Disponible en ligne sur ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

Revue européenne de psychologie appliquée

Revue européenne de psychologie appliquée 58 (2008) 201–213

Original article

Explicative models of musculoskeletal disorders (MSD): From biomechanical and psychosocial factors to clinical analysis of ergonomics

Modèles explicatifs des troubles musculosquelettiques (TMS) : des facteurs biomécaniques, psychosociaux à la clinique du geste

J.-B. Lanfranchi *, A. Duveau

Équipe de psychologie de la santé EA 4165, laboratoire de psychologie des universités Lorraines (LPUL), université Paul-Verlaine Metz, Île du Saulcy, 57045 Metz cedex 1, France

Abstract

Following the apparition of new working schemes and work organization in companies, a so-called "reactive productivism" was set up at the worker level. This is characterized by an increased workload, flexibility efforts and productivity requirements, which show noticeable impacts on the worker's health in their own professional environment. Among these consequences are musculoskeletal disorders (MSD) which have become the most current form of professional disease in France. Such troubles and disorders, in relation to working conditions, are complex mechanisms, often expressed by chronic pain and associated with functional troubles and even disability. The majority of researchers are currently in agreement in affirming the multidimensional aspect of these disorders in biomechanical and psychological terms. The purpose of this paper is to list and review the main risk factors leading to such consequences. These epidemiological and psychological factors will be related to francophone clinical and ergonomic concepts and positions. This perspective is oriented more towards the "meaning of activity" with a clinical and a psychodynamic approach. In our conclusion, we present a predictive model on musculoskeletal pain in relation to maneuver margins, workload and work recognition.

Résumé

Avec l'apparition de nouvelles formes d'organisation du travail, s'est mis en place un productivisme réactif, caractérisé par une intensification du travail, une production au plus juste et le flexi-travail, qui a sensiblement dégradé la santé au travail. Parmi ces dégradations, les troubles musculosquelettiques (TMS) sont devenus la catégorie majoritaire des maladies professionnelles en France. Les TMS sont des maladies complexes ; la douleur chronique en est l'expression la plus manifeste ; et les TMS sont souvent associés à une gêne fonctionnelle invalidante. La plupart des auteurs s'accordent actuellement pour affirmer le caractère multifactoriel de cette affection en termes biomécaniques et psychosociaux. Une recension des principaux facteurs de risque est ici proposée en s'appuyant sur des synthèses de la littérature. Cette position majoritairement admise est, par la suite, complétée par la position francophone de l'analyse clinique de l'activité et du geste. Cette seconde position met l'accent sur le rapport psychique au travail et sur le sens attribué au geste professionnel comme opérateur de santé. En s'appuyant sur cette synthèse, un modèle prédictif de la manifestation d'une souffrance musculosquelettique, mettant en jeu les facteurs de marges de manœuvre, d'exigences et de reconnaissance dans le travail, est proposé en conclusion.

Keywords: Musculoskeletal disorders; Systematic review; Psychosocial factors; Clinical ergonomics

Mots clés : Troubles musculosquelettiques ; Recension ; Facteurs psychosociaux ; Clinique de l'activité et du geste

1. New forms of work organization and MSD

The world of work has undergone numerous transformations over the past twenty years, of particular importance are organizational changes which have led to the setting up of a model of

* Corresponding author.
Adresse e-mail : lanfranchi@univ-metz.fr (J.-B. Lanfranchi).

1162-9088/$ – see front matter © 2008 Elsevier Masson SAS. All rights reserved.
doi:10.1016/j.erap.2008.09.004

reactive productivism. (Askenazy, 2004). This model, constantly evolving, was first developed in Japan with systems of "productivity requirements". It was then developed further in the United States thanks to the contribution of new information and communication technologies, and then arrived in France where it was accompanied by various practices of flexibility (i.e., flexibility of working hours, forms of precarious employment or subcontracting). In terms of innovating practices, this productivism is composed of five important complementary dimensions: versatility; multicompetence; team work; productivity "requirements"; and the client's total quality satisfaction. Each of these dimensions contributes to a maximal adaptability to market evolutions by churning out custom-made products en masse with the greatest speed. Originally, this model of production should have made it possible to satisfy all of the market protagonists: more profits for the *companies*; a renewal of *employee* motivation; and enhanced satisfaction for *consumers*.

The surveys carried out by DARES[1] on working conditions, however, do not cease to show that these transformations of work and employment lead to deleterious effects characterized by more important psychological pain at work and continuing physical difficulties (Arnaudo et al., 2004; Hamon-Cholet and Rougerie, 2000).

Currently, one of the most visible manifestations of these forms of pain is musculoskeletal disorders (MSD). These professional illnesses are complex, chronic pain being the most evident expression of it, and they are often associated with functional troubles which can become disabling. In a general sense, they cover a large range of pathologies which affect the osteoarticular system, muscles and conjunctive tissues. As a result, the main possible problems are focused on tendinous, vascular, nervous and muscular, affecting either the upper or the lower member, or the back.

MSDs have become the largest category of professional illnesses in France. Hence, 75% of the illnesses recognized by the General Health Plan in 2003 were MSDs, and a constant progression of +15% has been observed each subsequent year (Gary et al., 2005). Moreover, they are also the primary cause of sick leave of two to four months among the workers of the General Health Plan, with more than one worker out of four being on sick leave (Vallier et al., 2004). Finally, the survey conducted on the working conditions of 21,500 European workers (Merllié and Paoli, 2000) testifies to the magnitude of the phenomenon with 33% of workers complaining about back pain and 23% about muscular pain in the neck and shoulder.

Consequently, MSDs constitute a major health problem at work which currently mobilizes various scientific disciplines (such as the biomedical sciences, ergonomics, work psychology, sociology and economics) and workplace safety organizations (ANACT, INRS, occupational medicine, etc.) with the joint aim of pinpointing the risk factors of this illness and determining effective health actions.

[1] DARES : direction de l'animation de la recherche, des études et des statistiques.

Faced with the multiple causes for the epidemic of MSDs and the diversity of scientific approaches to this phenomenon, we offer an overview of the different positions at issue in the understanding of this professional pathology by taking into account the biomechanical and psychosocial aspects as well as the clinical analysis of activity and gesture. This synthesis will result in the presentation of a predicative model of musculoskeletal disorders which integrates these different conceptions.

2. Biomechanical factors and MSD

According to biomechanics, MSD does not exist without biomechanical effort. This seems to be a fact shared by all of the scientific community. But what does one mean by biomechanical efforts and what is their role in the development of MSD? The basic conceptual model can be seen as a closed cybernetic model in which the muscle both initiates the action and is the protagonist (Aptel and Gaudez, 2003). In this representation, working conditions produce external loads through, for example, repetitiveness or handling heavy loads, which will cause a muscular reaction, a muscular activity that is transmitted to the tendons and the articulations. This transmission constitutes an internal biomechanical loading. These internal loads can then exceed the tolerance of biological tissues and lead to medium or long-term musculoskeletal injuries resulting in discomfort and disabilities (Delisle, 2005).

Consequently, the musculoskeletal response is considered to be directly proportional to the intensity of the constraint. The response and constraint are physiologically and physically quantifiable. Biomechanical metrology typically resorts to instruments attached to individuals in order to measure their postures and movements (e.g., accelerometers, electrogoniometers), the level of surface activation (i.e., surface electrode) and exerted forces (i.e., unit of force, biomechanical mode). In addition to these methods, which are awkward to apply and exploit, numerous simple tools have been conceived in order to evaluate a much larger number of work situations without specific measuring machines (for example, the check-list). These analytical tools, which can be used directly in the field, are based on observation of the employee's work activity, either indirectly or based on a recording (Aptel et al., 2000).

Epidemiological and laboratory studies currently consider the following biomechanical risk factors: articular postures; efforts; repetitive work; working in a steady static posture; and vibrations. The intensity of these factors, and their duration, the duration and the moment of recuperation as well as low temperatures can modify the effects (Warren, 2001). Epidemiological reviews have recently been conducted in order to specify the links between these different factors and the anatomical areas which are affected most by MSDs. Table 1 takes into account five journals which are devoted to the subject, that of the National Institute for Occupational Safety and Health; Bernard, 1997 (NIOSH) which is concerned with all of the upper body; the NRC (National Research Council, 2001) which is centered on the upper limb in its totality and on the lumbar rachis. Finally, three reviews have been published dealing specifically with biomechanical risk factors in the neck (Ariëns et al., 2000), the

Table 1
Summary of the epidemiological reviews: relationships between biomechanical risk factors and MSDs in the upper limb, the neck and the back.

	NIOSH, Bernard (1997)	NRC (2001)	Hoogendoorn et al. (1999)	Ariëns et al. (2000)	van der Windt et al. (2000)
Neck	¤ Articular and/or static posture * Repetitiveness * Effort 40 studies selected			* Flexion of the neck * Vibration in the arm * Effort and Posture of the arm * Duration of the sitting posture * Articular P. of the trunk 40 studies	
Shoulder	* Repetitiveness * Articular posture 20 studies selected				¤ Repetitiveness ¤ Vibration * Articular posture 29 studies
Elbow	¤ Combination Effort + repetitiveness Effort + Articular posture * Effort 20 studies selected	¤ Vibration ¤ Combination Effort + Repetitiveness Effort + Cold T. * Effort * Repetitiveness 42 studies selected			
Hand/wrist					
Carpal Tunnel Syndrome	¤ Combination Effort + Repetitiveness Effort + Articular posture * Repetitiveness * Effort * Vibration 30 studies selected				
Tendinitis	¤ Combination of 2 or more factors * Repetitiveness * Articular posture * Effort 8 studies selected				
Back	¤ Manual handling ¤ Vibration * Heavy physical work * Articular posture 40 studies selected	¤ Manual handling ¤ Vibration ¤ Articular posture ¤ Heavy physical work 43 studies selected	¤ Manual handling of objects ¤ Articular posture ¤ Vibration * Handling of patients * Heavy physical work 31 longitudinal studies		

Notes. Strong evidence (¤): the authors of the different reviews consider that in the light of the good methodological quality of the studies, the consistency of the effects and the number of studies which affirm the relation, it is possible to maintain with confidence the existence of a relationship between MSD and the risk factor. Average evidence (*): the authors of the different reviews consider that in the light of the average or weak methodological quality of the studies, of the statistical consistency of the effects and the number of studies which affirm the relation, a relation between MSD and the risk factor reasonably exists. Weak or non decisive evidence has not been reported.

lumbar rachis (Hoogendoorn et al., 1999) and the shoulder (van der Windt et al., 2000).

A relative agreement between these reviews is observed with regards to the links between biomechanical risk factors and musculoskeletal disorders. One can therefore affirm with confidence that links exist between muscular exertion, repetitiveness, vibrations, articular postures and the appearance of MSD in the upper limbs or the back, particularly when these risk factors are combined. The back region shows the most links with strong evidence between each of these risk factors taken independently (with the exception of repetitiveness) and the manifestation of musculoskeletal disorders.

Consequently, on the one hand, these epidemiological reviews make it possible to prove the responsibility of work in the origin of these illnesses and, on the other hand, to attempt to demonstrate that the risk is proportional to the intensity of these factors in work activity. However, this last point seems unsatisfactory in light of certain facts:

- according to biomechanical norms, "hard" work activities do not necessarily result in pain provided that they are part of a gestural strategy valued by the workers[2] (Bourgeois and Hubault, 2004; Bourgeois et al., 2000, 2006);
- musculoskeletal pain can also be present in situations in which the intensity of the gestural demands is low but where the stress and the mental load are considerable (Aptel and Gaudez, 2005).

This last point evokes the problem of the appearance of MSD in the shoulder when working on computers and assembling electronic components. According to Aptel and Gaudez (2003), physiopathological knowledge cannot explain these cases of MSD where the level of muscular demand is extremely low (most often below 5 to 8% of the voluntary maximum force [VoMF] on the trapezius muscle). It is then necessary to turn to the neurophysiology of motor units in order to understand these phenomena. The hypothesis of "Cinderella's fibers","the first one up, the last to go to bed", proposed by Hägg (1991), in particular assumes that certain type C muscular fibers with a low threshold of activation are the first to be engaged during a motor activity and remain active until the trapezius muscle is completely relaxed. This constant activity of the same motor units, without sufficient recovery time, can provoke their degeneration and the appearance of pain over middle and long-term. Moreover, signs of muscular fatigue, the possible precursors of pain, cannot always be perceived or are inadequate, leaving the individual to continue his work without him being aware of the overload (Lundberg et al., 2002). In a review of the literature, Aptel and Gaudez (2003) proposed the following two points:

- whatever the posture of the upper limb, certain identical motor units are continually in demand;
- the same motor units can be activated during a mental load or during stress (experimentally provoked by Stroop's test, the cold pressor test or tasks of mental calculation) in the absence of any physical activity.

Nevertheless, the authors indicate that the idea that there is no substitution in the engagement of the motor units at the moment when the muscle is tired remains to be confirmed.

Consequently, the unidimensional approach, centered uniquely on the biomechanical audit, seems at present largely insufficient because of disappointing or paradoxical results, the advances in neurophysiological research and the biological plausibility of links between stress and MSD, and also the recognition that movement, in addition to its biomechanical dimension, has far reaching cognitive and psychological dimensions (Douillet and Schweitzer, 2005).

3. Psychosocial factors, stress and MSD

The role of psychosocial factors and stress in the appearance of MSDs has been the subject of numerous studies in epidemiology, work psychology and the field of occupational health for more than 15 years (Westman et al., 2008). These study areas have become essential along with research on the biomechanical aspects. In order to synthesize the influence of the main factors at issue, we will use Bongers' model (Bongers et al., 1993; Bongers et al., 2002) which will enable us to develop a general framework of the plausible relationships between these variables (Fig. 1).

The biomechanical load and psychosocial factors in this model can be considered as risk factors which reflect organizational dimensions underlying work (such as management methods, production methods, the forms of contribution/remuneration between the individual and the organization). Thus, in a broad sense, the psychosocial factors refer to the individual's perception of the work characteristics which are susceptible to a positive intervention in his activity (by increasing motivation, satisfaction, well-being or performance; Mottay, 2001), but which can constitute professional stressors.

Effectively, as soon as these work dimensions, or the organizational operation, show demands, these demands are evaluated by the individual as surpassing their own resources or threatening their well-being which then results in conflict (a "threatening discord"), which subsequently builds up stress (Rascle, 2001). A work situation, which is considered to have a risk of MSD because it is repetitive and fast paced for example, is not necessarily pathogenic in this transactional perspective of

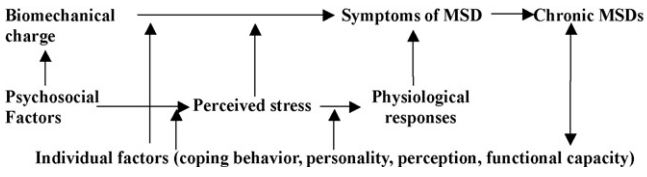

Fig. 1. Model of the relations of influence between the biomechanical, psychosocial and individual risk factors and their impacts on the development of MSD (according to Bongers et al., 2002).

[2] This paradox will be dealt with in more detail in the clinical and ergonomic analysis developed in part 4 of this paper.

stress. Effectively, if the individual can cope with it by adjusting the intensity of his work by reducing production or by sharing the constraints within his team (Bourgeois et al., 2000; Douillet and Schweitzer, 2002), it is then no longer problematic for the individual.

Bongers considers two paths of action concerning psychosocial factors on the appearance of MSDs. The first path is the direct effect of these factors on the biomechanical load of the individual. The information perceived, for example, on the "work demands", forces the individual to accelerate his movements or to adopt an uncomfortable posture in order to cope, increasing the biomechanical load. Depending upon the functional capacities of the individual and the perceived stress, this can result in symptoms (pain) and disabilities.

The second path of influence is established once these psychosocial factors are evaluated by the workers as being potential threats for which a solution must be found. This perceived stress will then bring about important physiological responses in the central nervous system (CNS), the vegetative nervous system (VNS), the "endocrine system" and the immune system. But the activation of these network systems is not without repercussions on the muscles and tendons. As Aptel and Cnockaert (2002) have shown, this can result in the following symptoms:

- an increase in the muscular tonus following the CNS's activation of the reticulate, which increases the biomechanical load;
- a decrease in the microcirculation in the muscles and tendons which results in fatigue and a slower healing of tendinous microlesions following the VNS's activation of the catecholamineric path;
- edemas following activation of the suprarenal cortex and a hydromineral imbalance;
- an inflammation of the tendons resulting from the secretion of cytokines by the immune system.

The persistence of these biological activations due to the impossibility of finding an adequate "outcome" to the perceived work constraints can then result in MSDs, depending on what the individual has already attempted to do and his functional capacities.

But what are the psychosocial factors which can constitute professional stressors or psychosocial resources in the framework of MSD? Bongers does not define them theoretically nor does he clearly specify where these resources are situated: among the psychosocial or individual factors? At the present time, two models of professional stress, that of Karasek (demand/latitude/social support at work; Karasek and Theorell, 1990) and that of Siegrist (unbalanced efforts/work rewards; Siegrist, 1996; Siegrist et al., 2004) make it possible to shed light on the importance of certain factors in the appearance of professional stress.

Karasek's model suggests taking into account the following three types of factors which, in combination, could provoke tension at work and professional stress:

- *the psychological demand* which refers to the psychological load represented by the quantitative and qualitative work demands, by the level of concentration required and management of interruptions and the unexpected;
- *the decisional latitude* which covers the notions of decision-making autonomy and control as well as the possibility of using one's skills and developing new ones in one's job;
- finally, *social support* which is defined by the help and recognition of colleagues and hierarchical superiors.

According to Karasek and Theorell, the combination of a high psychological work demand and low decision-making latitude would lead to high psychological tension which is detrimental to the individual's health. Moreover, this tension would be amplified in the case of low social support. A recent summary of the literature, based on 45 longitudinal studies using this model, aims to show, however, that these factors operate independently of each other more often than they interact (de Lange et al., 2003).

As for Siegrist's model, it identifies pathogenic working conditions as being those which associate high efforts and low rewards: this model is much more centered on distributive justice in the organization. The efforts can result from two sources: extrinsic or intrinsic. The extrinsic efforts refer mainly to the psychological demand factor of Karasek's model. There are three types of rewards: monetary gratification, the esteem given to the individual and the possibility to have control over one's job (prospects of promotion and job security). As for intrinsic efforts, they express attitudes and motivations associated with an excessive commitment to work such as the inability to distance oneself from work. The model postulates that disequilibrium between the extrinsic forces and the rewards (associated with an excessive commitment to work) will lead to an emotional state of distress inclined to cause physiological deteriorations. Unlike Karasek's model which is often used in surveys on MSDs, the variables of Siegrist's model have, to date, been used little in the understanding of musculoskeletal complaints. However, two studies show the importance of the disequilibrium between "efforts/rewards" and continuous preoccupation of one's work in the manifestation of this disorder (Joksimovic et al., 2002; Tsutsumi et al., 2001).

Numerous reviews of the literature on the impact of psychosocial factors, stress and satisfaction on MSDs have been made since the 1990s. We have retained those which are the most often cited or the most recent on the subject, with the aim of having information on different anatomical areas. Tables 2 and 3 summarize the results of these eight journals (Ariëns et al., 2001; Bernard, 1997; Bongers et al., 1993; Bongers et al., 2002; Hoogendoorn et al., 2000; Linton, 2001; NRC, 2001; van der Windt et al., 2000).

Regarding these results, the dimensions of Karasek's model are again found with more or less weight:

- *The psychological work demands* appear to be recurrent in all of these studies. The more the psychological workload is important for the individual in terms of density (varieties of tasks to assume without errors and with concentration) and/or

Table 2
Summary of the epidemiological reviews: relationships between psychosocial risk factors, stress and MSDs in the upper limb and the neck.

	Bongers et al. (1993)	Bernard (1997)	van der Windt et al. (2000)	Ariëns et al. (2001)	NRC (2001)	Bongers et al. (2002)
Neck	*Monotony * Temporal pressure * Workload * Combination Weak social support + Strong demands * Symptoms of stress 28 studies selected	* Monotony * Workload * Lack of control * Social support 17 studies selected		* Work demands * Social support * Decisional latitude * Dissatisfaction 29 studies selected		
Shoulder			* Lack of control * Monotony * Dissatisfaction 29 studies selected		* Work demands * Stress 28 studies selected	* Combination Lack of control + demands Demands + stress 28 studies selected
Elbow					* Work demands * Stress 28 studies selected	* Combination Demands + stress 28 studies selected
Hand/wrist					* Work demands * Stress 28 studies selected	* Combination Demands + stress * Stress * Work demands 28 studies selected

Notes. Strong evidence (¤): the authors of the different reviews consider that in the light of the good methodological quality of the studies, the consistency of the effects and the number of studies which affirm the relation, it is possible to maintain with confidence the existence of a relationship between MSD and the risk factor. Average evidence (*): the authors of the different reviews consider that in the light of the average or weak methodological quality of the studies, of the statistical consistency of the effects and the number of studies which affirm the relationship, a relationship between MSD and the risk factor reasonably exists. Weak or non decisive evidence has not been reported.

Table 3
Summary of the epidemiological reviews: Relationships between psychosocial risk factors, stress and dorsopathies.

Bongers et al. (1993)	NIOSH, Bernard (1997)	Hoogendoorn et al. (2000)	Linton (2001)	NRC (2001)
*Monotony	* Temporal pressure	¤ Social support	¤ Work demands	¤ Work demands
*Social support	* Workload	¤ Decisional latitude	¤ Monotony	¤ Temporal pressure
* Combination	* Lack of control		¤ Social support	¤ Monotony
Weak social support +		¤ Dissatisfaction	* Lack of control	¤ Social support
Strong demand	¤ Dissatisfaction	13 longitudinal studies selected	* Temporal pressure	* Lack of control
	13 studies selected			
*Symptoms of stress			¤ Dissatisfaction	¤Stress
* Dissatisfaction			21 longitudinal studies	¤ Dissatisfaction
31 studies selected				59 studies selected

Notes. Strong evidence (¤). Average evidence (*).

of intensity (obligation to quickly meet the demand, to respect deadlines, dealing with quantitative work demands), the greater is the likelihood of musculoskeletal disorder, whatever the anatomical area (average evidence of this link). However, the evidence of a link is stronger in the back area in two studies (Linton, 2001 and NRC, 2001).

- Concerning *social support*: the impossibility of collectively sharing the constraints of work because of little cooperation among colleagues and the lack of hierarchical support seems more frequently linked to MSDs concentrated in the back (with strong indications in studies by Linton and the NRC) or the neck, and more rarely to MSDs in the upper limb.
- As for *control over work*: being able to influence the sequence of one's work in terms of rhythm, quantity and operating methods, in short, having the possibility to negotiate certain work constraints in one's own way, makes the appearance of MSD less likely. This variable is present in the MSDs of the neck, the shoulder and the back areas with an average indication. On the other hand, there is no specific link between MSDs of the elbow and the hand.
- Finally, *regarding the use of skills and monotony at work*, being confronted with a monotonous job lacking variety which does not permit an individual to learn new things nor to use his skills, constitutes a risk factor particularly in the framework of dorsopathies. Conversely, using many skills is rather protective although some studies have shown a deleterious effect in the neck area both with a low and high use of skills (Ariëns et al., 2001).

Dissatisfaction and stress are more difficult to understand due to the fact that they are "composite" categories of factors which can be considered as "reflections" or close indicators of other psychosocial factors which are not taken into account simultaneously in the equations of regression. However, aspects of tension at work, of worry or of overall distress play a role even when the psychological demand remains constant (Bongers et al., 2002). Finally, if dissatisfaction is considered to represent a negative or "perturbing" emotional experience resulting from an evaluation made by the individual of his work characteristics or the methods of retribution/contribution at issue, then dissatisfaction can be reintroduced as a participating factor in this psychological tension at work (Siegrist et al. 2004). Here again, this link between MSD and dissatisfaction is most strongly evident in the back (4 out of 5 studies affirm strong evidence for this link).

In looking for the main effects of each of these categories of biomechanical and psychosocial variables, however, all things eventually remaining constant in other respects. One ends up with a very artificial decomposition of the links between pain, the day-to-day life of workers and the constraints of work. The objectivation of pain is made by a mechanistic and an elementarist view in which the risk factors are stacked no matter what their type (social-demographical, biomechanical, psychosocial etc.). If understanding the psychosocial phenomena at issue seems essential to us, we also uphold the idea that these factors form a system of relations, which is important to respect, by using the theoretical models which explain these links (Huang et al., 2002). By using the structural approach to these factors, it is possible to update this multicausality and vicariousness of the processes in the appearance of musculoskeletal pain. Within this structural perspective (Reuchlin, 1995; Bacher, 1999), one looks more to establishing a system of so-called "explicatives" (latent and observed) whose contribution to the appearance or the attenuation of musculoskeletal pain will be the subject of study.

The variation in this pain will then be "explained" by the structure of the retained variables a priori, rather than by taking each variable independently. Here the effect of each variable in the system is no longer presumed to be independent of the other variables of the system. Non recursive relationships are even considered. For example, pain can modify the effect of psychosocial and biomechanical variables in a retroactive manner. It can create more dissatisfaction, negative emotions, provoke a cognitive distortion or even impose a reduction in the most painful efforts (Ginies, 2005).

Consequently, this focusing on pain manifestation, linked to structures of occupational stressors, must no longer overshadow the importance of the gesture itself for the worker and what is at issue because of it.

4. A clinical and ergonomic analysis of gesture

Schematically, two important positions with respect to MSDs are currently in opposition (Coutarel et al., 2005). The P1 position, seen above, is based on a representation of occupational health in the workplace as proposed by the World Health Orga-

nization (Gary et al., 2005), the goal of which is to promote the physical, mental and social well-being of workers. From this perspective, MSDs are the result of a combination of biomechanical and psychosocial pathogenic risk factors for the workers' health. Thus the advocates of this position attempt to develop heuristic models in an attempt to specify the contribution of each of these factors in the etiology or the perseverance of MSDs. In this framework, the mission of ergonomic interventions is to reduce, even to eliminate, these risk factors, by being concerned with the conception of adapting work to the individual and each individual to his task.

The second position, P2, which is discussed here, is based on a complementary and original method which is regulated by another view of occupational health. Health is here a dynamic intersubjective construction (Dejours, 1995) in which each individual has the possibility to have a say in what happens to him (Daniellou, 2003). Therefore, workers' health is constructed by personal influence on work situations (Coutarel et al., 2005) and thanks to the development of a professional identity forged within a professional group. The models of prevention of this second position then attempt to restore the workers' maneuver margins, to develop the resources and technical means to confront all that is not envisaged by work prescriptions.

This new line of research was developed in the late 1990s by two driving forces. On the one hand, under the impetus of the currents in occupational psychodynamics and psychosomatics (Dejours, 2000; Pezé, 2002), the clinic of activity (Clot, 1999), and, on the other hand, from a voluntarist approach on the part of practitioners and researchers in ergonomics who specialize in work activity in order to answer prevention paradoxes, sometimes without success (Bourgeois et al., 2000). In other words, gesture is central to this new line of research, both in the activity analysis and in the analysis of the real activity, and also in the psychopathological analysis of a dynamic of identity at work.

4.1. Analysis of the activity, the real activity and MSD

The particularity of the francophone approach to the analysis of work (Daniellou, 1996; Leplat, 2000) is that it was developed on the distinction between prescribed work, such as it is defined by designers on the one hand, and, on the other hand, the activity, the real work of the individual. Hence ergonomic studies have shown that effective work, in other words what the worker realizes, can deviate more or less markedly from the work such as it has been prescribed. This deviation can be due to different factors such as the "interpretations" of instructions by an operator (for example, incomplete or poorly understood instructions), reorganizations for dealing with the uncertainties of work, or even the existence of conflicting demands (for example, to be fast and yet be vigilant about quality). The analysis of the activity can then be apprehended through a breakdown of different tasks ranging from the officially prescribed and formal tasks of work, to the activity elaborated by the worker (Leplat, 1997). Effectively, the individual must appropriate the task (redefined task), take into account the uncertainties and the constraints of the situation (updated task) to regulate the execution (effective task) in order to reach the goal that he has set for himself (task realized for the agent). This more or less important discrepancy between the prescribed task and the activity makes it possible to make the work feasible. Effectively, work is "the coordinated activity of men and women in order to confront what cannot be obtained in the production by the strict execution of the prescribed tasks" (Davezies, 1993). The individual will then be able to confront his work situation by increasing the spatial, temporal or postural maneuver margins or by delegation (Coutarel et al., 2003). The vast ergonomic study carried out by Coutarel (2004) in a factory for cutting up ducks made it possible to test this model of maneuver margins using an ergonomic assessment in conjunction with the workers. The maneuver margins, among other points that were developed, were:

- temporal, by lessening the pace of cutting up as a result of an increase in the distance between two ducks in the production line;
- spatial, by the creation of open areas between the operators' posts which enables one to make up a delay by moving along the production line and thereby avoiding the self-acceleration of the operators at their posts;
- social, through some modifications in production methods which encourage mutual support between operators.

These maneuver margins therefore proved to be beneficial in terms of health protection and also in economic terms because the meat was cut up with more precision and less loss. Consequently, such margins make it possible to develop the operators' power to act on their own work situations (Clot, 1997; Coutarel et al., 2003), and their absence could be associated with a general syndrome of feeling powerless (Daniellou, 1999). Effectively, MSDs result from a triangular conflict between an atrophy of the "power to act" in work situations, an impossibility to "be able to think" about the expended human activity, and to "be able to discuss" the issues involved in the survival of the company (Daniellou, 1998).

MSDs are, therefore, the symptoms of an organization which is supposed to be flexible in its production methods but without giving individuals the resources to assume the intensity of their activity in a creative manner (Hamon-Cholet and Rougerie, 2000; Hubault and Bourgeois, 2004).

The analysis and adjustment of work posts carried out with the single objective of increasing production and reducing costs have, in this sense, attained their limits. It is rather by analyzing work situations in consultation with workers that ergonomists will be able to offer solutions for the prevention of MSDs which respect organizational and personal issues. These solutions for prevention are thus based on the principle of the maximization of the "useful effect" for individuals and the company, by jointly developing the individuals' possibilities to act (i.e., improvements in skills and autonomy) and the company's efficiency (i.e., reliability and quality) (Bourgeois et al., 2006).

In addition to this analysis of activity which is necessary to promote maneuver margins at work, Clot (1999) nevertheless

questions the ergonomists concerning the real activity. From this perspective, the activity realized by the operator is differentiated from the real activity. In effect, this comprises "what is not done, what one tries to do without succeeding – the drama of failure – what one wanted to do or could have done, what one thinks it is possible to do somewhere else" (Clot, 2001b). According to Clot, the analysis must then take into account "the suspended, thwarted or hindered activities, and even the counter-activities" (Clot, 2001b). This maelstrom of real activity can be destructive if the operator cannot draw from it the means to find a new way of being at work and to do what there is to be done.

The aim of the clinic of activity analysis is then the transformation of work situations through a confrontation between the individuals themselves and their work (Clot, 2001c), following the hypothesis "that those who work can draw on the recognition of unsuspected resources by themselves to protect and even promote their health" (Clot, 2001a). The clinic of activity analysis is then a consequence of francophone ergonomic practices combined with the contribution of occupational psychopathology. The solutions for prevention are found here via the initiatives of the worker and workgroups based on self and hetero-confrontation with their own activity. The methodology in clinic of activity is based on the method of a 'double' whose instructions are complemented by that of crossed self-confrontation. This methodology is used with a workgroup in which an operator is given the following instruction: "Imagine that I am your double and that tomorrow, I will find myself in the position to have to replace you in your job. What are the instructions that you must give me so that no one is aware of the substitution?" (Clot, 2001c). The clinic of activity practitioner takes on the role of the double by questioning the operator about the "how" of this activity in order to obtain all of the details that must be integrated. The confrontation with his own activity, and that of the others, is crossed with a group analysis of a tape of the double's instructions or with a video-tape of work sequences. On the one hand, this analysis becomes a means for the workers to become aware of what they have done and what they were not able to do and, on the other hand, thanks to the "controversies" that arise between the observers, to find novel work modifications.

In this framework, the "amputated gesture" and the "repressed activity" do not automatically result in work disorders on the condition that, through clinic of activity analysis, this experience is a source of new development. Suffering is then linked to a reduction in the power to act which cannot be transformed within a workgroup. Thus Clot and Fernandez (2005), through their intervention in a mechanical assembling factory, show that MSDs, as a gesture pathology, are linked to repetitive movements without a real possibility of variation: not being able to "repeat without repeating". In other words, there is an underdevelopment, a hyposolicitation of the gestural abilities which are expressed by a hypersolicitation of the same motor units. By confronting other movements, either his own or those of his peers, the worker can then envisage this experience in order to discover new means of protection.

4.2. Psychodynamics, psychosomatics and MSD: the importance of social recognition

In keeping with the perspective of the clinic of activity discussed above, health is perceived as the possibility of being confronted with one's activity or that of others in order to be developed or preserved. Whereas, according to the perspective of occupational psychopathology, health is apprehended as a process of normality, a state of equilibrium that the individual has reached or attempts to reach which is always precarious (Dejours, 1995). This tendency, both psychodynamic and psychosomatic, attempts to discover how workers manage to preserve their psychological equilibrium in spite of the deleterious effects of work (Dejours, 1990). Health is then a "normality" in which work disorders are sufficiently compensated through individual or group defense mechanisms. MSDs are a symptom of physical and psychological wear resulting from a process of decompensation.

Social recognition, what others think, is central to psychodynamic analysis. Effectively, recognition is one of the three poles of the triangle of occupational psychodynamics, along with work and pain (Dejours, 2000). The absence of social recognition, of what others think, destabilizes the equilibrium of identity. There is an identity crisis, an alienation, when one of the poles is cut off from the others. Effectively, pain is only bearable as long as work has some meaning, in other words, when it is recognized. Attributing a meaning to work through social gratification allows one to transform the pain felt into pleasure, then into possibilities for self-fulfillment. This reward of a symbolic nature, of what others think, has healing effects. Recognition is expressed by judgments made of accomplished work. They can be of two types: on the one hand, a judgment of utility (i.e., a form of vertical recognition from the hierarchical channel); and, on the other hand, a judgment of beauty (i.e., recognition from peers for an acquired and mastered technical gesture) (Dejours, 2000).

Bourgeois et al. (2006) illustrate these narcissistic rewards by using the metaphor of the "painter dancer". The development of a second paint production line at an automobile parts manufacturer created an opportunity to analyze the activity in order to meet the objectives of reducing flaws in quality linked to dust (in suspension) and the postural constraints of the painters. The analysis carried out by the ergonomists attempted to show that the movements and postures adopted by these painters were painful and restrictive. When this analysis was presented to the painters, the latter revealed the importance of these movements and postures in order to obtain a homogenous coat of paint, a criteria which had not been taken into account by the production line designers. In other words, on the one hand, these movements and postures were not recognized by the company's managers as being useful since these painters, by adopting these gestures and positions, directly applied a quality coat of paint from an expected performance viewpoint. On the other hand, these gestures and postures, choreographed as a dance presenting the body in time and space, were shared and had meaning for the colleagues. The beauty of the gesture, of a mastered technique, of definite ease, was then recognized

by the judgment of other professionals and transmitted to the apprentices. These gestures and postures represented the expertise shared with the workgroup in which the painter creates his own gestures. Thus, even if the biomechanical analysis aimed at showing the risk of certain postures, the consideration of the gestures of the craft proved to be essential for the intervention, not to limit them, but to have them recognized by the designers and to find a compromise in the fight against the dust.

But present day organizations make these workgroups vulnerable and restrict the means to do a "good job" (Davezies, 1999). Hyperactivity thus becomes a defensive strategy in order to confront this social alienation; these movements become emptied of their meaning (Dejours, 2000; Pezé, 2002). The worker puts himself under a strenuous rhythm, an automatic and restrictive repetition of movements to "no longer think", to withdraw from all psychological activity and from all forms of relaxation. Physical fatigue and anxiety are the first symptoms of this vicious circle (Iselin et al., 1996). In other words, the body is solicited even more; the locomotory system is overused as a means of liberating the day-to-day anxiety, thus causing physical and psychological wear. When this defensive strategy is no longer sufficient to cope, a psychological decompensation occurs and a somatic liberating process in the form of MSD appears. From a psychosomatic perspective, two often connected paths permit the liberation of internal arousal stimulation: that of mental activity and that of sensorimotor activity (Marty, 1991). In the first case, the mental path, our internal tensions are put into images, ideas, fantasies or dreams. The second liberating path is the sensorimotor or behavioral path; the psychological system liberates its tensions through movement. Thus the choice of the organ where the psychological decompensation takes place is not neutral since it is a function of expressive acting[3] (Dejours, 2001). These are activities of expression, a mobilization of the body, to signify to others what one lives (Pezé, 1998).

MSDs can then be the result of a loss of identity, of decompensation by the somatic path, a sign of pathological search for greater social recognition than one finds in the professional group (Iselin et al., 1996; Pezé, 1998; Pezé, 2002). During hospital consultations involving 30-to 50-year-old women suffering from carpal tunnel syndrome, Pezé found similarities in the discourse concerning the difficult day-to-day lives of these women. At a turning point in their lives, they have identity crises and are wounded in their professional lives by the feeling of having a demeaning job (in the role of an executant unrecognized by male hierarchical superiors) and affected in their personal lives in their role as a mother which is coming to an end. The physical pathology becomes a means of focusing the attention of others on her psychological suffering. These women gained a new position through the status of an invalid, a victim, which is often more fulfilling than that of an operator, a mother or a wife. Professional and personal identify are then constructed and reconstructed through the eyes and judgment of others. These women found social recognition on the part of the medical profession through these painful symptoms which enabled them to escape from an unsatisfactory professional, social and family life.

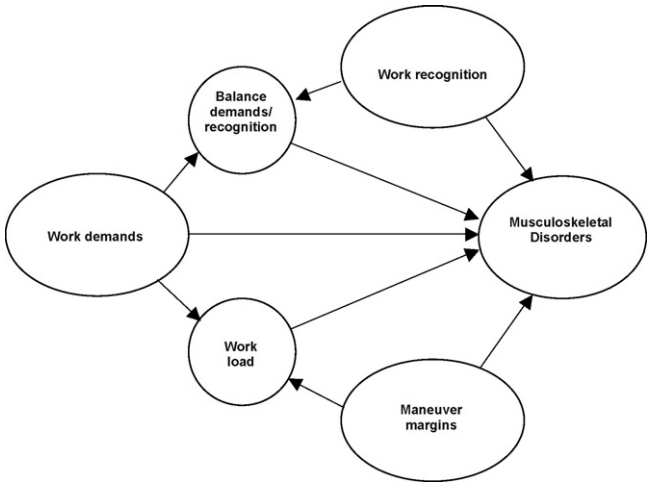

Fig. 2. Model of the existing relations between musculoskeletal disorders and the factors of maneuver margins, work demands and work recognition.

5. Conclusion: proposing a predicative model of musculoskeletal pain

According to the different theoretical points presented, MSDs can be the symptom of the impossibility felt by the worker to manage, indeed maintain, the reciprocal relation between the protection/development of his health and the protection/development of the desired efficiency in his work. The disciplinary and theoretical differences are expressed concerning the reasons for this impossibility, for the plausibility of their links with MSDs and the choices of intervention. Nevertheless, we believe that it is interesting to elaborate a unifying theoretical model which takes into account the clinical ergonomics of activity and gesture by reviewing the psychosocial models of occupational health proposed by Karasek and Siegrist. More precisely, we propose the fusion of these last two models by retaining some theoretical variables with a "broad spectrum" which must be considered like so many general operational factors across several dimensions. This model is centered on the individual's musculoskeletal complaints at work and on the cognitive and psychological dimensions which are at issue here (Fig. 2). It is an attempt at an integrated explanation of previous results. Three types of variables are considered: work demands, maneuver margins and work recognition.

Work demands refer firstly to the physical and psychological heteronymous demands which can be completed with the prescriptions that the individual has set for himself. The evaluations proposed in Karasek's extended model constitute an interesting basis for all of these physical and psychological demands

[3] The expressions can also be found in everyday language such as body aches, "I'm up to my neck…" to mean that one is exasperated and submerged in problems, "carrying too much weight on one's shoulders" when an individual is overwhelmed by responsibilities.

(Niedhammer, 2002). *Maneuver margins* are considered to be central in the struggle against MSDs in the ergonomic francophone approach. They include all of the individual's external and internal resources enabling an increase in self-control over the work activity as well as over one's job. The degree of decision-making latitude, the possibility to "negotiate" one's strategies of gesture as well as work constraints (degree of procedural autonomy and initiative) are many of the non exhaustive facets of this "maneuver margin" variable. Finally, *work recognition* refers to the judgments of peers and the hierarchy on the beauty and the utility of what is done. But this recognition can also be evaluated by material rewards, by the possibilities of evolving within the company and, more generally by the feeling of equity in the methods of symbolic and material remuneration. Social support is not directly present here: it is considered as a facet of the last two variables described. On the one hand, regarding maneuver margins (i.e., when the other is perceived as being able to offer help) and, on the other hand, regarding recognition (i.e., when the other is perceived as being a possible evaluator of the individual's contributions).

The model postulates that the more the worker feels that he is subjected to these strong demands, has narrow maneuver margins and lacks recognition within the organization, the greater musculoskeletal pain becomes. Moreover, these factors maintain interactive relations based on those which were advanced in the models of Karasek and Siegrist. A strong work demand and insufficient maneuver margins lead to an increase in the mental and physical load at work which is open to resulting in more pain. Likewise, a strong disequilibrium in the balance between work demands and level of recognition and gratification aggravates pain. This musculoskeletal pain must not be apprehended here in the form of a binary measure (presence/absence) but it must reflect the intensity of the pain felt by the individual.

The validation of this model in its entirety has not yet been undertaken: at this time it is a guide for analyzing the meaning of work and professional situations in order to better understand workers' complaints. Nevertheless, we have done several quantitative studies based on it, working with samples of workers obtained from French and Luxembourgian occupational medicine. These results tend to show that the lack of recognition and maneuver margins at work contribute to tension which facilitates the emergence of musculoskeletal disorders (Duveau and Lanfranchi, 2003; Duveau et al., 2006; Duveau, 2008; Lanfranchi, 2004).

At present, it is clear that MSDs are no longer simply a matter of respecting the biomechanical norms of work posts. A multiplicity of factors exist, susceptible to be combined, indeed to be substituted for, one and other, which contribute to the same effect: musculoskeletal disorders. The assertion of this vicariousness in the processes at issue requires taking into account the different groups of factors in the same structure of analysis in order to update weighting. Thus, by analyzing the contribution of each of these factors and their interactions within a system, it will be possible to envisage an orientation among the possibilities of transforming work situations.

Références

Aptel, M., Lafaurie, S., Tronchet, L. and Atain-Kouadio, J.J. (2000). OREGE : un outil simple d'évaluation des facteurs de risque biomécaniques de TMS du membre supérieur (NS 196). Coll. « Note scientifique et technique », Paris : INRS.

Aptel, M., Cnockaert, J.-C., 2002. Liens entre les troubles musculo-squelettiques du membre supérieur et le stress. BTS Newsletter 19–20, 57–63.

Aptel, M., Gaudez, C., 2003. Physiopathologie des TMS de l'épaule de type musculaire liés au travail : l'hypothèse des fibres de Cendrillon. In: Hérisson, C., Fouquet, B. (Eds.), Ceinture scapulaire et pathologies professionnelles. Masson, Paris, pp. 1–12.

Aptel, M., Gaudez, C., 2005. Santé mentale et activité musculaire : le cas des troubles musculo-squelettiques du membre supérieur (TMS-MS). In: Fouquet, B., Lasfargues, G., Roquelaure, Y., Hérisson, C. (Eds.), Santé mentale, appareil locomoteur et pathologies professionnelles. Masson, Paris, pp. 49–57.

Ariëns, G.A.M., van Mehelen, W., Bongers, P.M., Bouter, L.M., van der Wal, G., 2000. Physical risk factors for neck pain. Scandinavian Journal of Work, Environment and Health 26 (1), 7–19.

Ariëns, G.A.M., van Mehelen, W., Bongers, P.M., Bouter, L.M., van der Wal, G., 2001. Psychosocial risk factors for neck pain: a systematic review. American Journal of Industrial Medicine 39, 180–193.

Arnaudo et al., 2004. L'exposition aux risques et aux pénibilités du travail de 1994 à 2003. Premières Synthèses, 52.1.

Aptel, M., Gaudez, C., 2005. Les désordres du travail : enquête sur le nouveau productivisme. Éditions du Seuil et la République des Idées., Paris, pp. 49–57.

Bacher, F., 1999. L'utilisation des modèles dans l'analyse des structures de covariance. L'Année Psychologique 99, 99–122.

Bernard, 1997. Musculoskeletal disorders and workplace factors: A critical review ofepidemiologic evidence for work-related musculoskeletal disorders of the neck, upperextremity, and low back. Cincinnati: National Institute for Occupational Safety and Health.

Bongers, P.M., Kremer, A.M., ter Laak, J., 2002. Are psychosocial factors, risk factors for symptoms and signs of the shoulder, elbow, or hand/wrist? A review of the epidemiological literature. American Journal of Industrial Medicine 41, 315–342.

Bongers, P.M., De Winter, C.R., Kompier, M.A., Hildebrandt, V.H., 1993. Psychosocial factor at work and musculoskeletal disease. Scandinavian Journal of Work, Environment and Health 19, 297–312.

Bourgeois, F., Hubault, F., 2004. Prévenir les TMS. De la biomécanique à la revalorisation du travail, l'analyse du geste dans toutes ses dimensions. Activités 2 (1), 19–36, http://www.activites.org/v2n1/bourgeois.pdf.

Bourgeois, F., Lemarchand, C., Hubault, F., Brun, C., Polin, A., Faucheux, J.M., 2000. TMS et travail : quand la santé interroge l'organisation. Éditions de l'ANACT, Lyon.

Bourgeois, F., Lemarchand, C., Hubault, F., Brun, C., Polin, A., Faucheux, J.M., Douillet, P., Albert, E., 2006. Troubles musculosquelettiques et travail : quand la santé interroge l'organisation. Éditions de l'ANACT, Lyon.

Clot, Y., 1997. Le problème des catachrèses en psychologie du travail : un cadre d'analyse. Le Travail Humain 60, 37–48.

Clot, Y., 2006. La fonction psychologique du travail. Presses Universitaires de France, Paris.

Clot Y., 2001a. Éditorial. Éducation Permanente, 146, 7–16.

Clot Y., 2001b. Psychopathologie du travail et clinique de l'activité. Éducation Permanente, 146, 35–49.

Clot, Y., 2001c. Méthodologie en analyse clinique de l'activité : l'exemple du sosie. In: Santiago-Delafosse, M., Rouan, G. (Eds.), Les méthodes qualitatives en psychologie. Dunod, Paris, pp. 125–147.

Coutarel, F., Daniellou, F., Dugué, B., 2003. Interroger l'organisation du travail au regard des marges de manœuvre en conception et fonctionnement : la rotation est-elle une solution aux TMS ? Pistes 5 (2), 1–24, http://www.pistes.uqam.ca/v5n2/articles/v5n2a2.htm.

Coutarel, F. (2004). La prévention des troubles musculo-squelettiques en conception : quelles marges de manoeuvre pour le déploiement de l'activité ? Thèse de doctorat en ergonomie, Université Victor-Segalen. Bordeaux-2, Éditions du Laboratoire d'Ergonomie des Systèmes Complexes.

Coutarel, F., Daniellou, F., Dugué, B., 2005. La prévention des troubles musculosquelettiques : quelques enjeux épistémologiques. Activités 2 (1), 3–18, http://wwww.activites.org/v2n1/coutarel.pdf.

Daniellou, F. (Ed.) (1996). L'ergonomie en quête de ses principes : débats épistémologiques. Toulouse: Octarès.

Daniellou, F., 1998. Une contribution au nécessaire recensement des « repères pour affronter les TMS ». In: Bourgeois, F. (Ed.), Les actes du séminaire : TMS et évolution des conditions de travail. Editions de l'ANACT, Lyon, pp. 35–46.

Daniellou, F., 1999. Les TMS, symptôme d'une pathologie organisationnelle. BTS Newsletter 11, 34–37.

Daniellou, F., 2003. De la rotation sur les postes à la santé au travail : synthèse du colloque « La rotation, est-ce une solution ? ». Pistes 5 (2), 1–7, http://www.pistes.uqam.ca/v5n2/articles/v5n2a12.htm.

Davezies, Ph., 1993. Éléments de psychodynamique du travail. Éducation Permanente 116, 33–46.

Davezies, P., 1999. Évolution des organisations du travail et des atteintes à la santé. Travailler 3, 87–114.

Dejours, C., 1990. Nouveau regard sur la souffrance humaine dans les organisations. In: Chanlat, J.F. (Ed.), L'individu dans l'organisation : les dimensions oubliées. Presses de l'Université de Laval, Laval, pp. 687–708.

Dejours, C., 1995. Comment formuler une problématique de la santé en ergonomie et en médecine du travail. Le Travail Humain 58 (1), 1–10.

Dejours, C., 2000. Travail, usure mentale : essai de psychopathologie du travail. Bayard Éditions, Paris.

Dejours, C., 2001. Le corps d'abord. Payot, Paris.

Delisle, A. (2005). Métrologie biomécanique et démarche de prévention des TMS : problématique et aspect méthodologique. Communication orale au 1er congrès francophone sur les TMS, Nancy, 30–31 mai.

Douillet, P., Schweitzer, J.M., 2002. TMS, stress : gagner des marges de manoeuvre. BTS Newsletter 19, 64–66.

Douillet, P. and Schweitzer, J.M. (2005). Approche du réseau ANACT : Principes et illustrations de l'intervention comme une construction sociale. Communication orale au 1er Congrès francophone sur les TMS, Nancy, 30–31 mai.

Duveau, A. and Lanfranchi, J.-B. (2003). Impact des facteurs psychoorganisationnels et motivationnels sur la douleur musculosquelettique perçue. Communication orale au 2e Congrès international de psychologie de la santé de langue française, Metz, 26–27 juin.

Duveau, A., Dodeler, V., Tarquinio, C., Houbre, B., Tragno, M. and Majery, N. (2006). Facteurs psychosociaux et TMS : comparaison de la douleur musculosquelettique perçue entre le salarié et le médecin. XIVe congrès AIPTFL de psychologie du travail et des organisations. Tunisie, Hammamet.

Duveau, A. 2008. Douleurs musculosquelettiques et usure professionnelle : quand le rapport au métier est interrogé. Thèse de doctorat en psychologie, Université Paul Verlaine - Metz.

Gary, Y., Pacchiarini, J., Chardeyron, J., 2005. Troubles musculo-squelettiques et souffrance mentale. In: Fouquet, B., Lasfargues, G., Roquelaure et, Y., Hérisson, C. (Eds.), Santé mentale, appareil locomoteur et pathologies professionnelles. Masson, Paris, pp. 130–143.

Ginies, P., 2005. La douleur : son interférence sur la santé mentale au travail. In: Fouquet, B., Lasfargues, G., Roquelaure et, Y., Hérisson, C. (Eds.), Santé mentale, appareil locomoteur et pathologies professionnelles. Masson, Paris, pp. 30–39.

Hamon-Cholet, S., Rougerie, C., 2000. La charge mentale au travail : des enjeux complexes pour les salariés. Économie et Statistique 339, 243–255.

Hägg, G., 1991. Static work loads and occupational myalgia: a new explanation model. In: Anderson, P.A., Hobart et, D.J., Danhoff, J.V. (Eds.), Electromyographical Kinesiology. Elsevier Science Publishers, North-Holland, pp. 141–144.

Hoogendoorn, W.E., van Poppel, M., Bongers, P.M., Koes, B.W., Bouter, L.M., 1999. Physical load during work and leisure time as risk factors for back pain. Scandinavian Journal of Work, Environment and Health 25 (5), 387–403.

Hoogendoorn, W.E., van Poppel, M.N.M., Bongers, P.M., Koes, B.W., Bouter, L.M., 2000. Systematic review of psychosocial factors at work and private life as risk factors for back pain. Spine 25 (16), 2114–2125.

Huang, G.D., Feuerstein, M., Sauter, S.L., 2002. Occupational stress and work-related upper extremity disorders: concepts and models. American Journal of Industrial Medicine 41, 298–314.

Hubault, F., Bourgeois, F., 2004. Disputes sur l'ergonomie de la tâche et de l'activité, ou la finalité de l'ergonomie en question. Activités 1 (1), 1–20, http://www.activites.org/v1n1/hubault.pdf.

Iselin, F., Laroudie, S., Pezé, M., Thetio, M., 1996. Du canal carpien aux TMS : approche pluridisciplinaire d'une pathologie dite univoque. Performances Humaines et Techniques 82, 10–17.

Joksimovic, L., Starke, D., Knesebeck, O., Siegrist, J., 2002. Perceived work stress, overcommitment, and self-reported musculoskeletal pain: a cross-sectional investigation. International Journal of Behavioral Medecine 9, 122–138.

Karasek, R., Theorrell, T., 1990. Healthy work: stress, productivity and the reconstruction of working life. Basic Books, New York.

de Lange, A.H., Taris, T.W., Kompier, M.A., Houtman, I.L., Bongers, P.M., 2003. The very best of the millennium: longitudinal research and the demand-control-(support) model. Journal of Occupational Health Psychology 8 (4), 282–305.

Lanfranchi, J.-B. (2004). Stress au travail et TMS. Communication orale au Congrès international Hommes et Organisations : la santé au cœur des enjeux de l'entreprise, Nancy, Metz, Mondorf-Les-Bains, 22–24 novembre.

Leplat, J., 1997. Regards sur l'activité en situation de travail : contribution à la psychologie ergonomique. Presses Universitaires de France, Paris.

Leplat, J., 2000. L'analyse psychologique de l'activité en ergonomie : aperçu sur son évolution, ses modèles et ses méthodes. Octarès, Toulouse.

Linton, S.J., 2001. Occupational psychological factors increase the risk for back pain: a systematic review. Journal of Occupational Rehabilitation 11 (1), 53–66.

Lundberg, U., Forsman, M., Zachau, G., Eklöf, M., Palmerud, G., Melin, B., et al., 2002. Effects of experimentally induced mental and physical stress on motor unit recruitment in the trapezius muscle. Work and Stress 16 (2), 166–178.

Marty, P., 1991. Genèse de maladies graves et critères de gravité en psychosomatique. Revue Française de Psychosomatique 1, 5–22.

Merllié, D. et Paoli, P. (2000). Dix ans de conditions de travail dans l'Union européenne. Luxembourg : Office des publications officielles des Communautés Européennes.

Mottay, D. (2001). La structuration du travail ou « job design ». Cahier de recherche du GREFIGE, 2001-05, 1-30. www.univ-nancy2.fr/GREFIGE.

National Research Council (NRC) and the Institute of Medicine (2001). Musculoskeletal disorders and the workplace : Low back and upper-extremities. Panel on muskuloskeletal disorders and the workplace. Commission on behavioral and social sciences and education. Washington, DC: National Academic Press.

Niedhammer, I., 2002. Psychometric properties of the french version of the Karasek Job Content Questionnaire: a study of the scales of decision latitude, psychological demand, social support, and physical demands in the GAZEL cohort. International Archives Occupationnal and Environmental Health 75, 129–144.

Pezé, M., 1998. Les athlètes du quotidien : approche psychosomatique et psychosomatique des TMS. In: Bourgeois, F. (Ed.), Les actes du séminaire : TMS et évolution des conditions de travail. Editions de l'ANACT, Lyon, pp. 63–70.

Pezé, M., 2002. Le deuxième corps. La dispute, Paris.

Rascle, N., 2001. Facteurs psychosociaux du stress professionnel et de l'épuisement professionnel. In: Bruchon-Schweitzer et, M., Quintard, B. (Eds.), Personnalité et maladie : stress, coping et ajustement. Dunod, Paris, pp. 221–238.

Reuchlin, M., 1995. Totalités, elements, structures en psychologie. PUF, Paris.

Siegrist, J., 1996. Adverse health effects of high-effort/low-reward conditions. Journal of Occupational Health Psychology 1, 27–41.

Siegrist, J., Starke, D., Chandola, T., Godin, I., Marmot, M., Niedhammer, I., et al., 2004. The measurement of effort-reward imbalance at work: European comparisons. Social Science and Medicine 58, 1483–1499.

Tsutsumi, A., Tatsuya, I., Peter, R., Siegrist, J., Matoba, T., 2001. The japanese version of the Effort-Reward Imbalance Questionnaire: a study in dental technicians. Work and Stress 15 (1), 86–96.

Vallier, N., Saba, G., Ricordeau, Ph., Fender, P., Allemand, H., 2004. Motifs médicaux et environnement socioprofessionnel des assurés en arrêt de travail du régime général. CNAMTS, Paris.

Warren, N., 2001. Work stress and musculoskeletal disorder etiology: the relative roles of psychosocial and physical risk factors. Work 17, 221–234.

Westman, A.S.J., Linton, A.S.J., Öhrvik, J., Wahlén, P., Leppert, J., 2008. Do psychosocial factors predict disability and health at a 3-year follow-up for patients with non-acute musculoskeletal pain? A validation of the Örebro Musculoskeletal Pain Screening Questionnaire. European Journal of Pain 12 (5), 641–649.

van der Windt, D.A.W.M., Thomas, E., Pope, D.P., de Winter, A.F., Macfarlane, G.J., Bouter, L.M., et al., 2000. Occupational risk factors for shoulder pain: a systematic review. Occupational and Environmental Medicine 57, 433–442.