Preventing upper limb work-related musculoskeletal disorders (UL-WMSDS): New approaches in job (re)design and current trends in standardization

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Abstract

In industrialized countries, upper limb work-related musculoskeletal disorders (UL-WMSDs) are the most common form of occupational diseases. They are generating a growing population of workers with reduced working capacity. The link between these pathologies and different aspects of work organization has been convincingly proven. Recent experiences in Europe supporting the combination of traditional work design methods used in manufacturing companies with ergonomics methods are reported briefly, with special focus on the use of the occupational repetitive action (OCRA) method for risk assessment and management of manual repetitive tasks. The combined approach strives to achieve the goal of maintaining a satisfactory level of productivity while respecting ergonomics criteria and, definitely, workers' health. New ergonomics standards provide for interaction between job and machinery designers and ergonomists in the design of work processes and workplaces. These standards generally refer only to the healthy adult working population and do not always provide criteria for protecting particular working populations, such as that represented by workers affected by UL-WMSDs. The results of preliminary studies concerning productive re-employment of workers with UL-WMSDs allow the introduction of some criteria for implementing current ergonomics standards in this connection.

One aim of this paper is to summarize experiences of close cooperation between ergonomists, machinery designers and job designers to guarantee productivity and the prevention of musculoskeletal disorders. A second aim is to examine current ergonomics standards in the field of manual physical work (designed for healthy workers) and to suggest preliminary criteria for their implementation taking into account the capabilities and needs of specific sub-groups of the working population.

1. Introduction

Organized work has changed dramatically for both blue-collar and white-collar workers, and with the average age of the European working population increasing, occupational health risks have also changed.

After receiving rather little attention throughout the first half of the 20th century, work-related musculoskeletal disorders (WMSDs) have become one of the main focuses in the area of occupational disease prevention.

In particular, upper limb WMSDs (UL-WMSDs) are today the commonest form of occupational disease in Europe and in other parts of the industrialized world. In Europe, UL-WMSDs now account for over 45% of all occupational diseases (Eurostat, 2004). The link between these pathologies and several important aspects of work organization (high pace, repetitive tasks, lack of breaks and long working hours) has now been convincingly proven.

The number of workers with some kind of impairment or disability, as defined by World Health Organization (WHO), and therefore with a reduced working capacity, is ever increasing. These minor disabilities are widespread among the working population, and are quite distinct from major disabilities and handicaps in respect of the safeguards provided by specific legislation.

From this viewpoint, new and highly innovative technical standards in the area of physical ergonomics are
aimed specifically at protecting the healthy adult working population and their capabilities. Conversely, much less tangible attention is given to members of the workforce affected by minor physical disabilities.

One aim of this paper is to summarize experiences of close cooperation between ergonomists, machinery designers and job designers to guarantee productivity and prevention of musculoskeletal disorders. This collaboration could allow, in perspective, re-employment of subjects affected by minor physical disabilities, such as UL-WMSDs. A second aim is to examine current ergonomics standards in the field of manual physical work (designed for healthy workers) and suggest preliminary criteria for their implementation, taking into account the capabilities and needs of specific sub-groups of the working population.

2. Methods and experiences for risk assessment and management of upper limb biomechanical overload

Based on the most recent literature, a Consensus Document was produced by the International Ergonomics Association (IEA) Technical Committee on Musculoskeletal Disorders with the endorsement of the International Commission on Occupational Health (ICOH) (Colombini et al., 2001). The document concerns jobs that potentially cause biomechanical overload due to repetitive movements and/or exertions of the upper limbs. Risk assessment requires identification and quantification of the following main risk factors: frequency of action, awkward postures and movements of the upper limbs, excessive use of force, stereotypy (lack of postural variation), and inadequate recovery periods. There are additional factors likely to be considered as risk enhancing. Taken together, these factors characterize the worker’s exposure in relation to task duration.

The literature reports numerous methods for determining and measuring risks arising from exposure to biomechanical overload of the upper limbs (Delleman et al., 2004; Stanton et al., 2004). These methods include semi-quantitative or quantitative approaches disclosing some characteristics of a job leading to suspect the presence of risks and rank them using synthetic indexes (Strain index; Hal-ACGIH TLV; occupational repetitive action [OCRA]); other methods employ checklists to evaluate the problem rapidly.

Most of these methods have so far been used only by ergonomists and occupational health and safety experts for risk assessment. Use by other professionals for job and workplace design is limited, and one reason for this is because of a clear difficulty in using a common language, especially regarding aspects of work organization.

The most articulate of such methods, however, and the OCRA method in particular, contain definitions and procedures that can be shared, at least partly, with other professionals and used for ad hoc purposes of job and workplace design (or re-design).

This is one of the reasons why the technical groups charged with preparation of international standards on the matter have preferentially used, in those contexts, the OCRA method (CEN, 2005; ISO, 2005). The standards being addressed also (in some case exclusively) to machinery and job designers, the idea was to use a sufficiently validated quantitative method based on criteria and definitions fully comprehensible also to non-experts.

According to a review within an International Organization for Standardization (ISO) proposal (see below ISO/DIS 11228-3), the OCRA method (Colombini et al., 1998, 2002; Occhipinti and Colombini, 2004) was recommended, for the specific goals of that standard, having the following advantages:

- it provides a detailed analysis of all the main mechanical and organizational risk factors for UL-WMSDs,
- it uses a common language with respect to traditional methods of task analysis (predetermined time systems): this makes company technicians (production engineers, analysts) more familiar with the method and helps them improve work procedures,
- it considers all the repetitive tasks involved in a complex (or rotating) job and estimates the overall worker’s risk level,
- in epidemiological surveys, the OCRA index appeared to be well related to health effects (such as occurrence of UL-WMSDs) and so it is now a good predictor (within definite limits) of the collective risk at a given OCRA level.

2.1. The OCRA method

The OCRA method was proposed for analyzing workers’ exposure to tasks featuring various upper limb risk factors (Colombini et al., 1998, 2002). The OCRA method evaluates the main collective risk factors (frequency of action, awkward postures and movements of the upper limbs, excessive use of force, ‘stereotypy’ or lack of postural variation, inadequate recovery periods) based on their respective duration. Other additional factors are considered, such as mechanical, environmental, and organizational factors providing evidence of causal relationship with UL-WMSDs. Each identified risk factor is properly described and classified to help identify possible requirements and preliminary preventive actions. All factors contributing to the overall exposure are considered in a general and mutually integrated framework by a synthetic index (the OCRA index).

The method is observational and is designed mostly for use by technical specialists (occupational safety and health operators, ergonomists, methods and time analysts, production engineers), who proved in the practice to better learn and apply the method for risk management and task/workplace (re)design purposes. The method was applied in a wide cross-section of industries and workplaces. In
Europe, this method is estimated to be used currently in more than 7000 tasks, involving over 30,000 employees.

In the OCRA method, the technical action is identified as the specific variable characteristic relevant to repetitive movements of the upper limbs. The technical action is factored by its relative frequency during a certain period of time. The ‘frequency of upper limbs technical action’ is related to other risk factors, such as force (the higher the force, the lower the frequency), posture (the higher the joint excursion, the longer the time necessary to carry out an action), task duration and recovery periods. The concept of technical action (defined as any elementary manual action required to complete the operations within the work cycle, such as holding, turning, pushing, cutting) is similar to (even if not identical with) one of the ‘elements’ considered in traditional task analysis methods. Thus, the technical actions are more easily recognizable by technicians, since their identification and task analysis methods are both aimed at describing the technical movements carried out by the operator to complete a work cycle.

The OCRA index is the result of the ratio between the number of technical actions actually carried out during the work shift (ATA) and the number of technical actions that is specifically recommended (RTA). The overall ATA within a shift can be calculated by organizational analysis (number of actions per cycle and number of actions per minute, with the latter multiplied by the net duration of the repetitive task(s) analyzed to obtain ATA).

The following general formula calculates the overall RTA within a shift (RTA):

$$\text{RTA} = \sum_{n} \left[ CF(F_{om} \times P_{om} \times R_{m} \times A_{m}) \times D_{i} \right] \times R_{m} \times D_{m},$$

where $n$ is the number of repetitive task/s performed during a shift, $\text{CF}$ the constant of frequency of technical actions per minute $= 30$, $F_{om}$, $P_{om}$, $R_{m}$, $A_{m}$ the multipliers with scores ranging from 0 to 1, in each of the ($n$) tasks, $D_{i}$ the net duration (in minutes) of each repetitive task, $R_{m}$ the multiplier for lack of recovery period, $D_{m}$ the multiplier according to overall duration of repetitive tasks during a shift.

For additional details on criteria and procedures involved in defining the OCRA index calculation variables, please see Colombini et al. (2002).

On the basis of recent studies (Occhipinti and Colombini, 2004), the association between the OCRA index (independent variable) and prevalence of persons affected (PA) by one or more UL-WMSDs (dependent variable) can be summarized by the following simple linear regression equation:

$$\text{PA} = 2.39(\pm 0.14)\text{OCRA},$$

where PA is the number of persons affected by one or more UL-WMSDs $\times 100$ versus the number of exposed individuals and $\pm 0.14$ is the standard error of the regression.

This regression equation proved to be extremely significant ($p < 0.00001$) from a statistical point of view. In this context, it should be emphasized that the UL-WMSDs considered were all entrapment syndromes, tendinitis, peritendinitis of the upper limbs (shoulder included) confirmed by clinical examination and specific instrumental tests.

Using the standardized (by age and gender) PA variable in a reference population (Occhipinti and Colombini, 2004), the OCRA index reference limits were established starting from the 95th percentile as the driver value for the so-called green limit and from twice the 50th percentile as the driver value for the so-called red limit.

Those driver values of PA, as from the reference working population (not exposed), were compared with Eq. (2) at the level corresponding to the 5th percentile: in such a way, by adopting a prudential criterion of assessment of unacceptable (yellow or red) results, it was possible to find the OCRA index values corresponding to the green and red limits, respectively, and discriminating green, yellow and red zones.

In practice, the green limit means that, from that level, in the exposed working population are predicted, almost in 95% of cases, PA values higher than the 95th percentile (PA = 4.8%) expected in the reference (not exposed) population. The red limit means that, from that level, in the exposed working population almost in 95% of cases, PA values are predicted higher than twice the 50th percentile (PA = 7.4%) expected in the reference (not exposed) population.

The new classification of the OCRA index in the three-zones model (green, yellow, red) is reported in Table 1.

If Eq. (2), with its confidence limits, is used as a predictive model, the OCRA index becomes a tool for estimating the collective risk, for a given exposed population, to contract UL-WMSDs (in terms of PA). For instance, in Table 2, for different OCRA index values, the expected PA is estimated by calculating the central value and the confidence limits (in this case at 90%), and consequently also the 5th and 95th percentile of the estimate.

### 2.2. Traditional work design methods and ergonomics methods

In the last few years, several attempts have been made, and tested in different European major manufacturing companies, to promote the combination of the most traditional work design methods, here grouped under the term of predetermined time system (PTS), and the new ergonomic methods for the design of manual tasks and workplaces. These new approaches are developed to achieve integration of respective analysis methods, while maintaining the specific aim of each one of them. The combination has a twofold ambitious goal: maintaining a good level of productivity while protecting workers’ health and well being.
The authors’ direct experience teaches that in most small and medium manufacturing enterprises, job and work design rules are mostly arbitrary and based on the assumption of producing as much as possible: in those companies, occurrence of UL-WMSDs is often very high. Paradoxically, with respect to those contexts, jobs designed adequately using traditional PTS methods (usually adopted in large manufacturing companies), generally offer greater protection from UL-WMSDs. Hence, there is a common interest of PTS methods and physical ergonomics-based methods: i.e. to improve job design in modern industries and incorporate more advanced criteria of physical ergonomics.

Moreover, it is to be noted that recent developments in organizational analysis, such as ‘lean manufacturing’ methods, also tend to simplify manual jobs, thus contributing to a reduction of physical and repetitive workloads.

Several programs, tools and pieces of software have been developed with this purpose in different European contexts, as exemplified by the MIRTH program (musculoskeletal injury reduction tools for health and safety), whose final result will be a software tool usable by a wide cross-section of people employed in product and workplace design. Many of these tools will be presented at the 16th IEA Conference in Maastricht, and an exhaustive survey is not appropriate here, so we will just indicate (Table 3) the tools and software known to the authors aimed more directly at integrating traditional PTS and new physical ergonomics methods. Such methods have been developed in Germany, France and Italy in collaboration with respective method time measurement (MTM) associations. Obviously, the combination of different methods is just starting and there are a number of problems still to be tackled on account of diversified objectives. For example, MTM methods (Barnes, 1980) are aimed at identifying elementary movements and correlated times required to perform a given task in order to minimize time performances and increase productivity. The OCRA analysis approach is basically different, since it identifies number and duration of the performed technical actions (similar to elementary elements), in order to analyze related action frequency, resulting in a risk index for prevention purposes. Moreover, PTS methods generally consider the average skilled worker and do not duly account for the varying capabilities of the working population.

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### Table 1
The OCRA method: final assessment criteria

<table>
<thead>
<tr>
<th>Area</th>
<th>OCRA index values</th>
<th>Risk level</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>≤2.2</td>
<td>No risk</td>
<td>Acceptable, No consequences.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>UL-WMSDs (PA) forecast is not significantly different from that expected in the reference population</td>
</tr>
<tr>
<td>Yellow</td>
<td>2.3–3.5</td>
<td>Very low risk</td>
<td>Advisable to set up improvements with regard to structural risk factors (posture, force, technical actions, etc.) or to suggest other organizational measures</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>UL-WMSDs (PA) forecast is higher than previous but lower than twice the one expected in the reference population</td>
</tr>
<tr>
<td>Red</td>
<td>&gt;3.5</td>
<td>Risk</td>
<td>Redesign of tasks and workplaces according to priorities is recommended</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The higher the index, the higher the risk</td>
</tr>
</tbody>
</table>

### Table 2
Estimated PA (prevalence of workers with one or more UL-WMSDs) as a function of the OCRA index values (central value and 90% confidence limits)

<table>
<thead>
<tr>
<th>OCRA index</th>
<th>PA (5th centile)</th>
<th>PA (50th centile)</th>
<th>PA (95th centile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>3.24</td>
<td>3.58</td>
<td>3.93</td>
</tr>
<tr>
<td>2.2</td>
<td>4.75</td>
<td>5.26</td>
<td>5.76</td>
</tr>
<tr>
<td>3.5</td>
<td>7.56</td>
<td>8.36</td>
<td>9.17</td>
</tr>
<tr>
<td>4.5</td>
<td>9.72</td>
<td>10.75</td>
<td>11.79</td>
</tr>
<tr>
<td>9</td>
<td>19.44</td>
<td>21.51</td>
<td>23.58</td>
</tr>
</tbody>
</table>

### Table 3
New ergonomic methods, developed as software, to promote combination of traditional work design methods and ergonomics methods

<table>
<thead>
<tr>
<th>Software name</th>
<th>Author</th>
<th>Country</th>
<th>Mail address</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQUINOXE</td>
<td>Jean-Pierre Lachevre</td>
<td>France</td>
<td><a href="mailto:lachevre.sa@wanadoo.fr">lachevre.sa@wanadoo.fr</a></td>
</tr>
<tr>
<td>OCRA-MIDA</td>
<td>Michele Fanti</td>
<td>Italy</td>
<td><a href="http://www.epmresearch.org">http://www.epmresearch.org</a></td>
</tr>
</tbody>
</table>

Moreover, it is to be noted that recent developments in organizational analysis, such as ‘lean manufacturing’ methods, also tend to simplify manual jobs, thus contributing to a reduction of physical and repetitive workloads.

Several programs, tools and pieces of software have been developed with this purpose in different European contexts, as exemplified by the MIRTH program (musculoskeletal injury reduction tools for health and safety), whose final result will be a software tool usable by a wide cross-section of people employed in product and workplace design. Many of these tools will be presented at the 16th IEA Conference in Maastricht, and an exhaustive survey is not appropriate here, so we will just indicate (Table 3) the tools and software known to the authors aimed more directly at integrating traditional PTS and new physical ergonomics methods. Such methods have been developed in Germany, France and Italy in collaboration with respective method time measurement (MTM) associations.

Obviously, the combination of different methods is just starting and there are a number of problems still to be tackled on account of diversified objectives. For example, MTM methods (Barnes, 1980) are aimed at identifying elementary movements and correlated times required to perform a given task in order to minimize time performances and increase productivity. The OCRA analysis approach is basically different, since it identifies number and duration of the performed technical actions (similar to elementary elements), in order to analyze related action frequency, resulting in a risk index for prevention purposes. Moreover, PTS methods generally consider the average skilled worker and do not duly account for the varying capabilities of the working population.

However, the bases are encouraging in terms of common language used and classification criteria for UL-WMSDs prevention: there are actual cases of large manufacturing industries that, adopting the combined approach, fully redesigned assembly lines thus increasing productivity through keeping workers’ exposure levels below acceptable values of the OCRA index. It is worth mentioning the case of a big European company manufacturing washing machines in Italy, that, through an agreement with the Trade Unions, achieved a line production increase from 75 to 85 washing machines per hour, with workers’ individual exposure to acceptable OCRA index levels, obtained with...
an increase of recovery periods. On the other hand, this allowed retention of the present production workforce that otherwise would be greatly reduced.

For a better understanding of the issue, let us synthetically and anonymously present here an example of redesign of an assembly line production, checked using the OCRA index critical values.

The job designer was requested to increase productivity of an assembly line by a complete re-design of respective tasks and workplaces, taking into account OCRA limit values (all tasks should fall into the yellow–green exposure areas). The job designer, in this case trained to use the OCRA index, first increased productivity by simply reducing cycle time, but checking the result with the OCRA index he noted a marked risk increase and therefore proceeded with further designs and checks according to the following stages, as shown in Fig. 1:

(a) Rebalancing of work distribution over different line workplaces considering productive increase and OCRA index assessment: still high results.

(b) Introduction of other organizational solutions, such as a further break and re-assessment of this solution: result to still be improved.

(c) Improvement in workplace layouts and some tools to reduce force: re-assessment by the OCRA index showed an optimal result with productivity increase even higher than expected.

Fig. 1 shows that, on this assembly line, productivity could be increased from 61 to 69 pieces per shift, average direct product cost (figurative units) could be lowered and exposure to risks for the upper limbs, checked by the OCRA index, could be maintained within acceptable limits.

The experience illustrated above, although brief, shows that the OCRA index can be considered as a major support tool for machine designers and work organizers, allowing immediate tests of the validity of assumptions and a choice of a solution providing higher productivity, lower productive cost and lower cost for workers’ health.

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**Fig. 1.** Different stages in re-balancing an assembly line to increase production and a check of the different options by the OCRA index.
2.3. The “burden” of subjects with UL-WMSDs in industry and preliminary experiences for re-employment

Several data from official statistical and ad hoc studies are concerned with distribution of UL-WMSDs in different industrial sectors: it is not appropriate to make a systematic review here. However, on the whole, these data confirm the high-percentage of industrial workers affected by clinically diagnosed UL-WMSDs having to face, among others, the problem of an appropriate re-employment, both for production and their health. With this purpose, the data of some experiences carried out by the authors are reported here; we are well aware that they are illustrative, and not exhaustive, of the whole scientific production in this field.

In an Italian epidemiological survey (Colombini and Occhipinti, 2004), a total of 3511 workers (2166 women and 1289 men) employed in 15 different manufacturing plants or departments and involved in manual repetitive tasks were clinically monitored for UL-WMSDs. Of the whole sample, 15.9% of subjects examined were affected by almost one clinically diagnosed UL-WMSD; if the prevalence of the single pathologies is considered, the percentage rises to 27.9%: this means that, on average, the affected workers have almost two pathologies each. The highest prevalence rates were found in women (19.6% of workers affected, 33.1% of pathologies); for men, the figures were 10.4% of workers affected and 18.3% of pathologies. The prevalence of affected workers and pathologies was almost twice as high in women (17.4% of affected workers, 34.3% of pathologies) than in men (10.4% of affected workers, 18.3% of pathologies). Of all the disorders, carpal tunnel syndrome was the most frequently reported (35.2% of active clinical diagnosis), followed by periarthritis (22.1%), epicondylitis (17.1%) and tendinitis of the hand (12.9%). Other forms were rare.

The results reported here, which are obviously concerned with examined situations and adopted classification criteria, show a large number of workers (in the specific case about 16%) affected by UL-WMSDs who have to tackle the problem of an appropriate working re-employment under fitting productive conditions (beside, obviously, a proper clinical and therapeutic treatment).

To this end, preliminary studies (Colombini et al., 2002) concerning re-employment of workers affected by UL-WMSDs showed that, by adapting workplace and work pace correctly, it is possible to keep these workers usefully employed. A practical experiment was carried out in a major metal-working plant, in particular on the motor assembly lines for refrigeration equipment. The highest exposure values were observed in the electric motors department (mean OCRA index value in red area: 3.5–5.8). The workers with UL-WMSD pathologies classified as severe were transferred to workstations that had been completely redesigned (OCRA index value in green area or yellow area). In a longitudinal 5-year study on affected workers, 234 individuals were analyzed: 116 males (49.5%, mean age 46.2 years) and 119 females (50.8%, mean age 48.9 years). Their diseases were mainly carpal tunnel syndrome in 88% of the females; 58% had only one disorder, 27% had two, 10% had three. Following re-employment, the “severe” cases showed good levels of clinical and functional improvement (60%), especially in cases of carpal tunnel syndrome.

The result of this preliminary analysis shows that the redesign process has a strong impact on UL-WMSDs evolution, even considering the presence of confounding factors (some workstations only partially redesigned, different type, severity and location of pathologies etc.). They suggest also the hypothesis that exposure to repetitive movements that are in the ‘green’ area (OCRA index lower than 2.2 with action frequency of about 30 per minute, minimal force, absence of awkward postures and adequate recovery periods) could still be compatible with more common UL-WMSDs.

3. International standards in the field of physical ergonomics and related target populations

Expert groups have been working for several years at CEN and ISO to prepare standards in the field of ergonomics. The European Committee for Standardization (CEN) standards (harmonized standards) stem largely from a mandate received from the European Commission and the European Free Trade Association (EFTA) to support the basic requirements contained in European Directives, particularly in the relevant chapter of the so-called Machines Directive (Karwowski, 2006).

Designing manufacturing systems and machines ergonomically means improving safety and efficiency for workers and raising living and working conditions. Good ergonomic design positively affects manufacturing systems and worker reliability. Thanks to these new standards, when a new machine and workplace are being designed and manufactured, the designer and manufacturer should take into due account a number of basic requirements with respect to health, safety and ergonomics: they should evaluate and minimize all related risks.

In particular, the European standards specifically concerned with prevention of UL-WMSDs, is mentioned below.

EN 614-1 (CEN, 1995) and EN 614-2 (CEN, 2000) are highly relevant here. These standards provide general ergonomic principles for machinery designers, job designers and ergonomists in the integrated design of work processes, tasks, machinery and workplaces.

EN 614-1 already considers in the design process basic diversities of the target population (e.g. gender, anthropometry, etc) satisfying the needs and capacities of at least 90% of them (for instance, as regards dimensional parameters, at least the 5th to 95th percentiles should be considered). Generally, ergonomic standards refer only to the healthy working population and cannot always
provide criteria and reference values for particular sub-sections (e.g. older and younger workers, “impaired” workers).

However, this standard suggests fitting ‘as wide a range of the expected operator population as possible’ and ‘Special consideration will be needed when equipment is being designed for use by disabled people.’

Standard EN 614-2 entitled ‘Safety of machinery—Ergonomic design principles—Part 2: Interactions between the design of machinery and work tasks’ helps the designer to apply ergonomic principles by focusing attention on the interaction between machine design and job design. In other words, it asks the designer to create both machines or systems and the jobs associated with them. This is of crucial importance, because the success of a machine design depends on how competently and safely operators can use it.

When designers plan a machine and the tasks associated with it, all the ergonomic requirements outlined in Table 4 should be complied with in relation to the machine ‘target user’:

In particular, this standard states that, if repetitive tasks cannot be avoided, then the execution time must not be based exclusively on the average or estimated duration of the task under normal conditions. Tolerances must be allowed for deviation from normal conditions. Very short cycle times must be avoided: the operator must be given the opportunity to work at her/his own pace, rather than to a set pace. Albeit general, these principles are designed to encourage job designers to pay more attention to the ‘standard pace’ employed in their traditional methods.

The series of standards EN 1005, referring to assessment and management of risks associated with human physical performance in the healthy working population, also make provisions for diversity within the same population.

EN 1005-2 (CEN, 2003), concerning load manual lifting in relation to machinery, adopts variations of the National Institute for Occupational Safety and Health (NIOSH) lifting index method, which requires the job designer to first choose the target population, then set the maximum acceptable weight constant. It also supplies the relevant population percentiles potentially requiring protection (Table 5).

EN 1005-3 (CEN, 2002) concerns risks associated with actions requiring force. It is based on prior identification of the maximum force-generating capability for different categories of users and for different types of actions. In the initial phase, it is necessary to calculate the maximum isometric force ($F_{max}$) required to perform specific actions with reference to specific user populations, using, as a reference, capabilities of the 15th percentile for professional use and of the 1st percentile for domestic use.

EN 1005-4 (CEN, 2004) presents guidance in assessing and controlling health risks due to machine-related postures and movements. Generally speaking, the standard states that the model for assessing risks to human health, associated with postures and movements, is represented by a U-shaped curve, with jobs constituting a problem when requiring prolonged static postures at one extreme, and high-frequency movements at the other.

In order to assess and prevent risks associated with repetitive upper limb movements performed at high speed, two new standards are nearing completion by CEN (prEN 1005-5) (2005) and by ISO (ISO DIS 11228-3) (2005). These two drafts are devoted to different targets of users, but they are conceptually similar.

PrEN 1005-5 presents guidance to the designer of machinery or its component parts in controlling health risks due to machine-related repetitive handling at high frequency.

ISO DIS 11228-3 establishes ergonomics recommendations for repetitive work tasks involving handling of low loads at high frequency and provides information to all those involved in analysis, design or redesign of work, jobs and products.

These draft standards specify reference data for action frequency of the upper limbs during working operations, and present a risk assessment method aimed at reducing...
risk. They apply to the adult working population and recommendations are intended to give reasonable protection from occupational risks for nearly all healthy adults. Both draft standards make almost exclusive use of the OCRA index method and related risk classification criteria, as presented previously (Table 1). Accordingly, a compliance with these critical values in exposed working populations will protect healthy adult workers from the occupational risk of developing UL-WMSDs, while accepting low occurrences of such disorders as being due to other non-occupational factors.

At the moment of writing, the CEN draft underwent a second positive official enquiry and a forthcoming draft is now under final enquiry to be approved as a ‘harmonized’ standard. The ISO draft underwent two positive enquiries and is now ready to undergo, as a Final Draft International Standard (FDIS), the final official enquiry.

It is important to underline that in standards EN 1005 parts 2-3-4, the criteria concerning protection of the working population are based mainly on the concept of ‘capability’ as derived from physiological, psychophysical and biomechanical studies; in the draft standards on repetitive movements, the corresponding criteria are based mainly on the concept of collective occupational risk (for UL-WMSDs) as derived from epidemiological surveys focused on the health effects related to different exposures.

Finally, it is worth recalling the ‘group’ of international standards aimed at meeting the needs of population groups with reduced abilities. Such standards (or standard projects) were developed in connection with publication of ISO Guide 71/2001 Guidelines for standards developers to address the needs of older persons and persons with disabilities. Since we cannot go into more detail here, we point out that, on the whole, they represent a major attempt to consider, in designing products and services, these important categories of people and related residual abilities in, particular, as regards motorial and sensorial aspects. It is noteworthy, however, that they are concerned mainly with compatibility between major disabilities and usability of products and services, while less attention is paid to compatibility between minor disabilities (such as those from UL-WMSDs) and employment in productive work.

4. Conclusion: problems and prospects

The different elements provided (integrated job design by traditional and ergonomic methods; new ergonomic standards with their limits and future perspectives) point the way to the highly promising prospect of concrete ergonomic work design, accounting for biodiversity in the working population. To this end, some related problems must be examined.

4.1. Collaboration and interaction between ergonomists and machinery/job designers

It has been shown that the new ergonomic standards in the design of new machinery and related tasks take ergonomic principles into account both in design of workstations and the work organization to maintain workers’ physical and psychological well-being. Workstation design includes layout, workstation structure and line, selection of tools, organization of material flows and handling, and analysis of environmental parameters (lighting, noise, temperature, humidity, harmful substances). Defining the working method requires attributing tasks (and therefore defining cycle times), studying how tasks are performed, balancing and determining sequences of workstations, determining rest intervals and job rotation programs. Two traditional professionals are therefore brought into the equation: machine designer and job designer (i.e. MTM analyst). The two professionals have to know and plan work in order to avoid the usual accidents associated with safety, and prevent risk of an excessive and progressive deterioration of worker’s health in the medium to long term. Today, these professionals are increasingly

<table>
<thead>
<tr>
<th>Field of application</th>
<th>$M_{ref}$ (kg)</th>
<th>Percentage of</th>
<th>Population group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Females</td>
<td>Males</td>
</tr>
<tr>
<td>Domestic use</td>
<td>5</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>Professional use</td>
<td>15</td>
<td>95</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>85</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 5: EN 1005-2: reference mass taking into consideration the intended user population
being called upon to design machinery, methods and workstations that comply with ergonomic principles at the drawing-board stage, as well as to analyze and correct existing workstations and tasks not complying with current standards.

The issue is still open: are designers of machinery and industrial products and analysts quite aware of the criteria and ergonomics methods required for design of workplaces and tasks?

Given that the reply tends, on the basis of personal experience, to be negative, education and training have to be integrated. Machine and job designers both need (and often require) a sound educational background and a clear understanding of ergonomics principles and methods. In such a context, referring specifically to repetitive manual tasks, ergonomics methods (such as the OCRA method) should be targeted to these professionals, offering the advantage of speaking a common language, supplying the machine designer and analyst with clear and precise recommendations on the influence of individual risk factors, and consequently pointing out possible options for further improvement of their designing.

4.2. Study of working capability with reference to ‘emerging diversity’

In order to establish design principles that take into account different working populations and capabilities, it is necessary to collect much more information and experience, with particular attention to the large number of workers that have musculoskeletal chronic-degenerative pathologies, or who are old, partially unfit for the job or disabled, and that should be re-employed in productive work.

In this context, the hypothesis was formulated that workers with more common types of UL-WMSD could still be compatible with work conditions where the risk appeared to be fully acceptable (green area) for the general healthy working population. However, in this field, experiences are only preliminary and it is not yet possible to derive general orientation criteria and definite operating guidelines.

Therefore, the different experiences carried out by different research groups should be widened and coordinated to construct detailed and practical guidelines and to identify the relevant criteria for adequate re-employment of workers with different capabilities, so that they can be used productively, rather than losing their jobs. In this field as well, collaboration with properly ergonomically re-oriented job designers could be extremely useful.

4.3. Updating standards

It has been highlighted that present ergonomics standards concerning work process in principle are aimed at protecting an as wide as possible range of working population, but in practice they are aimed mainly at protecting only the healthy adult working population. However, since international standardization also shows a tendency to consider needs and abilities of non-healthy workers (for instance, workers affected by severe WMSDs), in perspective this gap should be filled on the basis of results from special research and applicative experiences.

These considerations point out the need for focus groups to produce new guidelines or revise international standards in order to upgrade and enrich the current target population (healthy workers) with procedures and criteria to help design work and workplaces, taking into account the capabilities and needs of specific sub-groups of the working population, with particular reference to workers with UL-WMSDs.

References


