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Possibilities for regulatory actions in the prevention of musculoskeletal disorders

by Åsa Kilbom, MD[1]

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This review argues that there is a need for regulatory action against work-related musculoskeletal disorders. Designing such regulation is fraught with problems, such as insufficient knowledge about mechanisms and exposure-dose-response relationships, and lack of consensus on definitions. The multifactorial character of the disorders, especially risks involving work organization, further increases the problems. Nevertheless, regulation is necessary because of the poor results of voluntary prevention and the large costs of these disorders. Some major regulations are reviewed, and it is argued that there is insufficient scientific support for quantitative regulations proposed for some European norms. The recent Nordic ergonomic regulations for the prevention of work-related musculoskeletal disorders is a step forward, since they succeed in providing guidance, including some on work organizational issues, with only few quantitative measures. Researchers should become more involved in these activities, and priorities in future research that would benefit a more scientific approach to ergonomic regulation are indicated.

Key terms Comitté Européen de Normalisation, directives, ergonomics, International Organization for Standardization, manual handling, postures, repetition, standards.

In the past 10—20 years, knowledge about work-related musculoskeletal disorders has grown exponentially. While scientific papers in the area were rare in the 1970s and the beginning of the 1980s and mainly concerned descriptive data, both experimental studies on mechanisms and epidemiologic studies became increasingly sophisticated from the middle of the 1980s on. Several important reviews in the last few years bear witness to the large steps taken forward in knowledge (1—5). As knowledge about mechanisms and risk factors grew, prevention or intervention came more into focus. Although the outcome of different prevention or intervention programs varies widely (6, 7), and the fraction of musculoskeletal morbidity attributable to work-related factors is not well established, there is scientific consensus that most work-related musculoskeletal disorders are preventable through actions taken at work (8).

Is regulation necessary?

Given that at least some musculoskeletal disorders are preventable through voluntary actions, is regulation really necessary? In the last few years guidelines for preventive activities have been proposed, partly based on available scientific evidence (9—11), but they are unlikely to have had an effect as yet.

Despite many voluntary efforts, reported musculoskeletal disorders still constitute more than 50% of reported work-related diseases and lead to more prolonged sick leaves than other reported diseases in Sweden, and, according to the United States Bureau of Labor Statistics, about 1/3 of all occupational disorder cases are due to overexertion or repetitive movements. In most countries the incidence in reported disorders seems to be unchanged or even increasing. The cost of work-related

1 Swedish National Institute for Working Life, Solna, Sweden.

Correspondence to: Dr Åsa Kilbom, Swedish National Institute for Working Life, 171 84 Solna, Sweden. [E-mail: asa.kilbom@niwl.se]

musculoskeletal disorders is immense; it has been estimated to correspond to about 1% of the gross national product in the Nordic countries and to USD 13 billion in the United States (12, 13). Thus it appears that voluntary actions to reduce musculoskeletal disorders are insufficient and that regulation is required. Nevertheless, regulations can be expressed and implemented in different ways, and probably with varying impact, which will be discussed in the following sections.

Problems in the design of regulations

The type of regulations most wanted by practitioners are probably those which give exact levels of exposure, in terms of distance, force, frequency, and duration. Exceeding these risk levels would imply a substantial risk of musculoskeletal disorders developing among a certain proportion of the exposed population. Such risk estimates would require an immense number of epidemiologic studies in which a large variety of different specific exposure conditions was studied for prolonged periods of time. In the author's view such an approach is not feasible; modern worklife is so varied that exposure changes continuously, and the exposed population is rarely stable enough to permit long-term prospective studies. Some well-controlled studies on exposure-response relationships are available, for example, Silverstein et al's study (14) on combined repetitive and forceful hand exertion and Punnett et al's study (15) on the effects of posture on low-back disorders. Nevertheless, they cover only a minor part of all possible combinations of physical work load. One solution is to widen knowledge about pathophysiological mechanisms so that a few, strategically designed epidemiologic studies could be used to predict the consequences of similar workload conditions. Unfortunately, current knowledge about the mechanisms of locomotor organ injury is limited. Thus scarcity of epidemiologic data and lack of sufficient knowledge of pathophysiology are serious problems in attempts to design quantititative regulations.

Another concern is the multifactorial nature of musculoskeletal disorders. They are work-related, not occupational, implying that factors at work contribute to the causation of the disorder, but that life-style factors, leisure-time hobbies, and individual characteristics also play a role. The same risk factors can actually operate during both work and leisure time. Attempts have been made to calculate the fraction of the disorders attributable to factors at work, with relatively varying results. Hagberg & Wegman (16) found high etiologic fractions for rotator cuff tendinitis and tension neck syndrome (about 90%) in some highly exposed occupational groups, and, according to an estimate from the Nordic countries, about 30% of all musculoskeletal disorders are attributed to factors at work.

The multifactorial nature of the disorders also implies that several work-related risk factors exist and that action against only one of them is likely to be insufficient. For low-back disorders, the National Institute for Occupational Safety and Health (NIOSH) in the United States identifies quantitatively a number of factors in manual lifting, such as distance from the body, frequency of lifting, height of the lift, its asymmetry, and the like, that influence the risk of injury apart from the weight of the object (17). Similar attempts have been made to calculate quantitative composite risk estimates, indices, for upper-extremity disorders (18, 19). So far, the scientific background of these upper-extremity indices is weak, and much more effort is needed to test their validity. Yet another problem with quantitative risk estimation methods is that they do not include work organizational and psychosocial factors, which are known to influence risk to a high degree (20, 21).

According to the traditional epidemiologic model, exposures are external factors that can imply risk, doses correspond to exposures in the body using measures such as concentration of injurious substances (or, eg, forces), and responses can be, for example, tissue damage, symptoms, or dysfunction. Neither exposures nor doses nor responses have been identified with sufficient accuracy for work-related musculoskeletal disorders. Commonly musculoskeletal exposures are defined generally as posture, repetition, and force exertion over time. In actual fact, it would be sufficient to define only the force and the posture over time (posture should be considered separately from force, as a given force has different consequences depending on the posture); given these parameters any expressions of repetitiveness, mean forces, peak forces, speed of movement, or postural changes can be calculated for the period of time under consideration. The preceding definition of physical exposure can be criticized on the grounds that the exposures are not truly external conditions but are the effects of the person's response to external demands (figure 1). They are really expressions of the person's coping behavior, and several studies have demonstrated the large interindividual variation in behavior among subjects exposed to the same external demands (22, 23).

Thus we have access to a large number of measures that are really steps on the process from exposure to dose and which partly reflect coping (ie, postures, movements, work sequence, and pauses and breaks). Alternatively, exposure measures can be defined by specific tasks (eg, computer work, nursing or cleaning) or by workstation and tool design, standard piece rate, method-time measurements (MTM), and the like. The definition of exposure is important when regulations are discussed — the aim is to change the work design and thereby influence the target tissue dose. Regulations only concerned with intermediate responses are therefore conceptually insufficient. Doses too are insufficiently defined for musculoskeletal disorders. As long as the "target tissue dose", according to the model for environmental disease processes, has not been better understood and defined for musculoskeletal outcomes, the internal processes leading to disease remains a "black box" (figure 1) (24). In the conceptual model by Armstrong et al (25), the dose-response relationship is seen as a cascading series of events in which one response, modified by individual characteristics, becomes a dose for a second response, and so on. A better understanding of these dose-response relationships would facilitate the prediction of outcomes.

Assuming that relevant expressions of exposure, dose, and response can be developed, what is the exposure-response and the dose-response relationship? In occupational hygiene a linear or positively accelerating function is usually found, but in musculoskeletal disorders a U-shaped curve has been suggested (26). The basis is that extreme physical inactivity, as well as physically very strenuous work, has been presumed to be related to increased risk of injury. One common observation is that prolonged sitting, as well as dynamic heavy work with manual handling, both seem to be related to low-back disorders. This observation can alternatively be explained by poor definitions and by a mixture of exposures. Prolonged sitting is frequently combined with both static postures and whole-body vibration. While whole-body vibration is without doubt related to low-back pain, the epidemiologic evidence with regard to static postures is much less convincing (5). Putting prolonged sitting on the left and heavy manual handling on the right of the same horizontal axis in an exposure-response model could thus yield a U-shaped curve. From physiology it is well known that muscles and tendons become stronger and joint cartilage thickens in response to physical training, while the reverse happens in inactivity. This response to inactivity also implies an increased vulnerability in the musculoskeletal organs, so that even moderate work loads can cause injury. This phenomenon should not be interpreted as evidence for a U-shaped curve, but as a shift to the left of a positively accelerating (or linear) relationship between physical activity and risk of injury.

In conclusion, the problems identified constitute reasons to exert great caution when regulations in which exposure is expressed in a quantitative way are being developed.

Critical review of some important regulations

According to Dul et al (27), about 700 published or draft standards relating to ergonomics exist. Thus the majority of them will have to be omitted from this short review. The standards and regulations selected here are those that have, or will probably have, a large impact in worklife and that represent a selection of different approaches in standard setting. Even with this strict limitation the selection is by no means comprehensive; for example, many national standards are not included. A more comprehensive review of available ISO and CEN standards in ergonomics has been given by Dul et al (28).

International standards — ISO

Since 1997, ISO (International Organization for Standardization) has developed about 15 draft or approved standards relevant for the prevention of musculoskeletal disorders. (See lifting and carrying standard in table 1.) ISO is a voluntary organization that develops standards applicable for employers, workers, and designers. The standards are not regulatory unless approved nationally or incorporated in the European Union regulation as an EN-ISO regulation (European Norm-ISO).

International standards — CEN

CEN (Comitté Européen de Normalisation) is a private European organization that develops standards for incorporation into European regulations (as EN standards). Thus the original CEN standards are not legally binding

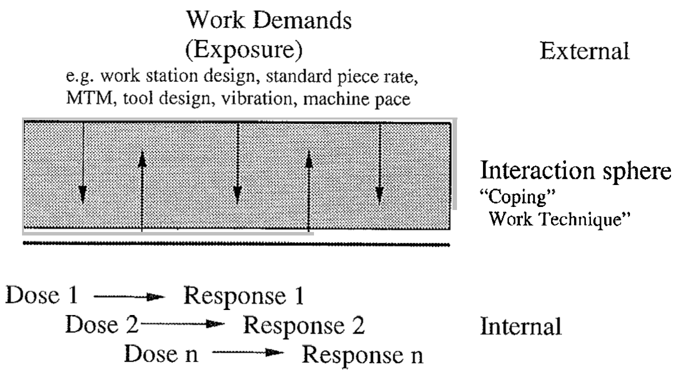

Figure 1. Schematic representation of the exposure- and dose-response relationship emphasizing interaction between the external and internal sphere. (MTM = measurement-time measurements)

Table 1. Examples of ergonomic standards covering aspects of manual materials handling. (NIOSH = National Institute for Occupational Safety and Health, EU = European Union, ISO = International Organization for Standardization)

Standard	Aim	Target group	Status	Quantitative or qualitative	Content
NIOSH equation, lifting	Prevention of back injuries	Occupational health service employer	Guideline	Quantitative	Calculates limits for acceptable lifting by frequency, distance, symmetry, coupling, also assesses variable lifting
EU directive 90/269, manual handling	Health and safety promotion (particularly for low back)	Employer	Minimum requirements (regulatory)	Qualitative	Annex defines risk characteristics of load, physical effort, work environment and activity qualitatively
EU directive 89/392 [Safety of Machinery, part 2 (1005-2)], manual handling	Health & safety	Designers of machinery	Draft (regulatory)	Quantitative (3—25 kg)	Screening of proposed design, detailed risk assessment, redesign, etc (modified NIOSH equation)
ISO/CD 11228-1.2, lifting and carrying	Prevention of musculoskeletal disorders	Employers, workers, designers	Draft (voluntary)	Quantitative (3—25 kg)	Modified NIOSH equation
Australian national standard, manual handling	Prevention of injuries, reduction of severity of injuries	Employer	Regulatory in most states	Qualitative	Risk assessment and control, according to *code of practice*, check-list, semiquantitative lifting limits (maximum for sitting 4.5 kg, for standing 16—55 kg)

until approved by the European Union. Representation in CEN is free (ie, private enterprise, national regulatory organizations, and researchers are welcome), and the final product of CEN is often a compromise between interests from industry and health and safety. The organization of CEN is complex, and Technical Committee 122, Ergonomics, develops standards of relevance for the prevention of musculoskeletal disorders. Each technical committee has several working groups, and within each group a varying number of writing groups develop the specific texts (figure 2). By agreement, ISO and CEN do not develop standards covering similar areas.

E standards

All E (European Union) standards are regulatory and apply to all member countries. The "framework directive" 89/391 was developed based on article 118A in the treaty of Rome and aims at procuring the health and safety

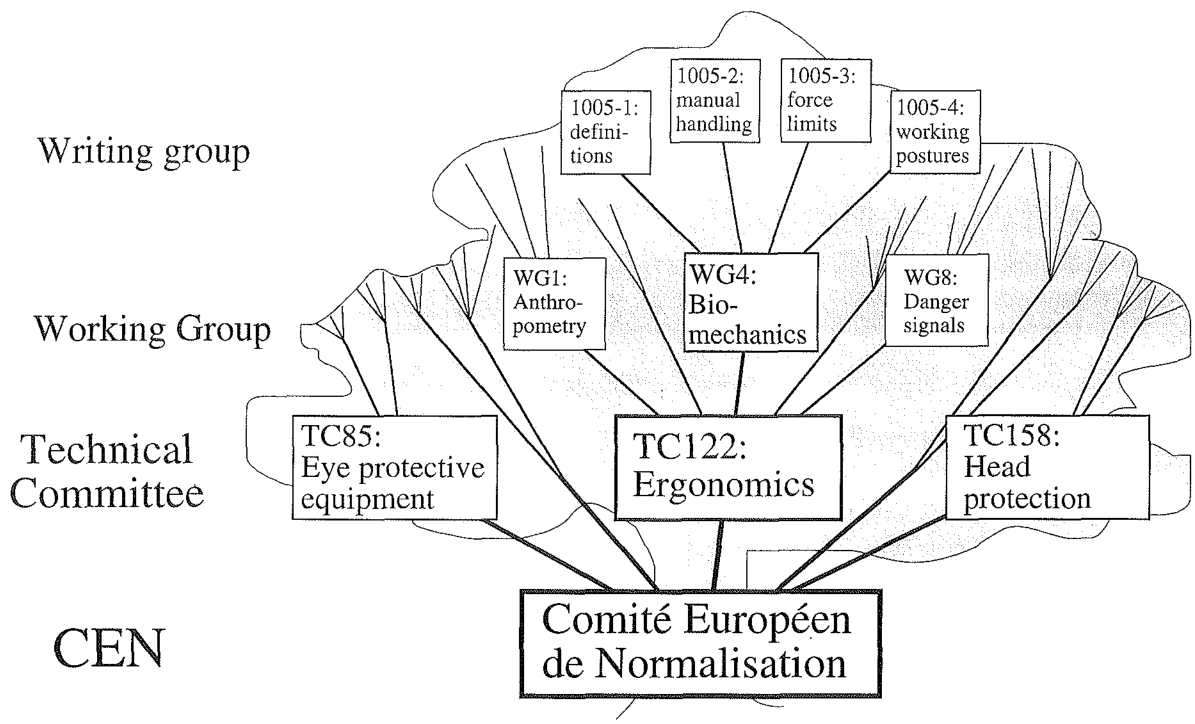

Figure 2. Schematic representation of the CEN "tree" of committees, working groups and writing groups, highlighting ergonomic contents. Origin: Svend Erik Mathiassen.

of workers. It has been further specified in the "Manual Handling of Loads with Particular Risk of Back Injury" (90/269) and "Safety and Health in Work with Display Screen Equipment" (90/270) directives. These directives set minimum standards, and individual member countries can supplement them with stricter requirements. Several countries have further developed the minimum directives, sometimes supplementing them with "advice", "codes of practice", "guidances", and the like, which give more specific support for workplace action.

The "product directives" are legally binding to the letter and must neither be compromised nor sharpened by member states. One of the aims is that ergonomic principles must be taken into account to reduce discomfort, fatigue, and stress, and thereby international competition should not be unfairly compromised by permitting poor work environments. The most important product directive is the "machinery directive" (89/392), which concerns the design of machinery and applies to work performed on or by machinery. It contains 162 EN regulations concerned with safety and health, including issues such as basic concepts, measurement procedures, and limit values. The target group is designers of equipment. Preliminary EN standards (pr-EN) are now under preparation as components of the EU machinery directive, and they apply to manual handling, forces, work postures, and repetitive work (tables 1 and 2). While the minimum directives are predominantly qualitative, the product directives are highly quantitative and partly cover the same musculoskeletal risk factors. Once the ergonomic components of the machinery directive are approved, conflicts between them and the minimum directives can be anticipated. Another foreseeable problem is conflicts arising when certain manual work is permitted outside the reach of the machine but not within, and vice versa. The main concern with the machinery directive is the anticipated very precise regulation of acceptable forces, weights, and durations. It is difficult to distinguish the scientific basis for such detailed regulation.

National standards

Many other countries have developed standards or regulations for the prevention of musculoskeletal disorders. In the United States, the National Safety Council developed a draft standard for protection against cumulative trauma disorders (ANSI Z-365) which has not yet been approved (table 3). While it is completely qualitative in its demands on all those responsible for the design of work and for medical management, the ergonomics protection standard proposed by the Occupational Safety and Health Administration (OSHA) is semiquantitative (table 3). It identifies conditions for further control of work conditions and, if these requirements are met, uses checklists and indices to calculate risk and select avenues for further action (28, 29). Although the proposed OSHA standard has not been approved as a regulation, it has had a large impact on present thoughts and discussions about ergonomic regulation.

In a similar way, the NIOSH-revised lifting equation (17) has had a large impact on currect thinking about manual lifting (table 1). The equation has been developed over about 20 years and is thoroughly supported by epidemiologic, psychophysical, physiological, and biomechanical research. It is probably the best documented recommendation available, but not accepted as a standard. Yet the NIOSH equation does not cover all manual lifting, and the first version of the equation, as well as other recommendations on manual handling, have been criticized for giving rise to unfounded expectations for accuracy in predicting injury (30). Some ISO and prEN standards have adopted the NIOSH equation, albeit with some modifications, so it will probably be implemented at least in Europe.

In the Nordic countries, a collaborative effort has been made by ergonomists of occupational health and safety boards to develop recommendations for the prevention of musculoskeletal disorders (31). Some of their major features imply a step forward in the design of ergonomic recommendations. First, the risk assessment

Table 2. Example of ergonomic standards on repetition, postures, and forces. (EU = European Union)

Standard	Aim	Target group	Status	Quantitative or qualitative	Supplementary content
EU directive 89/392 [Safety of Machinery, part 3 (1005—3)], forces	Health & safety	Designers of machinery	Draft (regulatory)	Quantitative	Determines forces by capacity of target population; multipliers for velocity, frequency, duration; gender and age considered
EU directive 89/392 [Safety of Machinery, part 4 (1005—4)], postures	Health & safety	Designers of machinery	Draft (regulatory)	Quantitative	Postures either acceptable, conditionally acceptable or not recommended; static or movement considered
EU directive 89/392 (Safety of Machinery, part 5), repetition	Health & safety	Designers of machinery	Draft (regulatory)	Quantitative?	?
California regulation, repetition	Prevention of repetitive motion injury	Employer	Regulatory	Semiquantitative, identifies conditions for control	Prevention (program: worksite evaluation, control exposures, training)

Table 3. Some major examples of standards covering multiple ergonomic risk factors. (OSHA = Occupational Safety and Health Administration, ANSI =American National Standardization Institute, CTD = cumulative trauma disorders)

Standard	Aim	Target group	Status	Quantitative or qualitative	Content
OSHA proposed ergonomics protection standard	Prevention of work-related musculoskeletal disorders, reduction of severity	Employer	Draft (regulatory)	Semiquantitative, identifies conditions for control: ±1 episode, presence of signal risk factors	Semiquantitative or qualitative, with time limits (analyze risk, employee training, medical management, "fix the job", evaluation)
ANSI Z-365	Control or work-related cumulative trauma disorders	Management, especially those responsible for health and safety programs, design of jobs, work environments and work procedures	Draft (voluntary)	Qualitative	Management responsibilities, training, employee involvement, surveillance, evaluation and management of CTD cases, job analysis, job design and intervention
Swedish AFS 1998:1	Prevention of musculoskeletal disorders and unnecessary fatigue	Manufacturer, importer, supplier, provider	Regulatory	Qualitative	In general recommendation: models of postures; lifting; repetitive work with 3 levels of acceptability (red, yellow, green); need for job decision latitude included; checklist

is subdivided by 3 levels (green, yellow, and red), the green implying that only 1 or 2, if any, employees are at risk of developing musculoskeletal disorders. When the red level is exceeded, most employees, or all, are at risk, whereas the yellow level indicates that a not insignificant number of employees is exposed to risk. Second, the recommendations also include advice on work organizational issues (job-decision latitude) during monotonous or repetitive work. These recommendations were incorporated as a guidance in the Norwegian ergonomic standard in 1995 (32), and they have been issued as a recommendation in Denmark. In Sweden, the general ergonomics regulation of 1983 was substantially revised in 1998, including a revised and more stringent version of the Nordic recommendations (table 3) (33). The regulation itself is qualitative and extends over most acknowledged risk factors for work-related musculoskeletal disorders. In the supplement 40 pages of general recommendations, including the revised Nordic risk assessment models and a checklist, are included. They have very few quantitative recommendations (eg, on push or pull forces, distance from body in manual handling, and repetitiveness).

Evaluation of regulations

Over the years, much work has been done on developing regulations, guidelines, and codes of practice. As demonstrated by the tables, regulations range from highly quantitative to entirely qualitative. The reason for these large variations is probably the varying weight ascribed to scientific support. Epidemiologic versus experimental studies are valued more or less, and quantitative data are frequently extrapolated far beyond the conditions under which they were obtained. "Common sense" and feasibility are allowed a high or low impact. The general impression, though, is the lack of support for most quantitative regulations with the exception of the revised NIOSH equation. The qualitative regulations too have limitations. They require a relatively high level of knowledge and experience among those who apply them, and they leave the designer without precise recommendations. One alternative might be a mixture of qualitative and quantitative data. This approach too has disadvantages; when the original ILO standard on manual handling is studied, it is striking that the original advice on work and workstation design has been forgotten, while only the maximum permissible weight of 55 kg is remembered (34). Thus quantitative rules have the appearance of accuracy in some areas, while they have to ignore other important risk factors which cannot be quantified.

Adding to the confusion is the almost complete lack of evaluation of existing regulations. Although the "bottom line" of such an evaluation is a reduction in musculoskeletal morbidity, it is questionable whether such an end point needs to be evaluated in the context of regulations. Several authoritative reports indicate clearly that a reduction in the level of the most important risk factors also induces reduced morbidity (6, 8, 35). Thus the most important effect to be evaluated is whether risk factors are influenced by the regulation. Other important aspects to be evaluated refer to the efficiency of the distribution of the regulation and whether increased awareness among employers, occupational health staff, and designers is achieved. The NIOSH lifting equation has been evaluated with regard to its interobserver reliability and validity, both being estimated to be fairly high (36, and Marras et al, unpublished manuscript). However, to the author's knowledge, no evaluation of risk reduction has been performed.

Five years after the "National Standard for Manual Handling" was implemented in Australia, an evaluation was performed (table 1) (37, 38). Among large employers about 90% were aware of the regulation, whereas only 40% of small employers were. In the United Kingdom the "Manual Handling Regulation and Guidance" was evaluated 5 years after its implementation (39), but the results were less encouraging than in Australia, despite the distribution of a large amount of supplementary information. Conclusions in Australia were that too much printed material is distributed from a number of different sources, while instead more effort should be spent on identifying the crucial target. For example, accountants and different regional industry-specific networks may successfully introduce regulations to small enterprises. In the United Kingdom penetration was particularly poor in the service and building industries; however, employers who had implemented the regulation were positive and thought it had reduced accidents and product damage, while also increasing staff morale.

All EU members are required to survey the introduction of EU directives in their respective country, but this has only been done in a limited way. The Trade Union Technical Bureau (TUTB) in Brussels recently published a preliminary assessment of the transition from law to practice of the "Health and Safety of Workers" framework directive, especially with regard to the implementation of directives on display screen equipment and manual handling (40). In essence, they see advantages with the minimum directives; they foster worker participation and multidisciplinary prevention and they permit national differences in culture. On the other hand, both the directives and many European nations are heavily criticized for not implementing the essential features of the directives (eg, developing an infrastructure for surveillance and prevention). In some countries the national interpretation has little resemblance to the directives in being diluted and in many instances heavily compromised.

Role of the researcher

Individual researchers play a role in the development of CEN and national standards. They take on a task that gets little recognition and is often very time consuming and difficult. In many cases they are outvoted by heavy industrial interests. It is unfortunate that research institutions and some international scientific organizations have shown little interest in how scientific results are used (or misused) in a context that will have a heavy impact on future worklife. A few important tasks that should be focused on in the future follow.

Researchers should play a larger role in the development and evaluation of standards and regulations, for example, by

- reviewing scientific literature with a view to standardization; in a recent initiative from the Nordic Council of Ministers available regulations in ergonomics will be reviewed with regard to the soundness of their scientific basis (Chair Nils Fallentin, Danish Institute of Occupational Health),
- studying the entire chain in implementation (ie, distribution, awareness, behavioral change, risk reduction, economic consequences, and, if possible, morbidity),
- attempting to develop semiquantitative or qualitative standards in which work organizational factors can be included.

In research, a better scientific basis for standards and regulations should be sought, for example, by (i) collecting information about exposure parameters (as well as proposed indices) used in standards and regulations in epidemiologic studies and relating these measures to measures of morbidity, (ii) attempting to reach a consensus on exposure, dose, and response concepts, (iii) putting more effort into research on the mechanisms of musculoskeletal disorders, (iv) acquiring a better understanding of the effects of prolonged or accumulated exposure, with a possible view to the use of time limits instead of exposure amplitudes as a basis for standards.

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