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ORIGINAL ARTICLE

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Co-ordinated strategy of prevention and control of the biomechanical factors associated with the risk of musculoskeletal disorders

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Abstract ***Objectives***: To propose a cost-effective set of methods (strategy) to improve biomechanical working conditions and prevent the development of musculoskeletal disorders. ***Methods***: The strategy was developed according to the philosophy already used for other aspects of working conditions. It was then tested in ten industrial situations with various characteristics, to check its understanding, its usability, and its efficiency. ***Results***: The strategy includes a five-page leaflet (*screening*) aimed at motivating the operators to check the problems and bring about immediate solutions if possible. A stage-2 *observation* checklist is then proposed to guide the discussions during a meeting of the protagonists (workers and management). The assistance of an occupational health practitioner might become indispensable at stage 3 to deepen the *analysis* of the remaining problems, while experts are requested only in exceptional cases (stage 4, *expertise*). This strategy was positively judged by the users and proved to be effective in motivating and co-ordinating the protagonists. ***Conclusion***: The strategy proved to consider effectively all biomechanical aspects that might contribute to the development of musculoskeletal disorders (MSDs). It proved also to be participatory, placing the operators and their management at the centre of the intervention as the main actors, and organising when to turn to an occupational health practitioner or an expert for assistance.

Keywords Prevention · Ergonomics · Repetitive strain injuries · Low back pain · MSD

Initial documents (in French and Dutch) can be downloaded from http://www.md.ucl.ac.be/hytr/new/fr/index.html

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Introduction

Numerous methods are described in the literature to evaluate the risk of musculoskeletal disorders (MSDs) of the upper limbs. These include checklists (Ahonen et al. 1989; Kilbom 1994; Silverstein 1997), assessment scales (Rodgers 1992; McAtamney and Corlett 1993; Moore and Garg 1995), observation techniques (Kemmlert 1995), or even very sophisticated measurement procedures (Ranaivosoa et al. 1992; Marras and Schoenmarklin 1993; Malchaire et al. 1997).

It appears, clearly, that the large majority deal with the biomechanical constraints only, and attempt to characterise the whole situation by a single figure or set of figures defined on semi-arbitrary scales of risk.

Most of these researchers published epidemiological studies aimed at defining the dose (constraints)–response or effect (complaints or disorders) relationship. In such studies, subjects from many diverse workplaces were included and the range of constraints was the largest possible. Numerical indices were required for the statistics (logistic regressions) and for including, in the study, constraints for different body zones. These methods were then proposed in the literature and used by practitioners to assess the risk of MSDs at a given workplace.

The RULA method (McAtamney and Corlett 1993) is probably the archetype of these indices, summarising in a single number the constraints in all main body regions. Other similar methods were proposed by Occhipinti (1998) and Moore and Garg (1995). In these methods, the main issue for the authors was the scoring system, scoring that, undeniably, also became, for many users in practice, the main objective of the study.

Questions can be raised concerning the significance of such methods for industry:

1. They usually require qualifications and technical and time possibilities that few people have in practice in the field, in industry. This is particularly true in small and medium-sized companies where, whatever the

country, more than 50% of the working population is employed. Only people educated and trained in this domain can use these methods validly. Therefore, advocating such methods amounts to advocating an occupational health (OH) management system where OH practitioners are indispensable in taking charge of the problems. As the number of such specialists remains limited, the number of interventions in industry is bound to remain limited and the efficiency of the system is bound to be low. In addition, the costs are high and they might divert employers from considering their OH problems and delay preventive actions in the field.

This seems to be the case as, according to the statistics from the European Foundation (Merllié and Paoli 2001), the number of employees complaining of musculoskeletal constraints (as well as physical agents) remains very important, despite the knowledge accumulated about the ways of solving the problems.

2. All these methods primarily describe quantification procedures and very few are orientated towards action. The postulate seems to be that quantification of the risk is required for prevention and leads to preventive measures. This can be disputed. As an example, the well-known OWAS method (Centre for Occupational Safety 1994) requires the analysis of some 100 still images in order for postures of the body segments to be recorded and 'action' levels defined. Systems are commonly available now that permit the systematic collection of the pictures that will be analysed one by one in the laboratory. Experience shows that, in many instances, the analysts concentrate on the codification and fail to recognise why such postures are adopted and what could be modified so that they would not be recurrent. It shows also that this search for solutions requires observation of the movements rather than still images. In that sense, as already stated, quantification detracts from the observation of the items leading to preventive measures.

It is also commonly argued that quantification of the risks is needed in order to determine whether the work condition is acceptable or not. Indeed, the epidemiological studies and the associated quantification methods were necessary to identify the various risk factors and to establish their causal relationship with MSDs. These studies were indispensable for the development of any prevention methods, and still, questions remain on the causal relationship.

In another context, risk assessment is necessary to determine whether an employee needs medical supervision. It might also be useful later for compensation purposes if an occupational disease develops. In some countries, it is definitely recommended for legal purposes. Nevertheless, working conditions and the risk of occupational disease are hardly different at 84 dB(A) than at 86 dB(A), at 90 ppm rather than 110 ppm of toluene, or with the arm just above or just below heart level. The dose–effect or dose–response relationships usually follow a quadratic function, and the objective in industry should not only be to reduce the hazards or nuisances to just below a conventional or legal limit (in order to comply with the law) but to implement all control measures "reasonably and economically feasibly", regardless of the fact that the residual constraints are below or above the 'safe' limits. Indeed, 84 dB(A) is unacceptable when 75 dB(A) is possible, while 94 dB(A) is acceptable (with hearing protectors) if it is not possible technically and economically to achieve a level below.

Measurements performed in the context of prevention can be completely different from those requested in risk assessment studies. While the second ones attempt to integrate exposure over a representative period, the first ones concern the sources, the environment, the materials used, and the task, and try to understand how they interact and how they could be adjusted to reduce the risk.

In a previous article (Malchaire 2000) we suggested that the scientific community failed to develop simple, inexpensive and efficient methods for employers and industry in general to prevent or control noise problems.

We suggest that the same holds true in the field of MSDs and that the approach must be systematically modified to involve workers and management directly and be orientated straight and resolutely towards improvement of the working conditions.

A strategy with similar objectives was developed and validated for the prevention of heat stress at the workplace (Malchaire et al. 1999). It is now proposed as an international and European standard (ISO 15265) (ISO/CD 15265 2000).

Similar methods were also published regarding the prevention of noise exposure (Malchaire 2000), as well as hand–arm vibration (Malchaire and Piette 2001).

The present paper attempts to reach the same goal concerning the prevention of musculoskeletal problems. It proposes a cost-effective strategy in four stages of increasing complexity, to be used successively, when necessary, by people (workers, then OH specialists) with complementary qualification levels. Its objective is to guide these people to recognise the conditions with a risk of MSDs and to identify the most adequate corrective or preventive measures.

Although it is well recognised now that MSDs can be directly or indirectly associated with psychosocial factors (Malchaire et al. 2001), the present strategy will still focus primarily on the biomechanical factors. The reason for this deliberate choice is that the psychosocial and organisational factors require a more specific approach for the promotion of the well being of the employees, and not for the reduction of MSDs only.

Principles of the strategy

The philosophy of the strategy is not specific to the problems of MSDs. It is, actually, quite obvious and follows the procedure spontaneously adopted in general to solve a problem in everyday life. For a health problem

for instance, self-examination might reveal something different (*screening*). If considering it to be suspicious, the person will see a general practitioner (*observation*) who is likely to solve the problem. If unable to solve it, the practitioner will refer the person to a specialist (*analysis*) who will probably find the solution after some complementary medical tests. In very serious cases only will the specialist turn to very sophisticated tests such as scanners, etc. (*expertise*).

The procedure was initiated by the person, who turned to outside help, progressively, as a function of the severity of the problem, as far as was necessary to find a permanent solution. At each intermediary step, intermediate measures were possibly taken, the situation was reassessed, and a decision was made whether it was acceptable or not and whether additional examinations were necessary, by whom and for what purpose.

As in this example, we suggest that the prevention strategy for MSDs includes four stages.

- At stage 1, the complaints or disorders are reviewed, the working conditions are quickly inspected and obvious solutions are implemented immediately. Ideally, this stage must be performed by the persons who are directly concerned and know the working conditions of yesterday, today and tomorrow. These are the workers and their technical managers. The method used to guide them must be short, simple to understand and use, and attractive. It must avoid scoring but lead to an inventory of the whole situation and detect and solve directly the most obvious 'problems'. It must not be time consuming, in order to be used systematically as soon as a 'problem' is suspected. It is then decided whether some risk factors need to be investigated in more detail in order to determine means to avoid them and make the work as comfortable as possible. This is stage 1, *screening*.
- For these risk factors, stage 2, *observation*, is then started by the same people: the workers themselves and the people in the company who are in charge of the organisation of the working conditions. A meeting is generally held to brainstorm the problems and determine what could be done in the short term.
  Still the procedure must be simple and straightforward. Its purpose is again to organise the review, in detail, of the working conditions. The relevant aspects must be considered one by one, systematically, trying to find for each of them the optimum condition. At the end, all information must be put together and reviewed as a whole, and decisions taken about preventive actions.
- If these persons are not able to define satisfactory solutions or if, after implementation of the technical or organisational solutions identified at this level, the problem remains, the assistance of an OH specialist is sought, and the more detailed stage-3 *analysis* is performed on the problematic aspects, again to better determine where the problems are and how to avoid them.
  The method can be more complex and involve measurements orientated towards the search of improvement measures. These OH specialists will be occupational physicians, occupational nurses, ergonomists, safety engineers, and so on. The mean qualification of these persons in any specific item of OH (noise, MSDs, stress...) remains limited, as does their equipment to quantify the risk factors. The stage-3 *analysis* method must therefore remain simple and affordable.
- When their qualifications or means are exceeded or when this *analysis* still does not make it possible to finalise the solutions, the complementary assistance of an expert might be required for stage 4, *expertise*, orientated towards a very specific aspect of the working conditions, in order to single out final control solutions.
  These experts should have extensive qualifications and means, not only to assess the specific risk, but, particularly, to bring about the most cost-effective solutions. Often, however, their expertise will be limited to this field. The proposed solutions must therefore be integrated in the whole context of the working conditions in order not to lead to other problems of a different nature.

Table 1 describes the characteristics of the four different stages. They will be discussed further in the following sections, more specifically in the context of MSDs.

Description of the strategy

Before the prevention strategy was developed, the main methods described in the international literature in relation to the evaluation of the risk of MSDs were reviewed. The documents prepared for the present strategy make use of some elements of these methods.

Stage 1: screening

A five-page leaflet was prepared with:

- Page 1, a set of pictures suggesting excessive forces, awkward postures of the arm, repetitiveness and vibration.
- Page 2, a graph showing the areas of the arms and neck with the possible symptoms (pain, discomfort, difficulties, stiffness) as well as some statistics about the prevalence of these symptoms.
- Page 3, an 80-word explanation of the strategy with indications about who can do what to solve the 'problems'.
- Page 4, an 80-word description of what to consider at the *screening* stage.

This leaflet is accompanied with a datasheet. An example of use of this sheet in a real situation is given in

Table 1. Characteristics of the 4 different stages of the strategy

Parameter	Stage 1 Screening	Stage 2 Observation	Stage 3 Analysis	Stage 4 Expertise
When?	All cases	If problem	Difficult cases	Complex cases
How?	Simple observations	Qualitative observations	Quantitative observations	Specialised techniques
Cost?	Very low 10 minutes	Low 2 hours	Average 2 days	High 2 weeks
By whom?	Workers and people of the company	Workers and people of the company	Workers and people of the company + specialists	Workers and people of the company + specialists + experts
Expertise				
Work	Very high	High	Average	Low
Ergonomics	Low	Average	High	Very high

Table 2. This datasheet invites the user (worker or manager) first to state whether and where musculoskeletal problems have occurred at the workplace. Then, the worker is invited to consider, successively for the postures, the efforts, the repetitiveness and the machines and tools, the circumstances when stressful conditions exist, the reasons, the possible simple straightforward methods of improvement and the aspects that need further investigation.

This information is not collected, pooled or analysed later. This document simply intends to induce the employees and their managers, individually or collectively, to consider with more attention the working situations and increase the efficiency of what they do spontaneously to improve those conditions.

Stage 2: observation

The method is intended to be used collectively, again by the workers, their technical managers and people from the maintenance, purchasing and/or engineering departments, when possible. A document was prepared to guide this brainstorming session. It includes a 1-page introduction to the symptoms, causes and social and economical significance of MSDs and a 2-page description of how to proceed. A co-ordinator is needed to organise and moderate the meeting. Suggestions are made about:

- Who this co-ordinator should be: foreman, engineer, and OH specialist, nurse if available.
- How the co-ordinator should organise the meeting: with five to eight well-informed and motivated persons, ready to consider or reconsider all aspects of the working conditions, from different departments (purchasing, maintenance, engineering, warehouse...), meeting near the workplace and discussing sequentially the aspects selected by the co-ordinator.

The *observation* method in itself includes a list of 50 work aspects grouped under 20 headings (Table 3). The co-ordinator is invited to eliminate from this list, prior to the meeting, those that definitely do not concern the work situation that needs to be improved.

Table 2. Checklist for stage-1 *screening* example

Work station: conditioning of cookies				
Problems or complaints in the neck, shoulders, elbows or wrists related to the working conditions	*Many complaints at the level of neck and the wrists, regular absences because of these problems*			
Item size	**When? (Particular phase of work...)**	**To what is this due technically?**	**What can be done immediately to avoid it?**	**What should be analysed in detail?**
Uncomfortable postures: torsion, arms raised, wrists bent...	*When packing the cookies in the boxes: torsion of the wrists*	*Work surface too high and not possible to sit down*	Lower the work surface by 10 cm and provide a seat	*Choose a seat with the help of the ergonomist and the occupational physician*
Heavy and repeated efforts with the arms or hands: tightening, pulling, pushing, striking...	*When emptying the boxes on the pallet*	*Boxes are too heavy and difficult to handle*	*Order boxes with side openings to improve handling*	*Review the weight of the boxes with the commercial department*
Repetition of the same movements and gestures all the time	*When packing the cookies in the boxes*	*Short work cycle of about 1 s*	*Job rotation with another worker*	*Compare the procedures used by different workers and determine how to do the job to avoid useless movements*
Inadequate machines or tools	–	*Forklift to handle the pallet*	–	*Provide a forklift with a system to raise the pallet easily*

Table 3. Stage 2, *observation*: list of the headings and aspects considered

Aspect considered
1. Work station: standing
Height of the work surface
Bending of the trunk forwards or backwards
Duration of standing posture
Supports for the knees, hips, trunk, arms...
2. Work station: sitting
Height of the work surface
Quality of the seat
Back support
Adjustment of the seat height
Foot rest
Duration of sitting posture
3. Work station: other postures
Twisted posture
Prolonged fixed posture
Posture kneeling, squatting, lying down...
4. Work with visual display units
Arrangement of the work station
5. Work station: obstructions
Obstructions at the work station
Obstructions under the work surface
6. Provision of tools, materials, controls
Visual monitoring
Grip distance
7. Tools
Tools fit for the work and the workers
Shape of the handle(s)
Weight
Controls
8. Vibrating tools
Adapted to the work and the worker
9. Postures: neck, shoulders
Posture of the neck
Posture of the shoulders
10. Postures: elbows, wrists/hands
Posture of the elbows and forearms
Posture of the wrists and hands
11. Efforts of the wrists/hands
Efforts of the wrists and hands
12. Repetitiveness
Movement repetition
13. Handling equipment
Fit for the work and the worker
14. Characteristics of the load
Handles
Dimensions
Sharp edges, rough surfaces...
15. Load lifting
Starting posture
Horizontal distance for grasping the load
Heights when grasping and dropping the load
Travel distance of the load
Frequency of lifting
Trunk rotation
Weight
16. Pushing–pulling with the arms
Effort with the arms
17. Work environment
Temperatures
Draughts
18. Lighting
Reflection
Glare
19. Temporal organisation
Time constraints
Rest periods
Overtime
20. Work organisation
Production bonus
Personnel rotation

A data sheet was prepared for each heading, with, at the bottom, and for each work aspect, two sections providing information about:

- *Why be concerned with this?* This section attempts to motivate the group in explaining what can result in the short and long run if this aspect is neglected.
- What can be done? A section, *recommendations*, provides indications about possible actions, easy to implement.

An example of such a datasheet is given in Table 4. These information sheets are not intended to be read by all participants, nor by the co-ordinator during the meeting, who is instead invited to read carefully each section of the relevant sheets prior to the meeting and refer to it to guide the discussions effectively.

During the meeting, the participants are invited to focus successively on each aspect on the list prepared by the co-ordinator for the specific working conditions. Rather than search for a consensus on how good or how bad the situation is, or on how often a given effort or posture occurs, they are invited to consider:

- Whether the situation is acceptable or should be improved.
- In what moments in the process and for what technical reasons this occurs.
- How the workplace, or the task, or else the work procedure or organisation could be improved to avoid this.

No limit values are specified at this stage, the optimum situation being simply the one that requires the minimum of rotations, twisting, forces, fatigue, and so on.

The recommended solutions should be technically detailed and not only vague wishes.

The participants are also invited to consider the efficiency of the foreseen solutions and to determine whether the assistance of an OH practitioner is requested.

After the meeting, a synthesis is prepared by the co-ordinator, summarising the findings and recommendations, specifying who is going to be responsible for what and when, and finally listing the work aspects for which an *analysis* is requested.

Stage 3: analysis

In most cases, working conditions can be significantly improved and the risk of MSDs eliminated if based on the *observation* discussed above.

Table 4. Example of the worksheet for the recording of information during stage 2

Work station: standing

How is the situation concerning:

The height of the work surface?: *the height varies according to the size of the parts to machine. It is fixed for the largest parts (60 cm) and we need to bent continuously for all the other parts*

The bending of the trunk forwards or backwards? *The body is often bent forward to get the parts from the conveyor located behind the workbench. This bench is too wide.*

Duration of the standing posture? *We are always standing and moving very little. Every 10 minutes approximately, we must take the part and place it in the basket located 3 meters away.*

Supports for the knees, hips, trunk, arms..? *When machining the part, we must bent forward, leaning the thighs against the squared edge of the workbench. This is painful after a while.*

In conclusion, the present situation is	***acceptable***	***To improve***

What can be done to improve this?

- *Arrange for the workbench to be adjustable in height rapidly*
- *Reduce the width of the bench to make it easier to take a new part.*
- *Study the possibility to install a seat.*
- *Bring the basket near the workbench on the right side.*

Is it necessary to analyse the situation or the projected solutions more in details?	***no***	***To analyse***

	Why be concerned with it?	***Recommendations:***
Height of the work surface	An inadequate height leads to • Raised shoulders or bending of the back and neck • General and local fatigue	Adjust the height according to the type of tasks • Precision Work: men 100 - 110 cm, women 95 - 105 cm • Light work: men 90 - 95 cm, women 85 - 90 cm • Heavy work: men 75 - 90 cm, women 70 - 85 cm Adjust the height of the work surface according to the size of the operators and of the task
Bending of the trunk forwards or backwards	Bending will soon or later lead to • Fatigue in the back muscles • Disk compression in the spine • Back problems and pain	• Locate the controls, tools, material... within the range of the operator • Maintain the circulation of the product to a constant height • Maintain a space for the feet at the bottom of the workbench or desk to allow the operator to stay close to the task • Locate the loads to be lifted or move at more than 60 cm height
Duration of the standing posture	Prolonged standing posture leads to: • Leg pain and varicose veins • Fatigue in the neck and back	• Study the possibility of providing with a "sit-stand" seat: Which? Where? • Include operations where the worker can walk and sit regularly, even for short periods of time
Supports for the knees, hips, trunk, arms	Local supports decrease the constraint associated with the standing posture: • Muscular fatigue • Leg and back pain	• Arrange the edge of the workbench to make possible a support at hip level • Never lean against a sharp edge, maximize the support area • Locate supports to be grasped at shoulder level or higher if work above shoulder cannot be avoided • Vary the tasks in order to change posture

In certain cases however, the task requires a combination of postures and efforts such that it is not possible to identify directly the postures and the operations at risk. A more detailed *analysis* is then required, orientated towards the body zone recognised as being at risk, during stage 2, *observation*. The assistance of an OH practitioner is now indispensable, but the method for this stage-3 *analysis* must, however, remain rather simple and must be essentially based on observations.

A clear distinction was made with the quantitative methods allowing assessment of the exposure and the risk encountered by the workers. As mentioned previously, these evaluations are requested in some countries or in some situations, in particular for compensation purposes. When this is the case, the proposed method is an adaptation of the OWAS method (Karhu et al. 1977). A video recording is made of the work during a representative period of time. It is focused on the body zone of interest. The recording is later played back and, at regular intervals, 100 instantaneous pictures are observed. The posture of the body segments in the zone of interest is compared with a set of reference postures defined in the literature, for the neck (Kilbom et al. 1986), the shoulders (McAtamney and Corlett 1993), the elbows (Grandjean 1988) or the wrists and hands (Armstrong et al. 1982; Punnett and Keyserling 1987).

This analysis provides the percentage of the time during which the body segment is in unfavourable positions and the degree of variation of these positions (repetitiveness). These percentages can be compared with limits proposed in the literature.

As discussed already, in many cases this quantitative analysis, by its nature (100 images at regular intervals), concentrates the attention of the analyst on codifying

the postures and diverts it from determining why these postures are adopted and how the work organisation and conditions can be modified to avoid them. Therefore, in the context of the present strategy, orientated towards prevention, the stage-3 *analysis* procedure deliberately avoids any coding scheme.

Recommendations are made to:

- Review the *observation* made at the previous stage.
- If needed, make a video recording of the different ways of performing the task.
- Observe more closely specific gestures, movements or efforts.
- Discuss alternative work procedures in more detail with the workers and the management.
- Suggest more specific or sophisticated solutions.

The stage-3 *analysis* procedure is therefore a qualitative description of how the OH practitioner and the people from the workplace can interact, combine their complementary knowledge and arrive at significant and cost-effective solutions or improvements.

Stage 4: expertise

Still, for some particularly sophisticated working conditions, some more-technical investigation methods can be required in order to determine adequate solutions. It might be the case, for instance, for some assembly lines where the work is so fast and complex, that the analysis of the video recordings still does not make it possible to single out the movements to improve or avoid.

The investigation can be based this time on the direct measurements of angles, of electromyographical activities of muscles and of speeds of movement. This requires the use of sophisticated and costly transducers and recorders, carried by a sample of workers during representative periods. It is important, again, to insist that the main goal here is not to arrive at a quantitative evaluation of the risk in itself, but to identify the motions, the postures or the efforts that are the most dangerous, and to determine how to modify organisation in the workplace in order to eliminate this dangerous situation.

Obviously, this stage-4 *expertise* requires the intervention of someone very specialised in the use of the sophisticated equipment, the collection of the data and the interpretation of the results. An expert is required, whose method will depend on the problem encountered, and does not need to be discussed here.

Validation of the strategy

Criteria

The validation study consisted in checking its user friendliness, its understanding and its efficiency in real situations. The criteria were:

1. External validity: the strategy is usable whatever the working situation.
2. Internal validity: the strategy is simple, clear, well formatted, pleasant to use and leads to effective solutions.

Method

To test the external validity, different conditions of work were selected, in the tertiary and secondary industrial sectors, with and without exposure to vibration, for sitting or standing subjects. Ten companies participated in the study. Contacts were made through OH practitioners (five safety officers and five occupational physicians). Seven of the companies were able to organise a meeting for using the *observation* method. The three others used the method themselves while conferring, at the workplace, with the operators and their managers.

One of the authors (A.P.) attended in each case, without intervening, in order to note the problems encountered in the comprehension and use of the documents, and, most of all, for evaluating the degree of success and the reasons for this success or failure, in finding adequate solutions. After the use of the method, each of the ten co-ordinators was invited to fill in a questionnaire about the problems encountered (time, length, understanding, relevance, user friendliness and so on). Each co-ordinator was also invited to comment and make suggestions.

The *analysis* method was more difficult to validate, as it consists mainly of the assistance of an OH practitioner, without any particular quantitative procedure. The need for such assistance, and its efficiency, depend on the case investigated and the qualification of the practitioner in this specific case.

The 'validation', therefore, consisted in checking that these OH practitioners did understand their role as described in the documents prepared for the strategy and were willing to co-operate in the required way with those who had conducted the *observation* stage.

Results

The *screening* folder and the datasheet were considered by the majority of the users to be clear, concise, easy to understand (10 min) and to use (10 to 60 min). Editorial suggestions were made to simplify some words and improve the layout. The datasheets were used adequately and led to the proposal of solutions that were easy to implement. The majority of the workers were clearly interested in the document and were motivated to use it. They also expressed the opinion that the method made it possible to decide whether or not to go further into the problem. Those who did not share these views were divided into two opposite groups, some finding the documents too difficult and too long, others estimating that

more information was needed to explain the procedure better.

The stage-2 *observation* method (documents and procedures) was equally positively appreciated. More editorial remarks were formulated. The co-ordinators spent, on average, 30 min to become acquainted with the document for the first time. The duration of the meetings varied from 2 to 4 h, while the simple application of the method by the OH practitioner was shorter (1 to 2 h). A rather long time was taken to arrange for the meeting and contact the adequate persons not familiar with this type of approach.

The duration of the meeting depended on the problem encountered and, clearly, on how much the co-ordinator was familiar with the subject and the procedure. All the meetings, however, were very productive, with great participation and brainstorming leading to effective solutions.

For lack of a meeting, the use of the method by an OH practitioner was far from a failure, providing that the practitioner could confer freely with the operators. The section *why be concerned with this* was, in some cases, amended for the sake of simplicity, but was always regarded as being useful for understanding the problems. The section *recommendations* helped the co-ordinator to suggest solutions or paths toward solutions.

One advantage of the method was to start again, in some cases from zero, reconsidering, in a new, co-ordinated way, problems, complaints and suggestions made previously. It made it possible for the various protagonists to stand back from previous discussions and reconsider the problems constructively. In particular, the participation of the operators was total, proposing solutions and comparing their way of accomplishing the tasks.

As for the *screening* method, the users could recognise the aspects for which they needed a more detailed *analysis* with the active participation of an OH practitioner.

On the basis of these tests, the documents and the procedure were revised mainly to facilitate their utilisation and stress the need for the co-ordinator to become very familiar with the method and to prepare carefully for the meeting.

At the end of the *analysis* stage, the OH practitioners were, at first, rather surprised not to be in charge of the problem and to be solicited only for specific aspects such as selecting an adequate seat or tool, defining the best layout of a workplace or proposing the optimal rotation procedure between workstations. Rather than assist the persons in the field to deepen the *observation*, the OH practitioners really took in hand the problems, and proceeded.

It appeared clearly that for many of them, as well as for the companies that were paying for their interventions, it was too early to propose solutions without having first provided the ordinary quantitative observations (percentage of time in awkward postures, repetitiveness, etc.). It seems, therefore, more realistic to include in the strategy a method allowing this, making sure that it is simple to use and multi-purpose, and minimising the time for these observations.

The RULA method (McAtamney and Corlett 1993) could fulfil those criteria. In some cases only, as suggested already, more sophisticated methods could be used when more accurate quantitative observations are truly required.

This aside, the OH practitioners clearly relied on the information from the *observation* stage, and their contribution was remarkable in giving shape to the solutions found or proposed at this stage. Therefore, in practice, the procedure proposed by the strategy worked efficiently, the qualifications and the knowledge of the OH practitioners and the people from the field complementing each other to arrive, at the lowest cost, at significant improvements of the work situation.

Discussion

The philosophy of the strategy, applied here in the case of MSDs, has not, so far, been readily accepted in the scientific world. One of the reasons is certainly that it appears to be in contradiction with the tendency to concentrate on risk assessment (as shown by the list of communications to the majority of the scientific congresses in recent years) with the underlying assumption that assessment leads to solutions.

As discussed already (Malchaire 2000), risk assessment requires the characterising of the overall exposure of the operator during the whole work task, while often the search for solutions needs to look closely at specific movements or compare different methods for accomplishing the task.

While risk assessment remains undeniably vital in a certain context, it must be recognised that risk prevention requires different approaches, more cost-effective and readily usable in the field.

The strategy was also criticised for reducing the possibilities of intervention by OH practitioners in industries. This is obviously not its intent, and the assistance of such practitioners will always improve the quality of the actions taken. Stage 1, *screening*, and stage 2, *observation*, were simply conceived so that this assistance is not indispensable. In view of the limited number of practitioners and the tremendous number of companies, in particular SMEs, concerned with MSDs, this is likely to increase the number of actions in the field. In addition, the strategy attempts to optimise the use of the respective qualifications: knowledge of the real work by the operators and knowledge of the ergonomic principles by the OH practitioners.

This strategy is sometimes criticised as being utopian. It might be true indeed that operators and their staff have formed the habit of transferring the problems to 'specialists', instead of playing a direct role in the management of their working conditions (Royster and Royster 1991). Obviously, the process of participation, with the operators not only collaborating with the

'specialist' but being the main actors, at the centre, needs to be started in each company. One of the roles of the OH practitioner is to do this, step by step.

The strategy in itself was well received by the operators and the people who used it. Obviously, these OH practitioners were contacted and motivated personally to participate in the validation study. This might have positively biased their opinion. Such a bias is not likely among the operators. In addition, the companies themselves were not asking for any assistance and were not particularly motivated for the study.

As stated before, the validation study consisted in checking its user friendliness, its understanding and its efficiency in real situations. This is completely different from validation studies for questionnaires or other quantitative methods. In the present case, the criteria of repeatability and reliability were clearly not applicable, as it was out of the question to repeat the meeting with different groups of workers or at a later occasion, or to make a thorough investigation to compare the results with reference values.

The criterion of validity of construct can be considered to be fulfilled as, from the literature (Malchaire et al. 2001), it is possible to conclude that any improvement of the work aspects covered by the methods will lead to a decrease in the risk of MSDs.

The validation study showed that the strategy and the documents prepared for its implementation were practicable, usable and cost effective in inducing dialogue between operators and their managers and the adjustment of solutions.

OH practitioners welcomed this strategy for the prevention of MSDs, which makes it possible to approach the problems, in the same way as was already possible for noise (Malchaire 2000), heat (Malchaire et al. 1999), and vibration (Malchaire and Piette 2001).

These tools contributed to the improvement of the social dialogue in the industries in demonstrating the respective role of each protagonist. They also contributed in optimising their intervention for greater efficiency in improving the health of the operators.

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