ERGONOMIC PRACTICE AND MUSCULOSKELETAL DISORDERS (MSDs) : OPENNESS TO INTERDISCIPLINARITY

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MSDs represent a complex phenomenon, and interdisciplinarity seems desirable not only in research but also in the intervention. First, a model is proposed for understanding work situations that result in the development of MSDs for the purpose of integrating several types of learning based on a systemic approach and of identifying the significance of different terms. An interdisciplinary study is then used as the springboard for dealing with three main issues. In fact, the results obtained prompted reflection on the questions often used to describe the decisional latitude, while questions directly describing the activity provided more conclusive results. Epidemiological studies are very important in recognizing MSDs, and help ergonomists be persuasive, but how can they best promote the formulation of questions and what difficulties can be encountered? Furthermore, since musculoskeletal load represents a major aspect of MSD-related activity, ergonomists seem to need a sufficient understanding of the different aspects of this component of the activity. One example of collaboration between ergonomics and biomechanics demonstrates the advantage of this association for better understanding the procedures and for identifying the determinants of the activity. Finally, in-company training on workstations represents a major issue in MSD prevention, and ergonomists are increasingly concerned about questions of versatility. The development of collaboration with professional training specialists therefore seems necessary. The conclusion discusses the importance of ergonomists contributing their viewpoint of the activity and promoting collaboration between several disciplines for the purpose of MSD prevention.

Key words: Musculoskeletal disorders – ergonomic intervention – interdisciplinarity – prevention

INTRODUCTION

We are gaining more and more knowledge about MSDs and means of action, as demonstrated by books such as those of Kuorinka and Forcier (14), Bernard et al. (3), and Bourgeois et al. (4). It is not a lack of knowledge that prevents action, and as stated by Daniellou (9): "Understanding all the mechanisms that explain the appearance of MSDs is not a prerequisite to their treatment". (free translation)

However, we have three concerns. The first has to do with the recognition of MSDs, their risk factors and the determinants of these factors in workplaces generally. This recognition by the different people dealt with in companies seems necessary to promote the motivation to act. The results of epidemiological studies and large-scale national surveys are essential. As can be noted in the analysis of Lippel et al. (18), epidemiological studies have a primary importance in the recognition of occupational injuries. If epidemiological studies can help ergonomists be persuasive, how can ergonomists best promote the formulation of questions drawn from their experience in work situation analysis?

The second concern involves our knowledge of physiology and biomechanics. Do ergonomists still receive sufficient training in these areas to properly analyze physical work and understand the musculoskeletal load necessary to carry out the observed operations? Are we still able to properly describe this load or is our attention often mobilized and limited by the biomechanical factors that are classically found in observation checklists? This ability to properly describe musculoskeletal load is very important, particularly in cases where the work is considered light and where the difficulty of the work is less readily visible, as is often the case in women's work (20). When the relationship between physical work and MSD development in a company is not understood, there is a risk of promoting the perception that MSDs originate from a "collective hysteria" (5) and of neglecting the important determinants of musculoskeletal loading, whether they be technical or organizational in nature. Collaboration between ergonomists and biomechanists within the intervention context could then be very enriching.

Third, considering the growing interest of companies in developing versatility in their employees, and the popularity of job rotation often considered as a means of reducing MSDs, ergonomists are increasingly concerned about issues of in-company training. The benefit of activity analysis in the development of professional training is not new, as reported by Chatigny (7); however, it is clear that ergonomists are rarely associated with education science specialists in developing in-company training or in learning a trade. However, training on workstations is a major issue in MSD prevention, and creating bridges between these disciplines is important.

Before developing further these three considerations by which ergonomics is spurred towards interdisciplinarity in MSD prevention, two parts will be presented. First, it seems useful at the start of this paper to present the model to which we will refer. It is in fact a model that combines several others taken from different types of learning, particularly from Guérin et al. (11), Franchi (10), Sauter and Swanson (25) and from our own experiences in MSD intervention. It is an attempt to deal with MSDs in a systemic way using a model focused on the activity, while integrating an approach based on the identification of risk factors and their determinants. This model also allows us to situate the different commonly used terms, which will then be the basis for our discussion. In the next part, we will present the case of a study with paradoxical results, which is the source of several questions raised in this paper.

AN ACTIVITY-FOCUSED EXPLANATORY MODEL FOR MSDS

This model will be presented using two figures, the first proposing an overall understanding of work situations, and the other detailing the components of the activity. The entire model is focused on the individual doing a work activity, where the activity is considered as the central organizational element structuring the components of the work situation (11). The individual is considered from the standpoint of all his characteristics. This person has an age, a gender, experience, and anthropometric, physiological, and psychological characteristics, etc. The person is in a more or less significant state of stress, fatigue, and possibly with pain. The person is more or less satisfied with his work, considering his aspirations, and has perceptions of his work, working conditions, what is expected of him, and what is thought of him, etc. Hence, what Kuorinka and Forcier (14) call "psychosocial factors" among the MSD risk factors, by defining them as the "subjective perceptions that the worker has of work organization factors", are simply in this model part of what the person is, and on what his activity will depend.

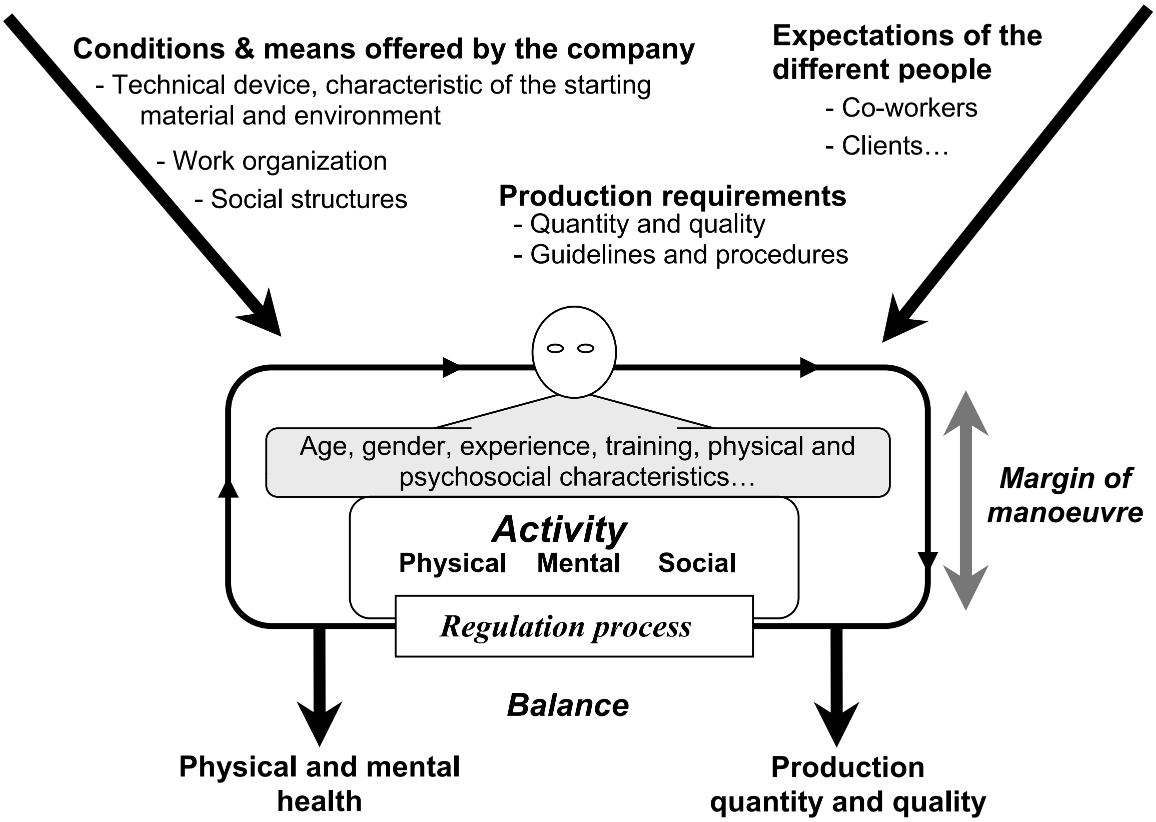

Figure 1: Model of the understanding of work situations focused on the person and his activity

This person carries out an activity that is described by taking into account his physical, mental and social makeup. For example, a female sewing machine operator in a boot factory analyzes the type of material handled before sewing it, and chooses a way of doing things and of positioning herself so that she can hold the pieces properly, press precisely at the right time, and maintain the speed that will allow her to meet the production objectives as well as make the work of her female co-workers easier. The consequences of this activity are twofold: the person's condition, namely her health in the sense of physical and mental well-being; and production in terms of both the quantity to be produced and the quality of the product. Her activity can thus produce a state of work satisfaction, just like it can result in a physical disorder such as an MSD, or a mental disorder such as psychological distress. A loop can therefore be added, going from the consequences of the activity on health, and returning to the centre of the diagram to the characteristics of the person doing the activity.

The activity is obviously carried out in response to the production requirements, while also taking into account the expectations of the different people she has to deal with, as for example, co-workers (figure 1). It is carried out according to the conditions and means offered by the company, which are many and of different types. They can be 1) physical means, such as workstation layout, and the characteristics of the tools and starting material, or 2) work organization, in terms of task distribution, dependency between workstations, schedule, method of remuneration, or 3) the social structures in the company, such as supervision, management style, or communications. All these aspects will constitute the many determinants of the activity and also the person's condition, whether directly or as a result of the activity. These determinants will weigh more or less heavily on the person by having an impact on the extent of the margin of manoeuvre that the person will have available to regulate his activity. It is these determinants as well as their links and interactions that must be understood in order to be able to propose improvements for the work situations.

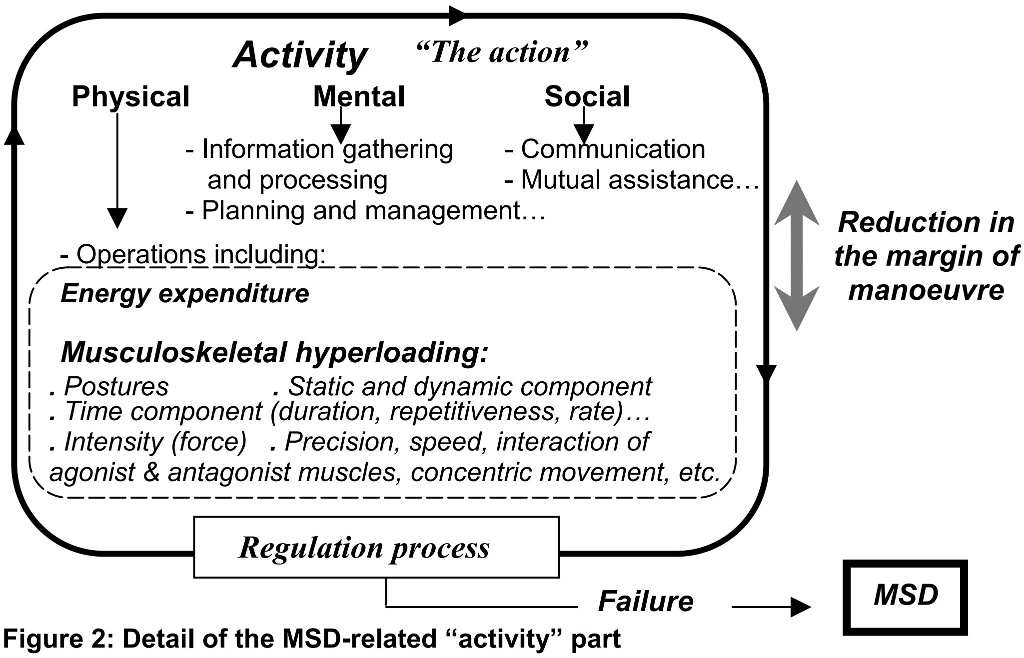

Figure 2: Detail of the MSD-related "activity" part

In this model, it was important to highlight the principle of regulation by the activity developed by Guérin et al. (11). It is based on the fact that this entire system is undergoing change and that the person through his activity will constantly have to adapt and adjust. The person will thus develop different ways of doing things or strategies that will enable him to take into account the variability in the working conditions and his own variability in order to maintain a balance between his health and his production. When this regulation process fails, health can be affected, as is the case in figure 2 where a reduced margin of manoeuvre led to the development of MSDs.

In figure 2, the activity is even further broken down, and it is understood that the physical activity itself constitutes, through the operations performed, the physical load borne by the worker. Thus, what we call "biomechanical factors" correspond to the physical activity itself, which in a case where it leads to hyperloading of the muscles and tendons, may result in the development of an MSD. The very nice concept of "action" provided by Bourgeois et al. (4) shows the importance of not reducing the activity analysis to movements, and of considering the physical activity with the person, the various components of his activity (mental and social), and his attempt to find a balance.

THE CASE OF A STUDY WITH PARADOXICAL RESULTS

In a study carried out in a boot factory where an increase in MSDs in sewing machine operators had been recorded following reorganization of the work into a modular and just-in-time system, we combined an ergonomic approach and an epidemiological approach (29). The purpose of the epidemiological component was to measure the prevalence of MSDs and to identify the predictive factors for 367 female workers in this plant. In the ergonomic intervention, the work activity of 23 sewing machine operators in three targeted modules was analyzed. During the second phase of the project (30), the questionnaire was reused to evaluate the impact of the changes carried out following phase 1, and the ergonomic component reanalyzed the work of the sewing machine operators in the targeted modules and offered technical and practical support promoting implementation of the changes. A sociological component was also added in order to support and follow the change-implementation process.

The results of the different components were very consistent and allowed a common interpretation of the situation; however, we also obtained some very paradoxical results that should be mentioned. First, the questions on decisional latitude did not reveal the very limited margin of manoeuvre described by the ergonomists. Second, very specific questions dealing with certain aspects of the work activity and particularly the loading of the lower limbs were strongly correlated with the MSDs of several body regions as well as with psychological distress. Third, comparison of the results in phase 1 and phase 2 of the study show significant improvements in psychosocial factors and a reduction in psychological distress, whereas a significant increase in MSDs is observed in the hands/wrists/ forearms.

Decisional latitude and margin of manoeuvre

In the epidemiological component, in order to take into account the multifactorial origin of the MSDs and the impact of organization-related factors, the "control and requirements" model of Karasek and Theorell (12) was used. According to this model, working conditions lead to a deterioration in health when they correspond to major psychological and physical demands when the person has little impact on his workstation. As in the epidemiological questionnaire, the measurement of perception of decisional latitude consists of two indices, namely decision-making authority and the use of competencies. For the analyses, a multiple logistical regression model was developed in stages for each of the body regions. None of these indices emerged significantly for any of the body regions.

However, the results of the ergonomic component in phase 1 show that the new work organization changed the time component and reduced the female workers' margins of manoeuvre, particularly at workstations where bottleneck situations occur. What happens then is an intensification of the work of the female sewing machine operators at these workstations and a reduction in regulation and control possibilities. The activity analysis shows that in these situations, intercycle times are non-existent, repetitiveness of movements increases, the rate is faster, and the static-posture maintenance time is prolonged. The new work organization conditions therefore resulted in an increase in exposure to certain biomechanical risk factors while creating difficult relationships between the workers.

Despite the pertinence of the questions on decisional latitude and the benefit of using these standardized questions that allow comparison with other studies, they did not explain the reduction in the margin of manoeuvre, these female workers' regulation difficulties, and their impact on MSDs. In particular, the questions dealing with the use of skills were not discriminating because more than 90% of the sewing machine operators considered that their work required many skills and that they learn new things.

Specific questions about the work activity bring unexpected results

In this plant, the introduction of modular work meant that sewing machine operators went from a sitting to a standing posture. Since this new condition was the subject of many complaints from these workers, we formulated several questions for identifying the different ways of standing and the percentage of time that a pedal is used, in order to verify the relationships with MSDs in the lower limbs. The results of a multiple logistical regression analysis that included several independent variables showed that the two variables "*maintaining a stationary posture*" and "*using a pedal more than 60% of the day*" were significant variables in the model involving MSDs in the lower limbs. However, the "*using a pedal more than 60% of the day*" variable was also a predictor of MSDs in the neck/ shoulders and of MSDs in the hands/wrists/forearms. When the MSDs in any region in the body were considered, the odds ratio for the "*using a pedal more than 60% of the day*" variable was 2.4 (C.I. at 95% of 1.2 to 4.8) and that of "*maintaining a stationary posture*" was 3.3 (C.I. at 95% of 1.3 to 8.6). The latter represented the highest odds ratio obtained in the model (29). These two variables were also predictors of psychological distress.

We believe that these results can be explained in two ways. First, the working standing "while using a pedal" and/or "while maintaining a static posture" variables necessarily included the female workers found at workstations most easily experiencing bottlenecks, meaning workstations where only one machine is used, where pieces can accumulate, and where the work can become very intense. These postures can then be thought to have consequences not only on the lower limbs but also on the entire body. From the observations, the use of the pedal leads to a general unbalanced posture by putting the entire body weight on only one leg. In addition, considering the precision and speed of the movements to be performed by sewing machine operators, static muscular work may increase at the top of the back, at the neck and at the shoulders in order to stabilize this region that supports the upper limbs. Therefore, specific questions about this environment and characterizing the physical workload were found among the most important predictors of MSDs. This prompted us to reflect further on the interdisciplinary exchanges between ergonomics and epidemiology pertaining to the formulation of questions.

From phase 1 to phase 2, an improvement in psychosocial factors and an increase in MSDs in the hands/wrists/forearms

Between phases 1 and 2, many changes took place in the company, particularly in the training of operators and work organization, thus allowing the sewing machine operators to occupy different workstations, to move around and to have a more balanced distribution of the tasks in the module. The results of the second application of the epidemiological questionnaire at the time of phase 2 show several significant changes in the sewing machine operators in the module: reduced psychological distress and perception of the physical load, and increased work satisfaction and perception of decisional latitude and co-worker support. The *severity* of the MSDs measured by questions on functional status (27) decreased significantly. Changes in the *prevalence* of MSDs varied with the body region: a major reduction in MSDs in the lower limbs, and nonsignficant differences for the neck, shoulders and back, and a marked increase in MSDs in the forearms, wrists and hands (30). This increase in the prevalence of MSDs in this region was difficult to explain, while the different explanatory variables in the epidemiological model showed an improvement.

The ergonomic analysis of the work activity in the modules and the follow-up on the implementation of changes provided an understanding of the situation that produced several hypotheses. In fact, the assessment of the application of the recommendations formulated following phase 1 showed that at the time of phase 2, the module-related recommendations and support offered by management and supervisors had for the most part been applied, while only half of the recommendations on workstation improvement had been implemented, and fewer than 25% of the recommendations involving services. Several of the service-related recommendations seemed difficult to apply because they were the responsibility of the company's central services which was not very concerned about the situation in the company. Several recommendations involving the characteristics of the starting material were therefore not implemented (stiffness of the leather, characteristics of the vamps and felt, uneven cutting of pieces, etc). The purpose of these recommendations was to reduce hand and wrist efforts and the awkward postures associated with the difficulty of fitting the pieces together. During this period as well, the company gradually increased the proportion of manufactured top-of-the-line models of boots, which increased the problems related to the starting material.

Thus, work organization within the modules and management support were improved, as demonstrated by the perception of the female workers in the epidemiological questionnaire (psychosocial factors). However, the biomechanical components of the work activity and several of its conditions (such as the characteristics of the starting material) maintained too narrow a margin of manoeuvre for better control of MSDs in the upper limbs. These results emphasized the already recognized importance of biomechanical factors in the genesis of MSDs.

Furthermore, the ergonomic analysis that enhanced the interpretation of the epidemiological component's results did not demonstrate the extent of the problem of MSD prevalence in the hand/wrist/forearm region. Therefore, it is by combining the two components that the necessary arguments can be developed for convincing the people whom they deal with in the company of the changes that need to be made.

QUESTIONS THAT EXPLAIN THE ACTIVITY AND ITS DETERMINANTS

Following our experience with questions on decisional latitude that emerged with difficulty, to our surprise, questions very specific to the activity were so strong in the logistical regression model, and the interest in developing questions that pinpoint the characteristics of the work situations that have an impact on health, we asked ourselves when epidemiologists and ergonomists join forces, how can ergonomists help in formulating questions and what difficulties may be encountered?

Questions for large-scale surveys

The association of ANACT and INSERM in France is exemplary in this regard. Leclerc (16) reports that the national epidemiological survey on periarticular conditions of the upper limbs was carried out on ANACT's initiative, and ergonomists were the source of the hypotheses on the role of work organization in MSD development. An entire series of questions was developed to explain organizational dependency and this large-scale survey demonstrated the link between between this organizational dependency and MSDs (4). It is interesting to reflect on the types of questions developed. For example, to explain organizational dependency, the questions asked involved the possibility of choosing the time of breaks and the possibility of varying one's work rate: "Outside the planned breaks, can you interrupt your work?", "Is your work rate imposed by the automatic rate of a machine or by the immediate dependence on the work of one or more co-workers?", "Are you able to vary your work rate? Work faster or slower?" (4, p.74-75).

These questions provide concrete information on work organization determinants; it is on these determinants that the people's activity and margin of manoeuvre will depend. The questions are more precise than those that we had used that were based on the model of Karasek (13) and that can lead to confusion: "My job allows me to make many decisions myself" or "I have a lot of influence on what happens in my work". In fact, particularly when new work organizations are involved, as was the case with the boot factory sewing machine operators, the female workers collectively have to make several decisions about production, at least many more than with the traditional system. This perception does not necessarily take into account the fact that they cannot decide when to take a break and that their margin of manoeuvre is very dependent on those of their co-workers.

Although perception is clearly involved, the ANACT-INSERM questions are also different from the questions that are seeking an opinion about the work more than information on working conditions. According to our model, this opinion could be associated even more with the person's characteristics (or according to Kuorinka and Forcier (14), with psychosocial factors). For example, the questions on the use of skills are part of the decisional latitude index in the Karasek questionnaire (13): "My job requires that I be creative", "I have the possibility of developing my personal capabilities". The answers to these questions depend on the person's aspirations, his training, his prior experience, his image of himself. They can be interesting for finding out the person's viewpoint and attitude at work.

With our model, questions that provide information on the person, on the activity and on the determinants of the activity could be differentiated. For example, the questions on standing posture that we used in the questionnaire for sewing machine operators in the boot factory directly involved the activity: the percentage of time that a pedal is used, and four different ways of standing (stationary in front of only one machine, stationary but using several machines, short displacements, long displacements). These questions were retrieved and reworked for use in the Enquête santé Québec (Quebec health survey) (1) and provided interesting results in that there is proportionally more lower-back and lower-limb pain reported by people who work standing (activity) and less pain when the person has the possibility of varying his posture (working condition). Other examples could be provided, such as that of Roquelaure (24) who participated in a national survey on grape growers. Some questions involved the activity, such as the number of vinestocks trimmed daily, the number of daily cuts or the duration of cutting.

The benefit of developing questions that describe the activity and that can be used over a large scale is clear. Questions relating directly to mental activity in terms of the quantities of information to be collected, adaptation to the variability in the products and incidents, planning, and time management, or questions relating to the social activity of communication, mutual assistance, exchange, etc., have, to our knowledge, not been extensively developed and used in studying MSDs. We should clarify that questions on the activity would be involved here (and not questions on the conditions or possibilities offered to the person), and therefore questions such as: "Do you change your work method according to the product manufactured?" or "Do you let your co-workers know about the difficulties that you encounter?". Seifert et al. (26) developed questions of this type in their survey of 305 bank tellers, as for example: "During your last week of work, were there times when you did not immediately apply the following rules of procedure (having cheques initialled, verifying signatures, reducing the amount of money in the bottom of the cash) in order to avoid having to move?".

The limits of the descriptive variables for the physical activity

Normally in epidemiological studies, questions about physical activity involve less the operations carried out, which tend to be limited to a particular sector, than more general components of the physical activity that describe the biomechanical risks, for instance. In Sweden, for example, the MUSIC Swedish Research Centre presented several papers at the most recent PREMUS congress (21, 22, 35). Ways are sought of asking questions that ensure the reliability of the collected information, involving, for example, handling and posture (ex.: *time spent with hands above shoulders)*. This seems to be a major challenge, but questionnaires completed during interviews and certain types of questions seem to ensure that the answers are reliable. However, it is certainly not easy to formulate a set of questions that can be representative of all of the requirements, particularly when the upper limbs are involved.

Furthermore, in several epidemiological studies (3), the questionnaires are associated with the ergonomists' observations and/or measurements of different components of the physical activity, mainly posture, repetition and strength. Observation checklists (14) have been developed to describe the different components. With this intention in epidemiological studies to describe the activity, we also immediately run into the difficulties of association between ergonomics and epidemiology. We should not be stopped by our contradictions, as proposed by Volkoff (34), who describes very well in his expression "an epidemiology of *the refined* versus an ergonomics of the *complex*" the difficulty of reconciling the ergonomists' need to deal with reality in all its complexity in order to give themselves the means for intervening efficiently, and the epidemiologists' need to pinpoint the variables for establishing links between work and health. We experienced this contradiction in the study on sewing machine operators, where the ergonomists could not provide the epidemiologist with measurements of the physical load at the different workstations, given the great variability in the work and conditions from one module to the next and from one day to the next (31). However, we realize now that if the ergonomic analysis had preceded the development of the questionnaire, as in the study of Seifert et al. (26), questions could have been formulated for documenting more precisely several aspects of the work activity for the plant as a whole.

For the ergonomist, there is a fear of simplifying a complex and variable reality too much. There is also the fear of limiting his description to the already well-identified physical risk factors. We know that work situations that appear to be not very constraining may be demanding from a biomechanical standpoint if they are not given special attention that goes beyond the range of postures, the force applied and repetition. The development of knowledge on work physiology and biomechanics is proving to be very important, and the integration of biomechanical measurement into ergonomic intervention may help in identifying aspects of the physical activity that are difficult to observe and to access through verbalizations.

IMPORTANCE OF MUSCULOSKELETAL LOAD AND INTEGRATION OF IOMECHANICS INTO THE INTERVENTION

MSDs are known to be related to musculoskeletal load, with the latter being associated with the use of anatomical structures, namely joints, muscles, tendons and ligaments.

Furthermore, it is generally accepted that an internal state of stress may add to the musculoskeletal load by increasing muscular tonus (14). Cnockaert (8), a physiologist, explained that stress would have an impact at other levels, such as an increase in water retention; a reduction in the rate of repair of the micro-injuries generated, for example, by repetitive movements; a reduction in immune defenses; or an increase in the secretion of pro-inflammatory substances. Returning to our model, it is understood that some conditions, such as the bottleneck situations created by the new work organization and experienced by the sewing machine operators in the boot factory, would have an impact on the physical work activity by increasing the biomechanical risks, as well as on the person's characteristics by increasing the state of tension and distress. The consequence of all this would be an increased risk of MSDs.

However, there is no evidence that psychological distress could create MSDs in a person without a corresponding musculoskeletal load. In fact, an MSD is a localized health problem and not a general condition. MSDs are in the left wrist, right shoulder, in the upper back or elsewhere; it is therefore important to identify the musculoskeletal loads corresponding to the MSD developed. A proper description of the musculoskeletal load therefore still seems necessary when an ergonomist receives a request involving MSDs. This assumes that ergonomists have proper training in producing this description, and that there is a need to promote the development of physiological and biomechanical knowledge.

Moreover, in the study on sewing machine operators (30), the improvement in working conditions resulted in a reduction in the severity of the MSDs and a reduction in psychological distress, while the prevalence of MSDs clearly increased in the hand/wrist/forearm region, demonstrating that the biomechanical load on this region was mainly responsible. In addition, we should note that in this study, the most important predictive factor for psychological distress was the perception of the physical load.

Here, we are reporting the experience from two studies showing, on the one hand, the importance that the ergonomist properly describe the musculoskeletal load, and on the other, how the integration of biomechanics can contribute to the intervention. The first study (32) was conducted in an automobile manufacturing plant where the employer wanted to implement rotation within a work team. In order to identify the advantages and disadvantages of this type of work organization, 250 workers were surveyed, and a team of six operators who were already rotating on a voluntary basis was followed. To understand the differences from one workstation to the next, including musculoskeletal loads, the ergonomists did an activity analysis, and a questionnaire was developed. It asked the workers to classify the workstations occupied during rotation according to different parameters and the loads on different regions of the body. To our surprise, workers classified the workstation where they stood under the automobile with their hands above their heads and their arms completely vertical as less stressful on the shoulders than another workstation where the shoulders alternated between different degrees of flexion from 0° to a maximum of 90°. In both cases, they held tools in their hands. From a more detailed interactive analysis with the workers, we understood that the second workstation was very stressful for the shoulders, considering the precision of movement and the fact that the movement of pushing to tighten a screw had to be controlled at the same time so that the screw was not inserted too far. It has been known for a long time that precision associated with speed of movement requires muscle contraction in regions that allow movement to be better stabilized (15); however these aspects are not always found on the observation checklists. This characteristic of the movement, which must be done forcefully but at the same time in a controlled way, was rarely mentioned. Letendre and Marchand (17) emphasized the importance of considering the co-contraction phenomenon because it could overload the musculoskeletal structures.

Several researchers (19, 6, 24) have shown the benefit of using quantitative measurements, such as electromyography, in an actual work situation. These measurements have a recognized benefit for comparing musculoskeletal load in relation to different work tools and equipment. However, their usefulness not only for describing musculoskeletal load but also for understanding the work activity within the context of an ergonomic intervention has rarely been shown. In the case of the study of Richard (23), electromyography facilitated the identification of an important determinant of musculoskeletal load that was not observable and that did not emerge from the workers' verbalizations. In fact, at the carcass saw in a pig slaughterhouse, the workers activate the locks on a saw whose weight is supported by a counterbalancing system. They then align the saw for a very precise cut along the pig's spine. The company did not consider this workstation very stressful since the workers did not support the weight of the saw. However, the workers encountered problems that were difficult to pinpoint. It was only when the operators were faced with the electromyography results (which revealed an increase in muscular load at certain well-identified moments in the operating sequence) that they were able to explain the relationship between cycle times, keeping the locks locked, saw alignment, and the motor's lateral vibration. This unnoticeable vibration corresponded to a movement from left to right during the first two seconds of activation of the saw. The workers waited for this vibration to stop before cutting in order to avoid the additional muscular effort needed to properly align the saw while it was moving. However, when there were time constraints on the workers and a few lost seconds had to be made up, some workers started cutting sooner, before the vibration had stopped, while others no longer released the locks between work cycles. By combining the investigation methods, an important determinant for the saw was identified within the context of this intervention, and the motor was then subsequently modified.

As explained by Roquelaure (24) who combined several approaches, " … ergonomic analysis methods can be enhanced by the use of biomechanical techniques. (…) However, electrophysiological measurements must not be done a priori, outside the context of the work activity, because they have meaning only if they are related to the work performed" (free translation). Bourgeois et al. (4) also reveal the fact that a simple biomechanical description of the action does not systematically result in a diagnosis of its "toxicity". It is the overall analysis of the work situation that may provide an understanding of the margin of manoeuvre that a person has or does not have for finding satisfactory compromises, efficient strategies and solutions to compensate for the constraints of the activity.

Furthermore, the development of knowledge about work physiology and biomechanics should be encouraged in order to help understand the phenomena. For example, how can you explain and anticipate the choices that are being made between the energy expended and the localized musculoskeletal load? Between general fatigue (remaining sitting) and overuse of the shoulder (difficult access)?

BUILDING BRIDGES BETWEEN ERGONOMICS AND OTHER DISCIPLINES: THE CASE OF PROFESSIONAL TRAINING

In the study of MSDs, ergonomics has been associated for a long time with epidemiology and biomechanics. However, there are several other disciplines with which exchanges could be productive. In this final part, we particularly want to discuss the benefit in MSD prevention of strengthening the bridges between ergonomics and professional training.

In the study on boot factory sewing machine operators and the study on automobile manufacturing plant operators, learning difficulties at the different workstations were the core of the problems involved in implementing the modular system and in implementing rotation. In each of these studies, the female and male workers expressed themselves in the same way about the different levels of learning that they had to achieve to master a workstation. The terms used are reported on the left in figure 3. Learning the operations is considered a first level, when the person learns about the company's expectations and the different people he has to deal with as well as the means and conditions that are offered to carry out the task. This learning lasts only a few days, or even a few hours, and it is often the only period in which the learners can benefit from a resource person. The second level is the one where the person tries to become "at ease" at the workstation. One of the automobile plant workers expressed himself as follows: "…it looks good, it looks easy, but it took three weeks to have… you know… to have some pain everywhere and then to be tired, worn out at the end of a day. Trouble recovering." During this period, they try to find their own method, try to find tricks: how to position themselves, organize the operations, prepare their tools, etc. To some extent they develop their own way of regulating their work to reduce the stresses, make up for lost time, widen their margin of manoeuvre and achieve a balance. This period takes weeks. One of the workers explained that for one of the workstations occupied during the rotation, he was not yet "at ease", even after several months, and that he was afraid he would develop an MSD.

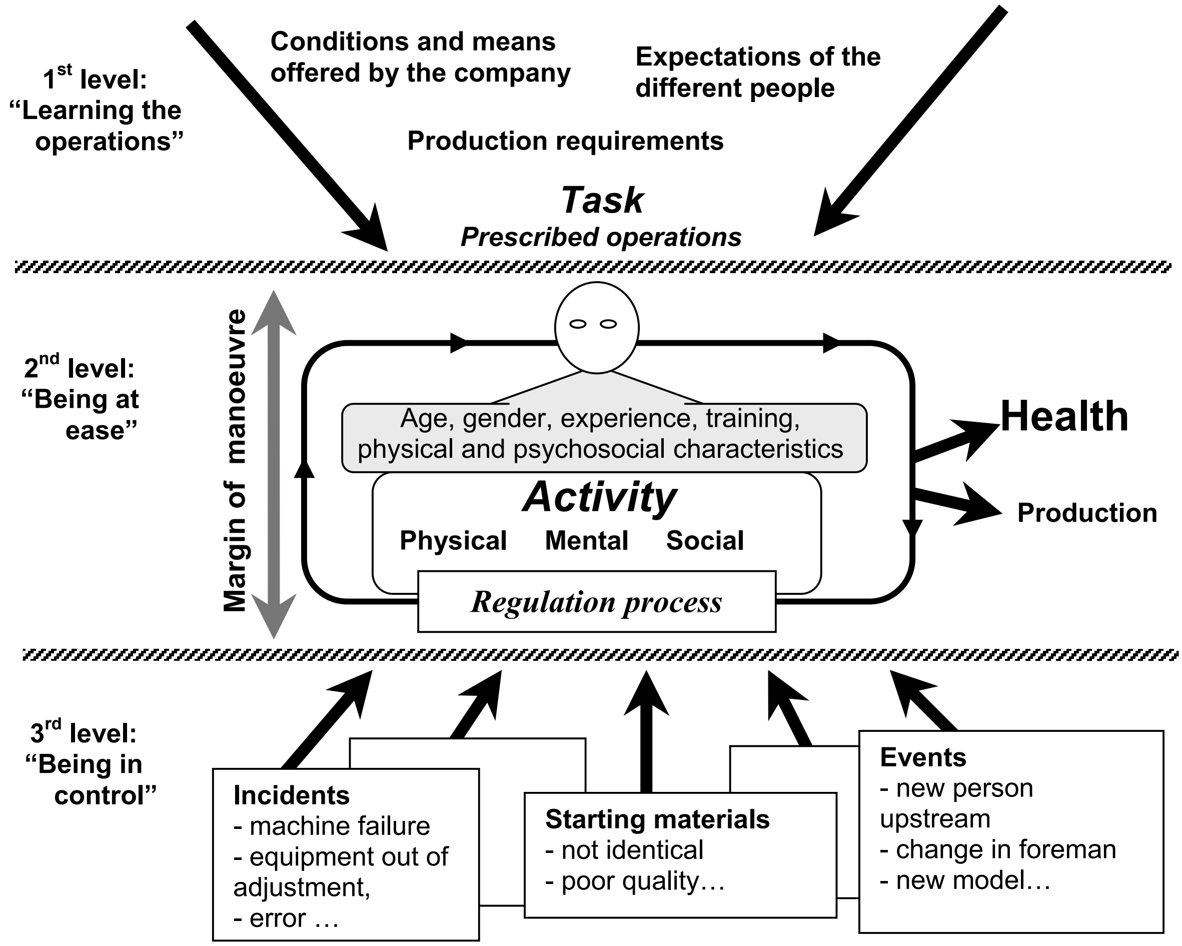

Figure 3: The different learning levels according to the male and female workers in two manufacturing plants

A third level can then be reached where, as the workers explain, you are able to deal with the variability in the work, the incidents, the events. The margin of manoeuvre must then be sufficient to remain "in control" of the situation and be able to do your work despite the different types of situations and difficulties encountered. With repetitive type jobs such as those in plants, the importance of the skills to be achieved to reach this level of competency is often underestimated. For one of the sewing machine operator workstations, the workers estimated the time necessary to reach this level of "control" at two years. It is not surprising that MSDs occur more often during special situations in which the developed strategies are insufficient to maintain a balance between health and production.

This viewpoint of the workers clearly shows the extent of the skills that they develop not only to be efficient at work, but also to protect their health. Training on workstations is therefore a major issue in the prevention of MSDs. In the development of in-company training, it then appears essential that work situations and all of the determinants of the activity be understood, so that the content can be developed and conditions favourable to learning can be implemented. Chatigny (7, p.14) clearly showed "the limitations of training whose conception is focused solely on the material and technical aspects of the work activity" and to what extent the learning conditions were intimately related to the work execution conditions.

In addition, work such as that of Authier (2) on manual materials handling or even on knife sharpening (33) has demonstrated that a detailed interactive analysis of work actions with the workers revealed knowledge and know-how that were difficult to verbalize and therefore difficult to pass on within the context of training. By putting this knowledge into words based on the activity analysis, ergonomists can develop training contents based on the valorization of the knowledge emerging from the companies and on respect for the variety of methods. The collaboration of ergonomists with professional training specialists then seems very important for both quality and training effectiveness to benefit.

CONCLUSION

For companies as for workers, MSDs represent a major problem whose economic and social costs cannot be fully calculated. If we rely on the applications received since 1992 for the Ergonomic intervention diploma in occupational health and safety at UQAM and that led to a practicum done by a student, MSD reduction would represent the intervention request most frequently addressed to Quebec ergonomists.

In this paper, the need for interdisciplinarity is discussed from the standpoint of increasing knowledge about MSDs and of improving the effectiveness of the interventions. It also reflects the concern about ergonomists' education for the purpose of establishing a common culture, as suggested by Teiger (28), and to develop wisdom and humility in dealing with the other disciplines. By knowing the contribution of the various disciplines, you can know the jargons, understand the different approaches, identify common objectives and interact effectively in companies. The contribution of your own discipline can also be better identified.

We considered the full significance of epidemiology in recognizing the determinants of the risk of MSDs in companies—a necessary recognition for encouraging debate and for being persuasive about the need to change work. This represents one of the three points of the triangle proposed by Daniellou (9), and the dynamics between these points should be maintained: "being able to think – being able to act – *being able to debate*". We placed biomechanics at the very centre of the analysis and understanding of the activity in order to ensure accurate diagnoses and to extend the possibilities of *thinking*. Finally, it was in organizing the transformation of an important aspect of actual work situations that we expressed the need to interact with another discipline, namely education sciences and particularly in-company training, in order to offer additional means of *taking action*.

Putting interdisciplinarity at the very centre of ergonomic practice opens the door to the contribution of various disciplines in the prevention of MSDs. For ergonomists, it also affirms the importance of the viewpoint of the activity and of their taking their rightful place.

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