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Participatory Ergonomics Training in the Manufacturing Sector and Ergonomic Analysis Tools
Formation en ergonomie participative dans le secteur manufacturier et outils d'analyse ergonomique
Formación ergonómica participativa en el sector manufacturero e instrumentos de análisis ergonómico

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Article abstract

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Participatory Ergonomics Training in the Manufacturing Sector and Ergonomic Analysis Tools

Marie St-Vincent
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This article discusses the importance of job analysis tools for training in the context of participatory ergonomic processes. It explains the major principles and challenges in the design of these tools for short-cycle repetitive tasks and for long-cycle varied tasks. The intervention framework is described and the proposed tools are presented and related to the literature. The participants' difficulties with the tools developed in both contexts studied are summarized. The discussion suggests that these difficulties are partly related to the company context and raises questions about the data relevant for the evaluation of solutions in the case of non-repetitive tasks.

For the past ten years, we have carried out participatory ergonomic interventions, first in electric appliance manufacturing companies and later in metal products manufacturing companies, in order to prevent work-related musculoskeletal disorders (WMSDs). In the first case, these interventions involved short-cycle repetitive tasks and the injuries were mainly to the upper limbs. In the second case, the tasks were mainly long-cycle non-repetitive tasks, and the injuries primarily involved the back. The main objective of these projects was to evaluate the impact and effectiveness of participatory ergonomics, as well as to determine the conditions for success, particularly with respect to training and learning. Despite the many

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participatory interventions carried out worldwide, it is difficult to establish an overall picture (Gjessing et al. 1994; Haims and Carayon 1996; Hornby and Clegg 1992; Imada 1991; Imada and Stawowy 1996; Kukkoken and Koskinen 1993; Kuorinka and Patry 1995; Laitinen et al. 1997; Liker et al. 1991; Moore 1994; St-Vincent et al1998; Vink and Kompier 1997; Wilson 1991a, 1995). The approaches vary and the participatory projects implemented and achievements obtained are often only briefly described (Haines and Wilson 1998; Noro and Imada 1991; Wilson 1991b). The focus has mainly been on identifying the conditions favourable or unfavourable to the implementation of participatory ergonomics and, except for a few authors, relatively little attention has been paid to the participatory process itself. However, to evaluate and improve participatory interventions, a prior systematization of this process seems necessary and this entails the development of a precise method and tools.

In a participatory context, the first constraint to be dealt with is the time limit. The focus is therefore on what information can be transmitted in limited-duration training, and on what are the key elements of an ergonomic intervention. Two aspects were favoured in the evaluation: analysis of the use of the method and its different steps by the participating groups, and the identification of the main difficulties encountered as this analysis process was being learned. The main purposes of this article are therefore, first to explain the major principles that served as a basis for organizing the activities of the participating groups and the choices made regarding training problems and, second to present the learning difficulties encountered by the participants in two different contexts, short-cycle repetitive tasks and long-cycle non-repetitive tasks.

The first section of this article describes the results of our approach: the problems to be solved, the challenges to be dealt with and the main principles retained. These subsequently guided the organization of the training and the development of the method and tools, which are explained in the following sections. As will be seen, the methods and tools developed for analyzing repetitive tasks differ from those developed for non-repetitive tasks.

STRATEGY AND ANALYTICAL TOOLS

The analytical methods in the literature can be divided into two major categories. The first, and dominant one, encompasses the methods based on the description of risk factors. These methods are designed for analyzing a large number of jobs and their objective is often the identification of problems (Buchholz et al. 1996; Braun 1992; Fransson-Hall et al. 1995; Kemmlert 1995; Li and Buckle 1998; Lifshitz and Armstrong 1986;

Malchaire and Indesteege 1997; McAtamney and Corlett 1993; McAtamney and Hignett 1995; Stetson et al. 1991). Generally speaking, few relationships are established with the intervention. In the second category, the methods involve intervention processes consisting of several steps, up to the implementation of solutions (Keyserling 1991; Mairiaux et al. 1998) and even their evaluation (Reynolds et al. 1994). These are more detailed analyses, which can be applied to only a limited number of jobs, previously identified as hazardous and requiring corrective action. The second type is the most relevant for participatory analyses.

Training people in these detailed methods is a major challenge. In a relatively short time, the participant must acquire knowledge and understand basic concepts. He or she must develop skills that will facilitate adaptation to different contexts. While a focus solely on WMSD prevention entails the development of a more limited body of knowledge, it still seemed impossible to transmit all the knowledge necessary for proper work analyses. To overcome this difficulty, we sought to develop a *method and tools that promote the emergence and expression of the participants' knowledge*. The resulting process focused primarily on the sharing and comparison of the knowledge of the operators and technical specialists. Means facilitating this emergence were therefore favoured: verbalization procedures (interviews, questionnaires), video recording as a concrete support for discussion, the teaching of group work techniques, and the insertion of new actors.

A second challenge was to merge two major approaches to participatory ergonomic processes as represented by the anglophone and francophone literatures. In the first approach, the analytical tools proposed, such as grids and checklists, focus on the identification of risk factors (Fransson-Hall et al. 1995; Keyserling 1992, 1993; Li and Buckle 1998; Lifshitz and Armstrong 1986). This approach is more systematized and coded, and reference values are proposed. The second approach emphasizes the analysis of the work activity and proposes more qualitative processes, often of a systemic nature (Guérin et al. 1991). In this approach, the work methods, namely how the worker does his or her work and what determines his or her activity, are the dominant subjects studied. More simply, using the example of a worker leaning forward, the first approach will tend to focus on the evaluation of this posture's risk for the back, while the second will mainly try to understand why this person is leaning forward. In a sense, the first approach highlights what is common while the second focuses on the variability (Guérin et al. 1991). This difference in perspective is apparent in studies on repetitive work (Teiger and Laville 1972; Toulouse 1995).

What was retained from the anglophone literature on WMSDs was its systematic character and the fact that it offers tools that integrate specific

knowledge and that are based on the concept of risk factors. By taking into account these concepts, which are coded and sometimes validated, one avoids being outside an important international trend. The initial planned training therefore focused to a great extent on basic WMSD-related knowledge. The entire process was organized into precise steps and, for several of these, the participant had tools similar to grids and checklists. A *systematization principle* therefore guided the developments. From the francophone literature, we retained the principle that participants must be able *to develop their intervention from an understanding of the actual work activity*. Thus, means (video recordings) and tools (analytical and interview guides) were developed to take the work activity into account.

As previously mentioned, francophone ergonomics tends to emphasize variability and what determines it. This approach informed two other principles that guided our analysis: the method must *allow variability to be integrated into the analysis and the determinants to be identified.* Several authors emphasize the importance of considering variations between workers and in their work (INRS 1997; Reynolds et al. 1994) and of identifying under what conditions observation has to be made (Keyserling et al. 1991). However, there are few clear guidelines for integrating this variation into the analysis and the strategies proposed are sometimes limiting. For example, Reynolds et al. (1994) propose observing different workers and choosing an experienced worker with no "bad habits" for the analysis. This could lead to a focus on the individual, which is not appropriate for finding open solutions or for understanding the activity. Another aspect not dealt with is how you can take into account, in the solutions, conditions that were not the subject of observation. Therefore, steps and tools have been developed for considering the main sources of variation in the work, even in the context of repetitive work. Determinants are a concept that does not feature in the tools developed in the anglophone literature, while they are at the core of the activity-analysis approaches developed in the francophone literature. Determinant identification is particularly relevant, because it makes the solutions easier to identify. In fact, a risk factor is difficult to correct without identifying its source. This corresponds to "why" type research. This seemed particularly important because the last principle subscribed to was *to emphasize the search for solutions*, and the method was therefore developed in order to achieve this. Particular attention was given to structuring an approach that also takes variations into account, so that solutions adapted to all situations can be developed.

The steps and proposed tools attempt to merge the systematic and organized dimension of the anglophone literature, as well as its knowledge of WMSDs, with the objectives and principles of the approach focused in the francophone literature. The job analysis method that we developed is

original because, among other things, it integrates the sources of work variations through interviews and a sampling plan. It further integrates a risk-factor and determinant identification step. Some evaluation steps, such as the prioritization of the problems to be corrected, are carried out on a qualitative rather than a quantitative basis. Lastly, a specific effort has been made to formalize the solution-finding process.

GENERAL ORGANIZATION OF TRAINING AND EVALUATION

Overall Intervention and Training Process

For all the interventions, an ergonomics committee (called an ergo group) was set up at the start of the project. Its core of approximately five people consisted of workers and technical specialists who, depending on the company, were mechanics or engineers. Resource persons could be added to this core for some steps in the process. The ergo groups' work was mainly carried out during meetings, but it also included fieldwork such as interviews with workers, video recordings, and field tests to perfect solutions. An intervention lasted 18 to 24 months, during which time the ergo groups analyzed three or four work situations. The groups met from eight to twelve times to analyze a job in the case of repetitive tasks, and from twelve to fifteen times to analyze a varied task.

Training consisted of an initial relatively formal step in which the ergo group received theoretical training and then did an initial job analysis. The aim of the theoretical training, which varied from 14 to 24 hours depending on the intervention, was to teach the basics and objectives of ergonomics and WSMD-related anatomical and physiological concepts, and to explain the main risk factors, as well as to pass on information about the mandate and role of the members of the ergonomics group. During this initial training, the job analysis tools used were outlined. With the ergonomists' help, the ergo group focused on hazardous work situations. The entire process was demonstrated in an initial complete study closely guided by the two ergonomists.

The second step in training was interactive, involving a type of mentorship system. Indeed, beginning with the second job, the members of the ergo group were responsible for conducting the meetings and all of the steps in the job analysis process. However, one ergonomist attended each ergo group meeting, but solely in a supporting role in order to answer the participants' questions and to intervene as needed to fill in any gaps. The expectation was that this ergonomist would intervene less and less. A second ergonomist also attended the meetings but this was mainly to document the progress.

Training therefore took several forms with several objectives: the acquisition of basic knowledge about WMSDs, risk factors and the core concepts of ergonomics; the development of a certain ability to understand the work activity as it is carried out, as well as the variability and the determinants; promoting the integration of the viewpoint and knowledge of several people, including the workers doing the job studied; and the development of multiple solutions and their critical analysis.

Evaluation of Training and Tools

A major concern in these projects was to be able to identify the aspects in the process and tools developed that needed improvement. Of the different possible options, one approach in this diagnosis was to analyze the difficulties encountered in learning the proposed analytical methods.

However, analyzing the interactions between the participants and ergonomists during numerous work meetings is a very cumbersome and difficult undertaking. A methodological tactic was therefore used: we assumed that an analysis of the active ergonomist's interventions during the meetings would provide information on the difficulties encountered by the groups' participants and we therefore focused the analysis on these interventions. The ergonomist intervened to fill in any gaps, answer questions, and give explanations so that the concepts could be understood. The ergonomists' interventions during these meetings were recorded, and then transcribed and recoded for the purposes of analysis (St-Vincent et al. 1996a, 2000). The analysis of these interventions was further developed in the project on non-repetitive tasks, so that the two plants studied could be compared. The ergonomist also had to assess whether or not the participants successfully applied each of the steps.

THE INTERVENTION IN THE CONTEXT OF REPETITIVE TASKS

The Process and Tools Implemented

The entire process is summarized in table 1: the planned steps, the means proposed, and the people involved.

The first step consisted of collecting preliminary information through interviews with the foreman and several workers doing the job. The group had a simple questionnaire to give to the workers and supervisors. A summary sheet summarized the information so that it could be presented to the group.

The second step—one of the most original aspects in our process—consisted of establishing a sampling plan to determine which workers and

TABLE 1

Work Situation Analysis Process

Step	*Means*	*Who*	*Tool 1: Repetitive tasks*	*Tool 2: Varied tasks*
1. Preliminary information	Planning of interviews	Supervisor	Principles dealing with the objectives, planning and conducting of interviews	Same as tool 1
	Interviews	Targeted workers	Questionnaires dealing with: – characteristics of the workers – accidents and symptoms or musculoskeletal pain – identifying the sources of variations in production conditions	Questionnaires dealing with: – same as tool 1 – same as tool 1 – description of operations, their layout, tools, equipment and related difficulties
			Interview summary sheet	Same as tool 1
2. Sampling plan and Observation	Discussion fed by the synthesis of inteviews	Committee Worker and supervisor invited	Principles dealing with the development of the sampling plan and the observation of the work activity	Same as tool 1
	Observation based on plan	Targeted workers	Video recording	Same as tool 1
3. Video analysis	Observation of videos	Committee Worker and supervisor invited	Principles of the breakdown of the cycle into actions and the identification of WMSD risk factors	Typology of problems, principles on the identification of determinants and WMSD risk factors encountered
			Risk factor identification grid	Identification grids for problems and related determinants
4. Prioritization of hazardous activities and identification of determinants	Discussion in order to assign a rating to the actions or operations in the analytical grid and their determinants	Committee Worker and supervisor invited	Criteria for assigning a priority rating to the actions in the analytical grid	Prioritization criteria
			Presentation of the main types of determinants encountered	Analysis summary sheet Determinant finding is part of the video analysis step
			Prioritization and determinant-finding summary sheet	
5. Solution-finding	Four-step process: 1. brainstorming 2. development of solution scenarios 3. critical analysis of scenarios 4. detailing of proposed solutions	Committee Worker Supervisor Technical specialists invited	Presentation of the solution-finding process Critical questioning for solution evaluation Summary sheet of the tasks to be carried out for solution-finding	Same as tool 1
6. Solution implementation and follow-up	Four-step process: 1. testing prototypes 2. implementation 3. first adjustments 4. final follow-up	Committee Worker Supervisor Technical specialists invited	Presentation of the steps in solution implementation and follow-up Summary sheet for analysis follow-up	Same as tool 1

production conditions or work situations would be observed or filmed. The proposed tool presents basic guiding principles in the choice of situations and workers to be filmed.

The third step consisted of breaking down the filmed activity into smaller units or actions and of identifying the risk factors using an analytical grid. This risk-factor identification step has generated the most proposals in the literature, ranging from the simplest (e.g., checklists, binary response as presence/absence; Braun 1992; Lifshitz and Armstrong 1986, Kemmlert 1995) to the more complex (e.g., analytical grids, evaluation of the duration or frequency of risk factors; Keyserling et al. 1992, 1993; Li and Buckle 1998). In the present case and similar to other authors (Armstrong et al. 1982; Braun 1992; Reynolds et al. 1994), the grid developed was specific to repetitive work and was based on a prior breakdown of the cycle into actions and then, for each action, the identification of the different risk factors as commonly recognized in the literature (e.g., posture, force, presence of mechanical pressure). This grid is very similar to that of Braun (1992), but with a few additions. In our approach, the risk factors were systematically documented, but no quantification effort was required of the participants.

The aim of the fourth step was to prioritize the problems before starting to identify the determinants. This step involved ranking the most hazardous actions within a given task; in other approaches, prioritization may instead involve ranking each job in relation to the others. The literature contains many attempts to quantify the establishment of priorities. This quantification might involve calculating an overall rating that is based on the sum of the positive responses to the questions in a checklist (Lifshitz and Armstrong 1986), or weighted according to the exposure duration or frequency (Keyserling et al. 1992, 1993; Li and Buckle 1998). The aim of the overall rating is therefore to situate one job in relation to others and/or to identify the jobs that must be analyzed in greater detail. For example, Reynolds et al. (1994) proposed a formula based on frequency, posture, and force requirements, while McAtamney and Corlett (1993) suggest an overall rating calculation that integrates different tables of ratings. As the authors themselves emphasized, the scientific bases for the quantification methods are not always clear. However, in order to be used correctly, these quantitative approaches require the implementation of a systematic observation process, which, to be reliable, requires observation-specific training (Denis et al. 2000). A qualitative approach, based on the understanding and integration of several sources of information, therefore seemed more appropriate. The criteria given to the participants for establishing their priorities were simply to take into account risk factor characteristics (intensity, duration, frequency), reported pain and the workers' perceptions.

The fifth step was the identification of the determinants for the different risk factors observed. Different classes of determinants to be investigated are proposed: working tools, work method, material feed, dimensions of a workstation and work organization. This step is rarely identified in the grids proposed, but is typical of a work analysis process.

The sixth step involved solution-finding. Technical specialists were then invited to join the group. As previously mentioned, this aspect is not extensively dealt with in approaches involving WMSDs. We attempted to formalize this step and we structured it into four additional steps. The first proposes using brainstorming techniques to generate a wide range of solutions. The second step consists of organizing the different ideas presented into solution scenarios. Then, through discussion, solution proposals are sought for some aspects of the job, rather than independent solution elements. Two or three scenarios can be developed by the different group members. These scenarios are then critically analyzed. For example, does the solution actually correct the targeted problem? If so, is the solution economically and technically feasible? Will it be compatible with the workers' work methods and characteristics? Could it have negative impacts on the jobs upstream or downstream? Finally, the fourth step, the detailing of solutions, is done using a summary sheet identifying the tasks to be performed. Several means are proposed: mock-ups, scale drawings and field simulations.

The final step is solution implementation and follow-up. Steps to be followed are proposed, as well as a summary sheet. Similar to Keyserling et al. (1991) and Reynolds et al. (1994), prototypes are recommended whenever possible before the final implementation of solutions.

The approach is articulated around the ergo group but importance is given to the workers in the jobs studied. Therefore, each time that a specific job is analyzed, one or two workers doing the job join the ergo group for the duration of the job analysis. At different times in the process, other workers doing the job are involved. At the beginning of the analysis, workers are questioned and some of them, or others, are then filmed. Throughout the solution-finding process, the workers doing the job are informed about the progress in the work. During the field tests, the workers are consulted and, finally, when a prototype is implemented, the members of the ergo group ask for an assessment by the workers doing the job.

Difficulties Encountered in Repetitive-work Analysis

The detailed results of the difficulties encountered by the participants from two companies in the electrical products sector are presented in another publication (St-Vincent et al. 1996a); only the highlights are reported here.

Easy Steps

Except for certain questions that required adjustments, the collection of preliminary information was quite easy. The participants had no difficulty learning how to break down the basic cycles into actions, undoubtedly because this step corresponded to something very concrete for them.

In general, even if reminders were necessary, the groups demonstrated a good understanding of the risk factors. The greatest difficulty, observed mainly in plant 1, was in considering the sources of variations. In plant 2, the main problem identified was in conducting the group meetings.

For the solution-finding step, we tried to evaluate whether the groups had properly assimilated the critical questioning introduced by the ergonomists. A qualitative analysis of the criteria used by the participants in solution-finding shows that they satisfactorily integrated this aspect in the two plants. In both plants, the members of the groups anticipated the incidents; took into account the demands of teamwork, the related tasks, and variations in production; and referred to the risk factors and the broader questions of health and safety. However, in plant 1, references to the activity sometimes appeared to be lacking, while in plant 2, the group, mainly the engineers, tended to underestimate the incidents related to the technical solutions.

More Difficult Steps

One of the most difficult steps was in establishing the sampling plan. Getting the participants to question the choice of workers to be filmed as well as the production conditions to be filmed is difficult. *Variability* is hard to integrate.

It was also difficult to identify the *determinants* and establish *priorities*. These concepts required extensive explanations during the second job studied (when the participants took over all the steps in the process). However, the two groups seemed much more at ease with the last job studied, even though certain concepts had to be explained again, such as the fact that several determinants may be associated with one problem. In plant 1, the participants tended to retain practically all of the problems rather than establish priorities; they thus overestimated the observed problems.

Even though the participants became more autonomous between the first and last job studied in both plants, the ergonomists still intervened significantly.

THE INTERVENTION IN THE CONTEXT OF LONG-CYCLE NON-REPETITIVE TASKS

The Process and the Tools Implemented

These ergonomic interventions in two other companies in the metal products sector were carried out after those described above. Plant 1 was a small economically healthy company, with a participatory culture and cordial work relations. Plant 2, on the other hand, had serious economic problems, work relations were strained, and there was no participatory culture. As will be seen, the method was modified on the basis of the knowledge acquired from previous projects, but mainly to take into account the new context of varied tasks. In fact, the analysis of varied (non-repetitive) tasks introduced two new major methodological difficulties: sampling, and risk factor interpretation.

Sampling. When a repetitive task is analyzed, a rather representative picture of the work carried out can be obtained by questioning the worker about the variations in his work and by filming a few work sequences. With non-repetitive work, it is more difficult to have a representative picture of the work carried out: the cycles are longer (when there are any) and there can be several work sites and different equipment and layouts. Knowing what to film is the initial challenge and requires a good prior understanding of the work.

Interpretation of risk factors. It is recognized that the severity or impact of a risk factor depends on its dose, which is evaluated by three parameters: duration, amplitude or intensity, and frequency. These are more difficult to estimate in the case of non-repetitive tasks, requiring a lot of time. In addition, even if the duration, intensity and frequency are known, the results can be difficult to interpret because the literature does not always give precise reference values. Evaluating a risk factor's dose is clearly beyond the competence of a participatory working group.

To get around these two difficulties characteristic of varied tasks, two steps were significantly modified: the collection of preliminary information through interviews and the analysis of video sequences.

With repetitive work, one of the goals of the *preliminary interviews* was to document the sources of variations. For varied (non-repetitive) work, these interviews were refocused on the identification of the different operations, layouts, tools, equipment and material used, and also the perceived difficulties. The "sampling plan" step was consequently retained but the guideline was simply that the sample be representative of the situations that the workers identified as the most difficult.

Video analysis. A grid (see table 2) was developed. The breakdown into actions was replaced by a breakdown into operations, which are larger entities that encompass more actions and movements. They correspond to the major steps in production. The identification of WMSD risk factors is retained, without quantification, and the risks of injuries, such as falls or cuts, have been added. The major difference is that the group members now had to identify the difficulties and the determinants of the problems. The concept of difficulty is related to any element that presents a problem in work execution. The descriptions of the difficulties are expressed freely, which implies that the members of the group have acquired an understanding of the concept of difficulty as well as master a basic typology of these difficulties. A guide given to the participants presents a typology of possible difficulties with examples: tools, equipment, physical layout, material, incidents/contingencies, knowledge/work method, etc. The participants do not have to rank the different difficulties identified. In fact, at this stage, the video analysis is mainly a means of helping the participants to verbalize more openly about the difficulties identified. The proposed grid is therefore more elaborate than the first one developed for repetitive tasks and risk factor identification is no longer the central focus. An example is presented in table 3. It describes the difficulties associated with an operation involving the threading and attaching of strips of scrap metal. Clarification of the problem and activity provides information about the determinants, or at least makes them easier to identify. Solution-finding is consequently easier.

TABLE 2

Identification Grid for Problems and Related Determinants

VIDEO ANALYSIS
PROBLEM IDENTIFICATION GRID JOB:

Operations	*Risk factors*	*Difficulties* *Causes of the problem*	*Accident risks*

In the case of varied tasks, the approach chosen for video analysis generated an analytical method much less linear than for the analysis of repetitive tasks. The approach developed is now more similar to the systemic approaches widely used on the francophone literature. Information on the activity can therefore be more easily collected. In contrast, this

TABLE 3

Summary Table of the Slitter Helper Workstation

Priority	*Operation*	*Risk factor Accident risk*	*Difficulty (summary)*	*Solution scenario*
1	Feeding and attaching the scrap	Force exerted (maximum force) Awkward postures: Back flexion Stretching of the body Risk of cuts to hands and forearms Noise due to the pump Heat	The workers consider this step the most difficult. Work space in this zone is limited. Due to its spiral shape, the worker must pull very hard to bring the scrap to the winding zone (scrapper), particularly if the material is heavy gauge. The scrap tends to detach frequently from the scrapper (yellow scrapper) because the door is broken. The scrap jams and breaks frequently.	DURING THE PROCESS: Replacing the two scrappers Installing a metal bar or modifying the scrapper to facilitate the folding of the scrap when it is inserted in the scrapper. Modifying the scrap driving system at the outlet from the knives and thus facilitate the handling of the scrap. Installing an inclined plane to guide the scrap towards the worker when it breaks.

information emerged less during the analysis of repetitive tasks, since the participants were basically focused on observing postures, the degree of effort and the presence of mechanical pressures.

Advantages and Difficulties in the Analysis of Non-Repetitive Work

Steps Made Easier

Sampling was quite easy. In fact, all of the operations were filmed, with a few additions when different models were produced.

Determinant identification and solution finding were easier. In plant 1, relatively complex solutions were developed, while in plant 2, despite the difficulties that will be described below, simpler solutions were developed involving the tools and equipment.

Difficulties Encountered by the Participants

It should be mentioned that the analysis of the ergonomists' interventions was more elaborate and systematic for non-repetitive tasks than for the previous projects, thus allowing the plants to be compared in greater detail (St-Vincent et al. 2000). We will focus here on two steps: video analysis and solution finding.

Length of video recordings. For repetitive tasks, a few work cycles filmed under the different conditions are sufficient. For varied tasks, the required length of the video recordings was significantly longer (several hours). The necessary permission for employee participation was harder to obtain and it was more difficult for the members of the ergo groups to make these recordings. In one of the plants, the participants did the video recording themselves, while in the other, this was impossible. This situation may have had a negative impact on the group becoming autonomous.

Analysis of video clips. Six categories of difficulties were identified: two involved the understanding of ergonomics, namely its fundamentals or basic principles and its goals (which are based on what is studied); and three involved "how to carry out the study," that is the methodological, logistical and technical aspects. The last category of difficulty involved gaps in basic knowledge.

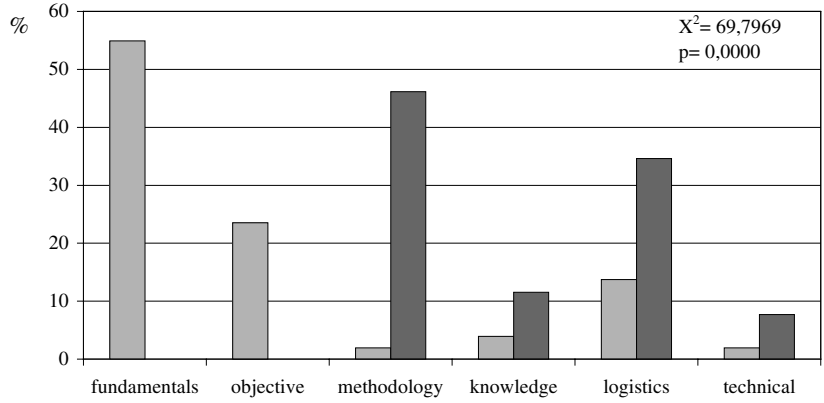
Figure 1. A presents the ergonomist's interventions for these six aspects in the two plants during the video analysis. Marked differences are noted between the two plants. In plant 1, the difficulties were mainly methodological and logistical ones. In plant 2, nearly three out of four interventions involved difficulties in understanding the fundamentals and goals of

ergonomics; difficulties about "how" therefore did not really emerge. A more detailed analysis of the interventions in this plant shows that the participants tended to consider the workers overly responsible for the problems and to limit themselves to questions of physical load, thus ignoring safety problems. The ergonomist had to intervene frequently to remind the participants of the importance of understanding the activity and its determinants and of broadening the scope of the problems considered.

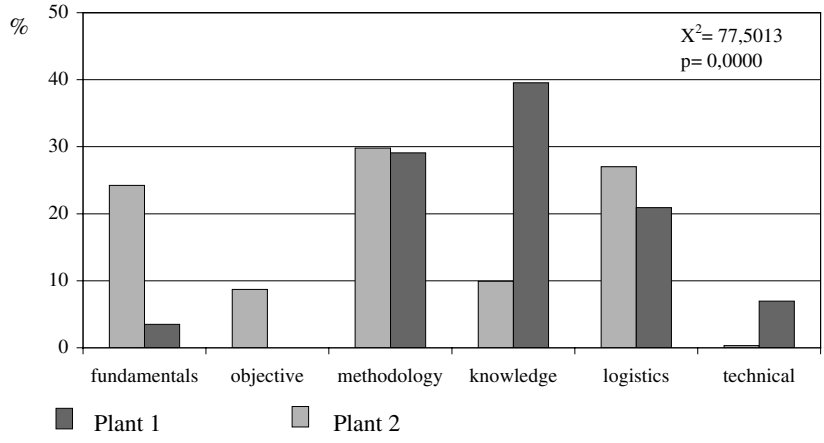
FIGURE 1

Comparison of the Difficulties Encountered by Participants of an Ergonomics Committee during the Analysis of their Second Job in the Two Plants

A- Types of difficulty identified in video analysis



B- Types of difficulty identified in solution-finding



The difficulty profile seems more comparable for the solution-finding step (see figure 1.B). However, a detailed examination reveals major differences. In plant 2, 27% of the difficulties were related to the fundamentals of ergonomics and involved the same problem of blaming the workers. In both plants, several interventions involved methodological aspects, but the nature of the interventions varied with the plant. In plant 1, as was expected with our solution-finding process, most of the interventions (40%) were to help the participants anticipate the impact of a solution, while a minimum percentage (10%) were to help them specify the solutions. In plant 2, there were fewer interventions related to the critical analysis of the solutions (18%), which suggests less discussion about this, but there were more interventions related to the definition of specifications (24%) and the importance of involving technical resources, mainly engineers (27%). This indicates that in this plant the participants had difficulty establishing the specifications for the solutions and were very reluctant to collaborate with engineers.

DISCUSSION

The Use of Job Analysis Tools

Training problems within the context of participatory processes implies two types of solutions: developing processes and tools that are learning tools, and improving the quality of learning. The job analysis tools formalized here were learning tools for the participatory groups. By using video material for non-repetitive tasks and by focusing on the identification of difficulties, the participants were therefore able to assimilate relatively spontaneously and concretely the difficult concepts of activity and determinant.

For participatory processes, effective strategies must be found because the time available is a major constraint. In this respect, a progressive learning formula proved effective. The participants pursue their learning in an application context, and they can see the results of their actions in a reasonable amount of time. Since the situations analyzed differ, this encourages the development of transfer skills. It is important, however, that the ergonomist orient the choice of initial jobs studied towards situations with a reasonable level of complexity. This requires a relatively long follow-up: two ergonomists attended all the meetings for about two years. At the end of the process, the degree of autonomy achieved varied by case. For the cases involving repetitive work, a clear evolution was observed in the two plants, even though full autonomy was not achieved. In the cases involving varied tasks, the results contrast greatly. In one plant, a very good

level of autonomy is achieved, while in the other, the level of autonomy is very low.

The results of these projects are difficult to generalize because of the variation in the plants and in the type and degree of difficulty in the work situations analyzed. The groups' dynamics also depended in part on their composition, which was somewhat unpredictable. The results, however, provided pertinent information about the difficulties that can be encountered and about what can be expected from such groups.

The tactic used here, namely the analysis of the ergonomists' interventions, proved to be an interesting way of dealing with the difficulties encountered by the participants. However, it is clear that the interventions also reflected the ergonomists' reaction to how these meetings were progressing. The ergonomists' interventions were modulated by at least three factors: what was felt to be important, what was thought to be a deficient, and by the experience with participatory groups. Very experienced ergonomists were involved here, both in job analysis and interactions within groups of workers. The work experience gained in participatory groups undoubtedly facilitated the process.

The results also show that the difficulties are contextual and that the processes and tools used must be adapted. Therefore, in the context of repetitive work, taking variability into consideration was the most difficult aspect. It is a concept that may in fact seem paradoxical in the case of short-cycle tasks since it was difficult to formalize precisely. For non-repetitive tasks, variability caused fewer difficulties, contrary to expectations. However, the time problem became important.

The method of linear and structured analysis in distinct steps worked well with repetitive tasks. In both plants, the participants clearly evolved even though, by the end of the project, complete autonomy was not achieved. However, at the end of the study, the participants used the different steps properly (St-Vincent et al. 1996a). This structuring of the process has been identified as a condition for a successful participatory process (St-Vincent and Chicoine 1996b). However, this process seemed inappropriate for non-repetitive tasks. The process adopted remained structured but the video analysis step became much more open. With this process, a good degree of autonomy was observed in plant 1 at the end of the project, with a proper use of the various steps. In plant 2, autonomy was less clear-cut. The participants did not do the filming themselves, and in the video analysis step, they did not discuss the methodology, but instead blamed the workers and wanted to limit solution-finding to questions of physical load, ignoring safety problems. The video analysis step was therefore not used as planned and, in this plant, did not really involve questioning the activity, difficulties and determinants. In addition, during the solution-finding, there

was very little discussion about critical analysis of solutions. The purpose of the ergonomists' interventions was instead to help the participants specify the solutions and to encourage collaboration with the engineers.

Therefore, in plant 2 the different steps in the tool were not used as planned and, at the end of the project, complete autonomy had not really been achieved. With varied tasks, particularly with an open approach in the video analysis, autonomy can be considered as being more difficult to achieve by an ergo group and only possible in the case of an optimal company context, as was the case for plant 1. However, because of the very good results obtained in one of the plants, particularly in the level of understanding of the work activity by the participants, the concepts retained for non-repetitive tasks (an open method not focused on the identification of risk factors) could have been considered an interesting strategy, even in the case of repetitive tasks.

Some of the difficulties encountered in plant 2 seem to be directly related to this company's context and specific culture (St-Vincent et al. 2000). It was noted that the participants had inadequate representations of the fundamentals and objectives of ergonomics and that they wasted a lot of energy blaming their peers. These problems can be explained by a lack of employee recognition by management and by marked difficulties in work relations. Communication problems may have been the reason for the participants' reluctance to collaborate with the company's engineers. This suggests that the use made of the ergonomic analysis tools is affected by company culture phenomena, which should be better understood. Although company culture may affect the results, the effect of individual factors cannot be denied. In our study, the participants' professional skills were similar, but other characteristics such as the ease in working as a team, receptiveness to new approaches, and the ability to listen are characteristics that helped explain the differences between the two plants. This prompts us to think that the desired characteristics of the members of the ergo groups should be better defined.

The Usefulness of the Risk Factor and Solution Evaluation

As has been seen, there is a significant difference in the way videos are analyzed for repetitive tasks and varied tasks. The more open method used for varied tasks, which was based on free expression by the participants, seemed to provide richer information for understanding the activity and for finding solutions, in contrast to a systematic identification of the risk factors as was the case for repetitive tasks. The open method was effective for solution development.

However, the open approach used for varied tasks leads to a major problem in following up on the solutions implemented. The aim during

follow-up is to demonstrate that the solutions improved the work and reduced the risk factors. For varied tasks, there was no initial systematic analysis of the risk factors and it was therefore difficult to assess the impact of the solutions in this regard. Follow-up was therefore based on interviews with the workers doing the job for the purpose of verifying that the problems identified during the video analysis had actually been improved. There was also an expert's assessment of the severity of the risk factors present, based on the videos, which was also subjective information. No systematic data were therefore obtained on the impact of the solutions on the severity of the risk factors, which is clearly a major deficiency. This was not the case for repetitive tasks, where systematic data were obtained for evaluating the impact of the solutions on the risk factors (St-Vincent et al. 1996a, 1998).

This leads to more general conclusion about the follow-up or evaluation of an ergonomic intervention. Our projects on varied tasks have shown that a systematic risk analysis was not necessary to proceed with the intervention. This raises the question of pertinent data for validating the solutions resulting from an ergonomic intervention. A systematic analysis of risk factors in the case of varied tasks is known to be demanding in terms of time. The work must be sampled, and the duration, frequency and amplitude of the different risk factors must be quantified. Furthermore, such systematic risk analyses, contrary to ergonomic work analysis, do not provide information about work-related difficulties and constraints nor about the work execution conditions. Thus a before-after evaluation focused solely on a detailed risk analysis provides very little information about the aspects of the work that were actually improved. To properly evaluate an ergonomic intervention using reasonable means, we should probably differentiate it from the classical epidemiological model and rethink our approach. An interesting avenue for evaluating solutions is to use systematic perception data to measure the before-after changes. Workers can therefore be asked to rank, using a perception scale (from 1 to 5), the variations in the difficulty factors identified during the job analysis, particularly in the physical effort and postural stresses. For a more complete evaluation, it would be useful to complement these perceptual data with biomechanical measurements appropriate to the work situations analyzed. However, although perceptual data are realistic for ergo groups, biomechanical measurements require an even more expert context.

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RÉSUMÉ

Formation en ergonomie participative dans le secteur manufacturier et outils d'analyse ergonomique

L'article présente et trace un bilan de l'utilisation d'outils d'analyse ergonomique conçus pour des interventions d'ergonomie participative visant la prévention des troubles musculo-squelettiques liés au travail (TMS). Ces interventions ont été menées, d'une part, dans le contexte de tâches répétitives et, d'autre part, dans le contexte de tâches variées à cycle long. Le but de l'article est d'expliquer les grands principes sur lesquels s'appuient la conception des outils, les choix effectués en regard des problèmes de formation et de présenter les difficultés d'apprentissage rencontrées par les participants, dans le contexte de tâches répétitives et dans celui de tâches variées à cycle long.

La première partie de l'article décrit les défis qui ont dû être relevés et les grands principes directeurs retenus pour la conception des outils. On sait que ce type de démarche nécessite la participation des acteurs de l'entreprise dans l'analyse ergonomique de situations de travail. Comme toutes les notions d'analyse du travail ne peuvent être transmises à des novices, le premier défi a été de développer une méthode et des outils qui favorisent l'émergence et l'expression des connaissances des participants. L'utilisation de moyens favorisant cette émergence a donc été privilégiée : procédures de verbalisation, enregistrement vidéo comme support concret de discussion, enseignement de travail de groupe, insertion de nouveaux interlocuteurs. Le second défi consistait à faire la jonction entre deux grands courants parallèles représentés typiquement par la littérature anglo-saxonne et francophone. De la littérature anglo-saxonne sur les TMS, il est apparu important de retenir le caractère systématique et d'offrir des outils qui intègrent des connaissances précises et s'appuient sur la notion de facteur de risque. Du courant francophone, les choix ont consisté à concevoir une méthode qui permet de capturer la variabilité et de repérer les déterminants. Finalement, des efforts ont été faits pour mieux formaliser l'étape de recherche de solutions qui est peu systématisée dans les outils centrés sur les facteurs de risque.

La deuxième partie de l'article résume le déroulement global de l'intervention et de la formation. L'intervention est structurée autour d'un comité d'ergonomie formé de travailleurs et de spécialistes techniques qui, tout au long du projet, sera encadré par des ergonomes. La démarche en est une de formation continue : elle vise le retrait progressif des ergonomes et une prise d'autonomie graduelle des participants. La formation est initiée par des notions théoriques qui sont consolidées lors de l'analyse d'un

premier poste ; pour les postes subséquents, les ergonomes se retirent graduellement. Par leurs interventions durant les réunions de travail, ils corrigent les lacunes et répondent aux questions des participants. L'analyse des difficultés rencontrées par les participants avec la démarche et les outils proposés a été réalisée par une analyse de contenu des interventions des ergonomes lors des réunions de travail. Ces interventions ont été enregistrées, codées puis analysées systématiquement.

L'article décrit ensuite l'intervention, d'une part, dans le contexte des tâches répétitives et, d'autre part, dans le contexte des tâches variées. Un tableau présente la démarche et les outils utilisés dans les deux contextes. Pour les tâches répétitives, une démarche en étapes bien structurées a été développée : entretiens préliminaires, plan d'échantillonnage et observations, analyse des vidéos à l'aide d'une grille d'identification des facteurs de risque, priorisation et identification des déterminants, recherche de solutions et, finalement, implantation et suivi. L'analyse des tâches variées présentait deux difficultés méthodologiques qui ont nécessité des modifications. D'une part, la question d'échantillonnage devient centrale. Dans les tâches variées, les cycles de travail, quand il y en a, sont beaucoup plus longs; il peut y avoir plusieurs sites de travail, divers équipements et aménagements. Le choix des séquences à filmer est donc plus ardu. L'autre difficulté porte sur l'interprétation du facteur de risque. Dans les tâches variées, il est beaucoup plus complexe et coûteux de faire une estimation des facteurs de risque et la littérature n'offre pas toujours des valeurs de référence précises. Pour contourner ces difficultés, deux étapes ont été profondément modifiées : le recueil des informations préliminaires et l'analyse des séquences vidéos. Les entretiens visent cette fois à faire le recensement des diverses opérations et contextes de travail en documentant les difficultés associées. Quant à l'analyse des bandes vidéos, une méthode plus ouverte, moins centrée sur l'identification des facteurs de risque a été adoptée. Les vidéos sont maintenant utilisés pour faire verbaliser plus librement les participants sur les difficultés et déterminants. L'article résume les difficultés observées chez les participants des groupes ergo dans les deux contextes de travail.

La discussion met l'emphase sur le fait que les outils d'analyse de postes ici formalisés ont constitué en eux-mêmes des moyens d'apprentissage pour les groupes participatifs. On constate que la stratégie adoptée pour les tâches variées a permis aux participants d'assimiler assez spontanément des notions d'activité et de déterminants qui sont pourtant considérées difficiles. Les résultats montrent que les difficultés sont contextuelles et que les démarches et les outils doivent être adaptés. La discussion soulève l'hypothèse voulant que les difficultés observées avec les outils d'analyse soient directement liées au contexte des entreprises participantes de même qu'à des facteurs individuels.

La discussion se termine par une réflexion sur l'utilité du facteur de risque pour l'évaluation des solutions. Dans le cas des tâches répétitives, il était possible d'avoir des données avant-après sur les facteurs de risque. Avec l'approche choisie pour l'analyse des tâches variées, on ne dispose pas de données systématiques sur l'impact des solutions sur les facteurs de risque. Les auteurs questionnent finalement la pertinence d'une évaluation avant-après centrée uniquement sur une analyse détaillée du risque.