor & Francis, New York, 1996, pp. 23-42.

16) Aptel, M., Gerling, A., "Démarche de prévention des TMS et outils", *Document pour le Médecin du Travail*, 2000; 65: 14-31.