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Evaluation of physical workload standards and guidelines from a Nordic perspective

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Summary

In 1997 the Nordic Council of Ministers decided to initiate a project with the aim of evaluating existing physical workload standards from a Nordic perspective as a background for possible future initiatives and needs. The decision reflects Nordic interest in critically validating the rapidly increasing number of European and American standards and guidelines being developed for physical workload.

A working group was appointed consisting of representatives of the Danish, Finnish, Norwegian, and Swedish institutes of occupational health. This report presents the results of the group's considerations and its main conclusions. In general, the project aimed at providing a thorough review of the different standards, a description of their legal status, and a judgment of their scientific and practical value.

Following a brief account of the history of physical workload standards and a theoretical account of the problems involved, 26 standards or guidelines are grouped and reviewed in the following seven categories: (i) general ergonomics standards, (ii) guidelines for manual materials handling, (iii) guidelines for repetition, force, and posture in monotonous, repetitive work, (iv) vibration standards, (v) guidelines for energy consumption, (vi) guidelines for specific industries, and (vii) acute overload guidelines. The standards and guidelines represent a variety of issuing bodies and organizations, for example, the European Committee for Standardization (CEN), the International Organization for Standardization (ISO), the American National Standards Institute (ANSI), the International Ergonomics Association (IEA), the (United States) National Institute for Occupational Safety and Health (NIOSH), and the (United States) Occupational Safety and Health Administration (OSHA).

As a means of promoting a "code of practice" for the evaluation of physical workload standards, a framework of criteria for identifying scientifically "good" and practically efficient standards was established, and the following three key areas were identified in the evaluation procedure: (i) scientific coherency, (ii) effectiveness, and (iii) usability. [Scientific coherency considers the degree to which standards are related to scientific knowledge on the causes of the injuries or diseases in question. The effectiveness of an occupational safety and health standard describes the impact of the standard with regard to the prevention of occupational disease and injury. And the usability criterion evaluates the potential for implementing the standard.]

Prior to the evaluation, the standards were divided into the following two groups according to their level of accuracy: (i) standards presenting quantitative guidelines for specific exposures with precise and numerical acceptance criteria and (ii) process-type standards presenting mainly qualitative guidelines and focusing on a program approach. The two groups were evaluated separately, and the results have been presented in two different sections.

In general the evaluation was the most favorable for process-type standards. The most conspicuous difference between process-type and quantitative-type standards was found for the "scientific coherency" criteria. The quantitative standards involve the dilemma of conflict between the intention of providing numerical acceptance criteria differentiating between hazardous and safe jobs and the paucity of scientifically well-founded data allowing such quantitative risk estimates to be established. To solve this problem as optimally as possible, better designed epidemiologic studies using good exposure and outcome assessment methods are needed.

The report provides some support for the view that regulatory actions against work-related musculoskeletal disorders will be the most successful if an integrated ergonomic program approach is adapted. A substantial number of case studies indicates that ergonomic programs can be efficient in protecting workers against work-related musculoskeletal disorders. The General Accounting Office (GAO) study of several companies with ergonomic programs in the United States gives strong — although indirect — support for the belief that well-managed ergonomic programs with high commitment on the part of stakeholders can be efficient.

In general, however, knowledge or documentation on the effectiveness of legislation or standards in reducing work-related musculoskeletal disorders is limited. The need for the development of the instruments required for a thorough survey and evaluation of the effectiveness of the regulatory actions is thus obvious. In Europe the Trade Unions Technical Bureau for Health and Safety (TUTB) has initiated several projects to monitor the transposition and application of European health-at-work directives, and these attempts should be encouraged.

At the same time, the potential benefits of quantitative guidelines or numerical threshold limit values remain to be proved. Despite remarkable efforts made by a large number of individual researchers and scientists involved in the process of standardization — and some promising elements in, for example, the new Washington State ergonomics rule — too many quantitative guidelines are still inconsistent and have limited scientific credibility.

The unfavorable rating for the majority of quantitative standards should not be interpreted as an argument against giving practical recommendations and quantitative suggestions. It should be recognized that quantitative guidelines identifying jobs at extreme high (or low) risk may be appropriate and useful in some cases. The limited amount of epidemiologic evidence calls, however, for concern when such recommendations are presented as "safe" thresholds capable of eliminating the risk of health impairment to workers.

The report emphasizes that efforts are needed to improve the usability and "user friendliness" of future guidelines and enhance the process of implementation through the involvement of labor market partners. The incorporation of workplace experience in the process of standard making is essential and the organized, systematized feedback of users' experience in the revision of existing standards should be given high priority.

In the Nordic countries, the use of regulatory actions in the prevention of musculoskeletal disorders is based on identical principles with strong adherence to the common European rules on safety and health at work established in the directives of the European Union (EU). The EU framework directive (89/391/EEC) and its individual directives have been implemented in national law in all the Nordic countries with only minor amendments to the minimum requirements set at the European level.

This project found that the combination of adapting the process-oriented EU directives and the use of nonmandatory, mainly qualitative guidelines and provisions constitutes a consistent and sound approach to regulatory action. The nonmandatory guidelines frequently represent a valuable compromise. They have been successful in covering many aspects of risk assessment and have avoided unsupported quantitative recommendations without appearing diluted.

A future challenge to this consistent approach may, however, be the voluntary technical standards that are being developed to give new products a presumption of conformity with the CEN machine directive. A series of draft CEN standards — addressing aspects directly related to musculoskeletal disorders and presenting highly quantitative recommendations — is presently in a stage of public hearing. If adopted, these CEN standards will be national standards in all the Nordic countries. Although the CEN standards are subordinate to national labor market regulation, a potential problem relates to the confusion of having two sets of standards covering the same musculoskeletal risk factors with an entirely different approach and paradigm. Currently this problem has not been recognized in the Nordic countries. The present report recommends that a debate on the pros and cons of introducing such an element of confusion into national work environment policies be initiated and completed before the voting procedure is terminated for the draft standards.

A final aspect in the implementation issue concerns the legislative framework of the European Union. The fact that EU legislation on safety and health at work forms the basis for regulatory actions in all the Nordic countries emphasizes the obligations placed on the Nordic countries to promote initiatives to improve this framework.

There is a need for new regulation at the community level, and also stock should be taken of existing directives, the most pertinent problem in this respect being the need to add to the number of individual directives within the realm of the framework directive. A directive on monotonous and repetitive work to supplement the manual handling directive could be an important and appropriate new initiative. A repetitive work directive would be potentially beneficial for all EU member states and would, at the same time, transfer momentum to preventive efforts in the Nordic countries.

Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ANSI	American National Standards Institute
CEN	European Committee for Standardization
EEC	European Economic Community
EFTA	European Free Trade Association
EU	European Union
IEA	International Ergonomics Association
IEA TG	International Ergonomics Association Technical Group
ILO	International Labour Organization
ISO	International Organization for Standardization
NIOSH	National Institute for Occupational Safety and Health (in the United States)
OSHA	Occupational Safety and Health Administration (in the United States)
US	United States
WHO	World Health Organization

MSD	musculoskeletal disorder(s)
TLV	threshold limit value(s)
VDV	vibration dose value(s)
WMSD	work-related musculoskeletal disorder(s)

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BACKGROUND AND PURPOSE

National and international regulations, legislation, standards, and guidelines addressing ergonomics or physical workload have become a vital and integral part of the efforts to reduce occupational physical workload and musculoskeletal and cardiovascular disorders. An important milestone was the establishment of the Committee on Ergonomics within the International Organization for Standardization (ISO) in 1975 in concordance with a proposal made by the International Ergonomics Association (IEA). The scope of the committee was to promote the adaptation of work conditions to "the anatomical, physiological and psychological characteristics of man" in order to promote safety, health, well-being, and effectiveness.

The relation between mechanical (physical) workplace exposure and the development of work-related musculoskeletal disorders has been known for centuries. In the last 30 years, however, the scientific and public interest in occupational physical workload and work-related musculoskeletal and cardiovascular disorders has increased dramatically. Since the early 1970s more than 6000 scientific papers on ergonomics and physical workload have been published (1). The focus on physical workload reflects the widespread occurrence of this exposure among the general working population. In a large European survey from 1991, 45% of the 130 million workers in the European Union (EU) were exposed to either manual materials handling (lifting, carrying), repetitive movements, or awkward work postures (2).

The commonness of problems related to physical workload is, at the same time, seen in the vast number of notified occupational disorders affecting the musculoskeletal system. According to, for example, the United States (US) Bureau of Labor Statistics (3), 32% of all cases of occupational disorders (N=705 800) are due to overexertion or repetitive movements, and therefore such problems form the single most prominent category of occupational disorders. Thus the prophecies in the 1960s and 1970s of physical load at work becoming obsolete through mechanization and computerization has proved to be incorrect.

The estimated costs of this large number of work-related musculoskeletal disorders are substantial. US figures point to an annual cost to society of USD 13 billion, while the corresponding figures for Denmark are estimated to be DKK 7.5 billion, corresponding to 1% of the Danish gross national product (4, 5).

Motivated by these figures and the obvious consequences for health politics and economics, strong public interest in and demands for preventive efforts were first seen in the Nordic countries and in the United States, but they have, in recent years, spread to the rest of Europe and Asia. Focus on the potential of preventive efforts gained momentum from calculations made by OSHA (the US Occupational Safety and Health Administration) indicating that, even when a conservative estimate is applied, 65% of work-related musculoskeletal disorders should be preventable through "ergonomic intervention" (ie, the removal or reduction of workplace exposure) (6).

The development of standards and guidelines as tools for a preventive effort has thus increased dramatically since the establishment of the ISO technical committee. In the period since 1975, ISO has published approximately 28 ergonomic standards. However, the development has been fast, and the standards today represent only a modest part of the more than 700 standards or draft standards and guidelines on ergonomics currently available to the public (7). The establishment of the European Union led to an "up-regulation" of the European market and has further contributed to this boom in the number of standards and directives related to physical workplace exposure.

The vast number of physical workload standards imposes several problems for intended users. In many cases the application area of the standards and the user population are obscure. The legal status with respect to national or international law may be difficult to apprehend, and often the contents and specific recommendations of different standards are conflicting. In general the diversity of the proposed standards and guidelines reflects a high degree of uncertainty with respect to the risk assessment process for physical workplace exposure. Jayjock et al (8) emphasized that a detailed and practical risk assessment procedure incorporates a process in which workplace exposure is assessed and compared with occupational threshold limits based on dose-response data. A high uncertainty in the risk assessment process is inevitable if poor dose-response data are combined even with fair-to-good exposure estimates (figure 1).

The de facto situation for physical workplace exposures is unfortunate in this context. On a general level, epidemiologic evidence indicates a causal relationship between several physical workplace factors and musculoskeletal disorders (1). On the other hand, poor dose-response data mean that the formulation of quantitative risk estimates — which requires threshold limits based on valid dose-response data — is inflicted with a high degree of uncertainty.

DOSE→ EXPOSURE ↓	POOR dose-response DATA	FAIR dose-response DATA	GOOD dose-response DATA
POOR EXPOSURE ESTIMATE	P / P	F / P	G / P
FAIR EXPOSURE ESTIMATE	P / F	F / F	G / F
GOOD EXPOSURE ESTIMATE	P / G	F / G	G / G

Figure 1. Uncertainty in risk assessment (8). (P = poor quality data, F = fair quality data, G = good quality data, shaded area = high uncertainty)

The dilemma facing the bodies issuing national and international standards is thus a conflict between a public demand for preventive guidelines differentiating between hazardous and safe jobs and a lack of scientifically well founded data allowing the establishment of quantitative risk estimates for the different physical workplace risk factors. In many cases this dilemma is not solved optimally. Too many standards are coincidental, with no explicit account for their factual basis (ie, whether they are based on scientific knowledge or a commonsense approach). As a result the end-users (decision makers, unions or companies) are left with an almost impossible situation when trying to relate to the different proposals.

The aim of our report is to ease this situation by presenting an overview of the "state of the art" for physical workload standards. A brief account of the history of physical workload standards and guidelines and a theoretical account of the problems involved are followed by a descriptive review of selected standards, a comment on their legal status, and a judgment of their scientific and practical value. Finally, recommendations for possible implementation in the Nordic countries are given.

HISTORICAL PERSPECTIVE

Guidelines focusing on occupational physical workload have existed for centuries. The French natural scientist Lavoisier (1743–1794) suggested that the payment of manual work should be adjusted in accordance with the energy requirements of the work to compensate for the extra cost associated with an increased demand for food. It was, however, first at the beginning of the 20th century that the "scientific management tradition" (Taylorism) systematically addressed the question of how to adjust physical workload to the capacity of workers in order to optimize production efficiency.

The focus on a large number of studies in this period, dominated by Taylor and Gilbreth, was to avoid fatigue and the associated reduction in performance or work output. It was frequently observed how efficiency deteriorated during the workday, and the way pauses and a temporal reduction in exposure could help optimize production was discussed. Work physiologists played an integral part in the time and motion studies of this period, and work physiology was seen as a subdiscipline to the rationalization that began in the 1920s (9). The main ambition was to determine individual work capacity and the optimal workload associated with maximal productivity.

This approach has remained a central part of motion-time-measurement (MTM) studies, and "fatigue allowances" (extra time or pauses in order to avoid fatigue) were established as an important part of all industrial time standards. The average physiological fatigue allowance is currently around 5.1% for US industry; this figure is added to the MTM-studied normal time to establish standard times for a job (10). The methods used to determine fatigue allowances are either empirical (common sense) or physiological measures of work demands in relation to individual capacity for, for example, static strength requirements, heart rate (working pulse rate), or energy requirements. The common concept is that a large mismatch between task requirements and individual capacity increases the need for recovery if fatigue has to be avoided and bigger allowances are needed.

Based on the same concept of avoiding fatigue, but emphasizing the consideration to the individual worker rather than production efficiency, some guidelines and standards from, for example, the International Labour Organization (ILO) and the World Health Organization (WHO) were issued on maximal acceptable energy requirements during work at the beginning of the 1950s. The workers' protection aspect was emphasized in statements such as " the main objective … is to make it possible for individuals to accomplish their tasks without undue fatigue so that at the end of the working day, they are left with vigor to enjoy their leisure [p 449]"(11). The threshold limits varied somewhat, but, in general, a relative workload corresponding to approximately 33% of the individual maximal oxygen uptake was suggested as the upper limit for an 8-hour workday (12).

A separate category of standards and guidelines for physical workload is found in the large number of industrial standards or national legislation presenting maximal permissible loads for lifting. They differ from the previously mentioned standards by incorporating biomechanically based health aspects (ie, the obvious risk for tissue injury with overexertion) and thus emphasizing workers' protection. One of the earliest examples of legislative measures was the weight limit established in the British cotton industry in 1926, the maximum lifting

weight for males over 15 years of age being 68.0 kg. In the 1967 ILO convention the maximum allowed weight to be lifted and carried was set at 50.0 kg. The large variety in the suggested threshold limits is however conspicuous and the current national weight limits in Europe — if available — present figures from 30 to 105 kg (13).

The overwhelming majority of standards on physical workload issued in the 20th century focus, however, on the avoidance of fatigue. Not surprisingly the scientific discussion in the 1980s on how to define fatigue influenced the basis of many of these standards. Fatigue was originally defined "as a transient decrease of working capacity resulting from previous physical activity [p 313]" (14) and thus was directly related to industrial performance and work output. In 1984, however, Bigland-Ritchie & Woods (15) suggested that neuromuscular fatigue should be understood as "any reduction in force generating capacity regardless of the force required in any given situation [p 691]".

The practical implication of this discussion with respect to the making of standards was a shift towards a more conservative or cautious approach. The idea was to detect and react to indicators of the decline in force-generating capacity before it actually interfered with performance. In the 1980s and 1990s, a large number of studies focused on, for example, changes in muscle metabolism, extracellular ion concentrations, or electromyographic indications of muscle fatigue during occupational work. A practical example of this approach was the suggested threshold limits introduced for static workload (2–5% of the maximal voluntary contraction for an 8-hour workday) by Jonsson (16). The general aim and concept of these standards was a continuation of the Tayloristic approach (ie, to avoid fatigue and the associated decrease in performance), but the difference was the ambition of and technical ability to base the standards on early signs of fatigue occurring before interference with performance.

In a critical review from 1996, Westgaard & Winkel (17) discussed the historical development of guidelines for occupational musculoskeletal load. The following three main periods or eras of guideline making were suggested to exist: (i) guidelines aiming at increased productivity (performance-based criteria), (ii) guidelines based on reduced fatigue, and (iii) guidelines based on health criteria. While it is debatable whether the performance and fatigue criteria are conceptually different, it is without doubt that the real shift in standard making was marked by the transition from fatigue-based to health-based standards aiming at reducing or eliminating the risk of health impairment to the individual worker.

The problems involved in this shift of paradigms from fatigue or performance to health-based standards and guidelines are substantial. An example can illustrate the complexity of the problems.

The threshold limits suggested for human exposure to vibration were initially based on performance criteria, and a so-called fatigue-decreased proficiency boundary was established. [Anecdotal: the critical vibration level that affected efficiency was based on experiences from bomber flights during World War II. The vibration level that seriously affected the ability of the bombardier to aim at the target was defined as the deficiency boundary.] When exposure limits to promote health and safety were needed, the chosen procedure was to start from the efficiency-related values for the maximal allowable vibration level. The criterion for health was then derived simply by multiplying the critical acceleration levels by 2, on the assumption that the potential risks to human health would be imminent only at higher exposure levels. A contradictory approach was taken when the fatigue-based standards for occupational static muscle load were to be converted into health-based guidelines. It was perceived that, even when exposure levels were below the suggested fatigue-based limit values, musculoskeletal disorders continued to exist, and it was suggested that the recommended exposure levels be reduced even further or that the exposure duration be reduced (18).

Apparently there is no mathematically defined straightforward relationship between the exposure levels associated with an avoidance of fatigue and the exposure levels associated with an increased health risk. For an understanding of the theoretical key prerequisites for making valid health-based standards, it is thus important to discuss the causal chain of events leading from exposure to, for example, musculoskeletal disorders and the general principles for making risk assessments. The relationship between workplace exposure and adverse health aspects is illustrated in figure 2.

The cardinal point in the model is the target tissue dose, which is the direct link to musculoskeletal disorders or other health effects. Attempts to measure different early responses to external exposure (eg, fatigue indicators) and relate them to disorders have failed mainly because of an insufficient knowledge of the

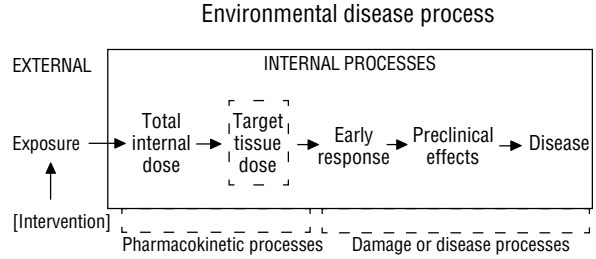

Figure 2. Relationship between the elements of an environmental disease process (19).

pathomechanisms or disease processes involved. Mechanical exposure at the workplace elicits a cascading number of early responses, as emphasized by Armstrong et al (20). Insufficient knowledge of the mechanisms involved implies that there are no criteria available to define whether the responses studied are relevant intermediate variables between an assumed target tissue dose and disease or disorder. In a risk analysis approach this lack of knowledge regarding exposure-dose relationship and dose-response relationship introduces a large element of doubt.

The primary objective of risk assessment is thus to estimate the likelihood and the severity of harm to human health as a result of exposure to a risk agent (21). The procedure used to perform risk analyses consists of the following different (but related) steps: exposure assessment, dose-response assessment, and, finally, risk characterization, in which results of the previous steps are integrated into a risk statement that includes one or more quantitative estimates of risk. In this context dose-response assessment involves determining the target tissue dose (see figure 2) received by the exposed population (exposure-dose relationship) and estimating the relationship between different doses and the magnitude of their adverse health effects. In other words, dose-response assessment is the ultimate step in which the qualitative relationship between an identified workplace hazard and adverse health outcome is transferred to quantitative estimates and in which the characteristics of the exposed population (eg, sensitive subgroups) are taken into consideration.

The insufficient knowledge of mechanisms for disease for most physical workplace factors reflects a limited understanding of the complex relationship between exposure and target tissue dose, as well as a limited understanding of the disease process from early response to disease or disorder. Both factors hamper the validity of any attempt to make a dose-response assessment. In essence, the limited amount of epidemiologic data to support findings from experimental studies means that the establishment of numerical acceptance criteria for, for example, the number of movements per minute, critical force levels, and the like for repetition, force, posture, and vibration involves considerable uncertainty.

To summarize this description of the "state of affairs" for physical workload standards — we are today facing a situation in which the performance-based standards from the Tayloristic period of the 1920s are being replaced by standards prepared in a climate "where the prevailing scientific thinking advocates the role of risk assessment [p 265]" (22). When the limited possibilities for making valid dose-response assessments for physical workplace exposure are taken into consideration, it can be argued that the prerequisites for making appropriate risk assessments is, in fact, not at hand. This situation is essential to relate to when the scientific and practical value of the large number of recent health- and risk-based standards is to be described and evaluated in this document.

INCLUSION CRITERIA

The number of standards, norms, or guidelines referring to ergonomics in general is substantial. A recent database-oriented search revealed more than 700 published and draft standards using the keyword "ergonomics" (7). In order to enhance the practical usability of our document and emphasize its focus on physical workload standards, the following inclusion criteria were used to limit the number of standards or guidelines chosen for a more-detailed review process.

Application area

Standards and guidelines were included if the main area of application specifically concerned physical workload (ie, was confined to physical exposures of the human organism as a result of the performance of work). This criterion rules out the numerous ergonomic standards focusing on, for example, workplace and equipment design, the environment (eg, noise, lighting, temperature), protective devices, or danger signals.

Issuing body

Documents were included if issued by official or semi-official national or international bodies (governmental or nongovernmental) or industries. This criterion rules out individual contributions to the scientific literature and enhances the likelihood that the selected standards, norms, and guidelines could have a potential impact on the regulation of workplace exposure.

Usability

Documents aiming at practical application at the workplace further emphasized the workplace-oriented aspect. Standards, norms, and guidelines that had proved their usability in specific industries or in regulating specific exposures were considered superior to documents with a purely theoretical basis.

TARGET AREA AND SUBDIVISION OF THE STANDARDS

Physical workload standards can be defined or described according to their main preventive aim (musculoskeletal or cardiovascular health) or with respect to the character of the workplace exposure in question (eg, monotonous, repetitive work or manual materials handling).

In this document, selected standards, norms, and guidelines focusing on a varied number of these different and partly intermingled aspects of physical workload have been included. In order to simplify the presentation, we have grouped and reviewed the standards in the following seven entities: (i) general ergonomic standards, (ii) guidelines for manual materials handling, (iii) guidelines for repetition, force, or posture in monotonous, repetitive work, (iv) vibration standards, (v) guidelines for energy consumption, (vi) guidelines for specific industries, and (vii) acute overload standards.

INFORMATION RETRIEVAL

Prior to the application of the inclusion criteria and the final selection of standards, we carried out an intense search using both CD-ROM and online commercial and governmental databases. Our main priority was given to a search conducted in the PERINORM International. PERINORM International is a CD-ROM-based bibliographic database of standards and technical regulations issued by the British Standard Institution. It contains approximately 480 000 records comprising current, historical, full and draft standards, including national European and international standards and American, Australian and Japanese standards.

On the basis of this search, a total of 26 standards, norms, and guidelines was chosen for detailed review. Note that documents from the Nordic countries are not included in the section Presentation of Standards in this document, but are instead reviewed in connection with the discussion on the present status in the Nordic countries (on pages 45—47).

This section contains a description of the chosen standards within the seven entities defined (general ergonomic standards, manual materials handling, repetition, force or posture in repetitive work, vibration, energy consumption, specific industries, and acute overload). The entities are presented in separate sections, each including a short verbal description of the scope and content of the different standards and a table summing up some of the general characteristics.

GENERAL ERGONOMIC STANDARDS

The standards presented in this section fulfilled the inclusion criteria for general ergonomics standards. See table 1 for a summary.

OSHA proposed ergonomics protection standard (OSHA'95)

In 1993 OSHA announced its intention to develop an ergonomic protection standard. Based on epidemiologic studies and literature reviews, a draft version of the standard (preproposal) was ready in 1995 (OSHA'95) (23), and it was put on the Internet for an informal public hearing. The proposed regulatory standard expresses the intent of OSHA to "prevent the occurrence of work-related musculoskeletal disorders such as tendinitis, low back pain and carpal tunnel syndrome, by controlling employee exposure to the workplace risk factors which can cause or aggravate them" and to "reduce the severity of work-related musculoskeletal disorders trough early medical management".

The draft standard sets up several mandatory requirements that apply to all employers with workplaces that meet one of the following two conditions: (i) one (or more) episode(s) of work-related musculoskeletal disorders recorded since the effective date of the standard and (ii) risk factors present on the job for significant periods of time. The signal risk factors whose presence indicates that the job is covered by the draft regulation are described as follows: (i) performance of the same motion pattern every few seconds for 2 hours continuously or for more than a total of 4 hours, (ii) unsupported fixed or awkward work posture for more than 1 hour continuously or for a total of 4 hours, (iii) use of vibrating or impact tools or equipment for more than 1 hour of continuous use or for more than a total of 2 hours, (iv) use of forceful hand exertions for more than a total of 2 hours, and (v) unassisted frequent or forceful manual handling.

If either of the two conditions is fulfilled, the ergonomic protection standard requires the employers to give employees information on work-related musculoskeletal disorders and workplace risk factors. At the same time the employer is obliged to complete OSHA risk-factor checklists or perform an alternative evaluation to examine exposure further and determine whether there are jobs which must be controlled.

The risk-factor checklists are nonmandatory guidelines or suggestions on how to perform the risk analysis that is included in an appendix of the standard. A checklist indicating risk-factor scores based on combinations of semiquantitative exposure levels and durations are available for "upper-extremity risk factors " (including repetition, hand force, awkward postures, contact stress, vibration and the environment), "back and lower-extremity risk factors" (including awkward postures, contact stress, vibration, push or pull, and work pace), and "manual handling" (including lifting distance, weight lifted, and frequency of lifting).

If jobs are categorized as risk jobs following the calculation of risk scores as described by OSHA, employers are required to control the jobs by reducing or preventing employee exposure to workplace risk factors and introduce training and medical management procedures. Nonmandatory guidelines on how to implement control measures are placed in a special annex, and they provide, for example, guidelines for the evaluation of manual handling by describing the factors used in the lifting equation of the National Institute for Occupational Safety and Health (NIOSH), the assumptions, the recommended weight limit, and the lifting index. These appendices are illustrative and detailed and have frequently been used in practical applications.

The main regulatory text of the proposed ergonomic protection draft and the mandatory obligations put on the employers elicited, however, strong opposition in industry towards the standard, and in 1995 the US Congress voted to stop funding any OSHA activity directed towards a regulatory ergonomic standard. OSHA subsequently stepped back from their preproposal and the OSHA "Proposed Ergonomics Protection Standard" (23) is today an unofficial document with no legal status or reference. Interestingly, the state of California recently passed an ergonomic standard on repetitive motion injuries that contains some elements from the regulatory

Table 1. General ergonomic standards. [CEN = European Committee for Standardization, EFTA = European Free Trade Association, EU = European Union, ISO = International Organization for Standardization, NIOSH = National Institute for Occupational Safety and Health (in the United States), OSHA = Occupational Safety and Health Administration (in the United States)]

Standard	Aim	Domain	Type	Legal status	Basis	Level of accuracy	Category	Reference
OSHA proposed ergonomics protection standard (OSHA'95)	Prevention of work-related musculoskeletal disorders	All types of work activities (industry-wide)	Regulatory standard	Unofficial draft	Epidemiologic, biomechanical, physiological, medical	Quantitative or semiquantitative checklists; manual handling section quantitative (adopts the NIOSH lifting guideline)	Health-based	OSHA, 1995 (23) (available on ErgoWeb)
Fitting the job to the worker: an ergonomics program guideline (State of Washington)	Prevention of work-related musculoskeletal disorders	All types of work activities (industry-wide)	Guideline	Voluntary guideline	Not specified	Qualitative	Health-based	State of Washington, Department of Labor, 1994 (24) (available on ErgoWeb)
British Columbia ergonomics requirements	Prevention of musculoskeletal injuries to workers	All workplaces within the inspectional jurisdiction of the Workers Compensation Board (most workplaces in British Columbia except mines and federally chartered workplaces)	Occupational health and safety regulation	Regulatory	Not specified	Qualitative	Health-based	Workers Compensation Board of British Columbia, 1998, (25) (www.worksafebc.com/policy/regs/bcrohs04.asp)
OSHA ergonomics program standard (OSHA'2000)	Prevention of work-related musculoskeletal disorders	General industry (construction, maritime and agricultural industries not covered)	Regulatory standard	Repealed April 2001	Epidemiologic, biomechanic, pathophysiological	Qualitative	Health-based	OSHA, 2000 (26) (www.osha-slc.gov/SLTC/ergonomics/)
Washington State ergonomics rule	Prevention of work-related musculoskeletal disorders (reduction of employee exposure to workplace hazards)	All types of work activities (industry wide)	Regulatory standard	Regulatory	Epidemiologic, experimental	Quantitative	Health-based	Washington State Department of Labor and Industries, 2000 (27) (www.lni.wa.gov/wisha/regs/ergo2000)
CEN prEN 1005-3: recommended force limits for machinery operation	Provision of guidelines (safety requirements) for designers of machinery	Force limits for actions during machine operation (construction, use, disposal)	Draft CEN standard (harmonized European standard)	If passed, implementation as national standard in EU/EFTA countries compulsory (standards subordinate to national labor market regulation)	Ergonomic knowledge	Quantitative	Health-based	CEN, 1996 (30)
CEN prEN 1005-4: evaluation of working postures in relation to machinery	Provision of guidelines (safety requirements) for designers of machinery	Postures and movements during machine operation (construction use, disposal)	Draft CEN standard (harmonized European standard)	If passed, implementation as national standard in EU/EFTA countries compulsory (standards subordinate to national labor market regulation)	Physiological and epidemiologic	Quantitative	Health-based	CEN, 1996 (31)
ISO/CD 11226: ergonomics — evaluation of working postures	Provision of ergonomic information to designers, employers, employees	Work postures; the standard applies to the adult working population	ISO standard (committee draft)	International standard (if passed); no legal implications for labor market regulation	Not specified	Quantitative	Health-based	ISO, 1995 (32)

text in the OSHA'95 proposal. [See "Guidelines for Repetition, Force or Posture in Monotonous, Repetitive Work" on pages 21—25.]

Fitting the job to the worker: an ergonomics program guideline (State of Washington)

The ergonomics program guideline "Fitting the Job to the Worker: an Ergonomics Program Guideline", was published by the Washington State Department of Labor and Industries in 1994 (24). Aimed at employers and managers in large and small businesses, this informative and advisory guideline describes an ergonomic program that can "help to prevent work related musculoskeletal disorders, and manage injuries if they occur". Four key elements for an ergonomics program (ie, worksite analysis, hazard prevention and control, medical management, and training and education) are defined and described.

The worksite analysis section presents methods aimed at identifying musculoskeletal symptoms and their associated risk factors. Examples of calculated incidence and severity rates for jobs in which work-related musculoskeletal disorders occur are presented, and the method is recommended as a means of targeting specific jobs for an "in-depth" worksite analysis. The procedure for the subsequent identification of workplace risk factors constitutes a major part of the guideline. Established generic risk factors (forcefulness, awkward posture, repetitiveness, static load, mechanical contact stress, extreme temperatures, hand-arm vibration, and poorly fitted gloves) are described, and criteria for their evaluation are presented in broad qualitative terms. In addition, several worksite analysis tools are listed (eg, employee interviews, checklists, videotaping, and narrative reviews).

In the hazard prevention and control part, the following three types of control measures aimed at changing the job and eliminating risk factors are presented: (i) engineering controls, (ii) work practice controls, and (iii) personal protective equipment. The emphasis is on engineering controls. A comprehensive list of types and examples of engineering controls, including workstation design, work methods design, tool and equipment design, controls and displays, connectors, and product design, is provided.

The medical management section covers three phases of medical management. Phase 1 deals with injury prevention through risk-factor analyses and symptom surveys, while phase 2 begins when a work-related injury occurs and focuses on early diagnosis and treatment. Phase 3 denotes chronic injury intervention and describes measures to ensure return to work without further complications and to prevent disability.

Training and education recommendations constitute the last section of the ergonomic program guideline. Aimed at giving workers and managers an understanding of the potential risk of injuries — their causes, symptoms, prevention and treatment — training and education is accentuated as a key element of an ergonomics program.

British Columbia ergonomics requirements

Ergonomic requirements were included in the 1998 revision of the Occupational Health and Safety Regulation of British Columbia, Canada. In sections 4.46 to 4.53 (25) of the new regulation several ergonomic requirements are outlined with the specific aim to eliminate or, if impractical, "minimize the risk of musculoskeletal injury to workers".

To comply with the requirements, employers are obliged to consult with the occupational health and safety committee (or workers' representatives) in order to identify, assess, and control risks of musculoskeletal injury to workers; educate and train workers; and evaluate the effectiveness of the process.

In general, a performance-based approach has been adapted. Functional demands are given for the different steps in the process, but the choice of methods is left to the employers, and no specific criteria are given for the identification of hazards or risk to workers.

The requirements oblige the employer to identify factors in the workplace that may expose workers to a risk of musculoskeletal injury and assess the level of risk these factors pose to the worker. The following general risk factors are specified and should be considered: (i) physical demands of work activities, including force required, repetition, duration, work postures, and local contact stresses, (ii) aspects of the layout and condition of the workplace or workstation, including work reaches, work heights, seating, and floor surfaces, (iii) characteristics of objects handled, including size, shape, load condition, weight distribution, container, tool, and equipment handles, (iv) environmental conditions, including cold temperature, and (v) organizational conditions, including work-recovery cycles, task variability, and work rate.

In the control phase employers are required to implement engineering or administrative risk controls that eliminate or minimize the risk of musculoskeletal injury to the degree feasible.

Personal protective equipment can be used as a risk control, but only in circumstances in which engineering or administrative controls are not practical.

Education and training obligations require employers to provide information to exposed workers on workplace hazards and risk identification, including the

recognition of early signs and symptoms of musculoskeletal injuries. If specific measures to control musculoskeletal injuries are adopted — for example, work procedures, mechanical aids, and personal protective equipment — training in the use of these measures is compulsory.

A mandatory evaluation procedure completes the ergonomic sections. Employers are obliged to review at least annually the effectiveness of measures taken to comply with the requirements and correct identified deficiencies.

OSHA ergonomics program standard (OSHA'2000)

In November of 1999, OSHA proposed a new standard to reduce work-related musculoskeletal disorders in the workplace. The proposed ergonomic standard was publicized in The *Federal Register* approximately 4 years after the US Congress forced OSHA to withdraw their original proposed ergonomic protection standard. The new version represented a major shift in OSHA paradigms and an approach to standard setting that was characterized by a strong commitment to a program approach and dissociation from specific or numerical criteria in the characterization of workplace hazards.

After a period of public hearing and comments, the proposal was thoroughly revised, and a final ergonomic program standard was issued on 14 November 2000 (26). The final standard (OSHA'2000) significantly modified the program approach in the proposal, and the balance between performance and specification was tipped towards a higher degree of specificity.

The ergonomics program standard became law on 16 January 2001. Only a couple of months later, however, Congress again interfered, and a resolution expressing disapproval of the standard was passed. The standard was repealed and officially removed from the Code of Federal Regulations on 23 April 2001.

The purpose of this now historical ergonomics program standard is to reduce the number and severity of musculoskeletal disorders (MSD) caused by occupational exposure to ergonomic risk factors. The standard is limited to general industry (agricultural, construction, and maritime activities being specifically excluded), and the main requirements apply only to jobs meeting the following two conditions: (i) a case of work-related MSD or signs or symptoms are reported and (ii) the job in question implies exposure to ergonomic risk factors of sufficient magnitude, duration, or intensity to warrant further examination. The criteria for this decision are given in a basic screening tool containing specific definitions of risk factors that can lead to an MSD hazard. The critical exposure levels and duration are consistent with those of the approach used to define caution zone jobs in the Washington State ergonomics rule (see next section), and the covered risk factors are repetition, force, awkward postures, contact stress, and vibration (eg, working with the back bent more than 30 degrees for more than a total of 2 hours a day.)

If this "two-stage action trigger" is met, employers are required to set up an ergonomics program for that job (and other jobs involving the same physical work activities) with the following elements: management leadership and employee participation, hazard identification and information, job hazard analysis and control, training, medical management, and program evaluation.

Some specific criteria for identifying possible job hazards and evaluating control measures are provided in the standard, but alternative methods that are "reasonable and appropriate for the risk factor present" may be used. Employers can demonstrate compliance with the hazard analysis requirements in the standard by using one or more of the following hazard identification tools listed in a mandatory appendix: the job strain index, the NIOSH lifting equation, threshold limit values (TLV) for physical agents of the American Conference of Governmental Industrial Hygienists (ACGIH), the rapid entire body assessment (REBA), the rapid upper-limb assessment (RULA), appendix B to the Washington state ergonomics rule, the Snook push/pull hazard table, and the OSHA checklist for workstations with video display terminals.

In the final control of identified hazards related to musculoskeletal disorders, the standard sets three optional control end points, indicating that employers are in compliance when (i) MSD hazards are controlled to the extent that they are no longer likely to cause musculoskeletal disorders (eg, when ergonomic risk factors are reduced below the levels set in the basic screening tool), (ii) MSD hazards are reduced below the critical levels indicated in the hazard identification tools used to conduct the job hazard analysis, (iii) MSD hazards are reduced to the extent feasible.

An important and prominent feature of the standard is the use of one work-related MSD incident as the initial trigger. This practice reflects the intent of OSHA to focus on jobs in which problems are severe and, at the same time, minimize compliance requirements for employers. "A quick fix" alternative to setting up a full ergonomics program has further been added to the standard to increase flexibility for employers that have experienced few isolated cases of MSD. If the employer can remove the hazard and fix the one job that has caused an injury in 90 days, no further actions are needed. In addition, some special provisions have been included for small businesses (eg, the exemption of employers with 10 or fewer employees from recordkeeping requirements).

Washington State ergonomics rule

Adopted in May 2000 almost simultaneously with the public hearing on the OSHA ergonomics program standard, the Washington State ergonomics rule represents a different approach to standard setting (27). In contrast to the injury-based (incident triggered) OSHA standard, the Washington State rule is primarily a hazard-based standard. Its aim is to reduce employee exposure to workplace hazards that can cause or aggravate work-related musculoskeletal disorders (WMSD). Interestingly, the Washington State ergonomics rule seems to be a development and refinement of the version of the ergonomic standard proposed by OSHA in 1995 (OSHA'95) with strong concordance with respect to paradigms and approaches.

The ergonomics rule presents a two-step approach for the identification and control of workplace hazards. In the first step "caution zone jobs" are identified. The identification of a caution zone job is essential to the rule because employers in any industry that has a caution zone job are covered by the rule. A caution zone job involves exposure to one of the following physical risk factors: awkward postures, high hand forces, highly repetitive motions, repeated impact, heavy frequent or awkward lifting and moderate-to-high levels of vibration. The risk factors correspond roughly to the "signal risk factors" in OSHA'95, but the critical exposure levels defining a caution zone job are quantified in greater detail [eg, working with the neck or back bent more than 30 degrees, without support and without the ability to vary posture, for more than a total of 2 hours per workday or lifting objects weighing more than 75 pounds (34 kg) once per workday].

In the second step, requirements for employers responsible for a caution zone job are specified with respect to the following elements: (i) awareness education (employees working in a caution zone job must receive ergonomics awareness education), (ii) job analysis (a job hazard analysis must be performed in order to identify caution zone jobs with WMSD hazards), and (iii) hazard reduction (if hazards exist, employers are obliged to reduce them).

In the process of analyzing and reducing the risk of work-related musculoskeletal disorders, employers can choose between a "general performance approach" and a "specific performance approach". The specific performance approach includes detailed and specific quantitative criteria for the identification of hazards, while the general performance approach allows employers to choose alternative methods for hazard identification provided they "are as effective as widely accepted nationally recognized criteria".

The criteria included in the specification-based approach are presented in an appendix that constitutes a major part of the rule. Some sheets are included that provide graphic illustrations and present the criteria for assessing WMSD hazards for the main physical risk factors (the same factors used in the caution zone job identification). The criteria take into consideration the duration of exposure and the combination of risk factors. For example, pinching an unsupported object weighing more than 2 pounds (0.9 kg) per hand is considered a WMSD hazard per se if performed more than a total of 4 hours per workday. Pinching in combination with highly repetitive motions, however, reduces the critical duration to a total of 3 hours per workday.

In general, the criteria used in the specification-based approach sharpen the criteria used to define caution zone jobs. Working with the back bent more than 30 degrees (without support and without the ability to vary posture) constitutes, for instance, a caution zone job if performed for more than a total of 2 hours per workday. To be considered a WMSD hazard, the 30-degree bent position has to be performed more than 4 hours or, if the duration is kept at 2 hours, the forward bent position has to be more than 45 degrees.

In the final correction of identified hazards, employers must reduce the hazards to a degree that is below the level mentioned in the criteria established in the specific performance approach or "to the degree technologically or economically feasible". The latter statement is included to recognize "that there may be circumstances where controls for WMSD hazards may not yet be feasible".

CEN prEN 1005-3: recommended force limits for machinery operation

The standards of the European Committee for Stardardization (CEN) that are related to the machine directive [1] of the European Union can be divided into the following three types: (i) type A standards, which cov-

1 The EU machine directive aims at providing basic essential safety requirements for the design of machines within the common European market allowing products of an agreed standard to circulate freely within the European Union. The machine directive is currently being implemented by a framework of harmonized European standards (CEN standards) in accordance with 110a of the treaty of Rome. [The term "harmonized" implies that the standards are automatically — when passed — transposed into national standards in the membership countries. The obligation to transpose CEN standards to national standards should however not be confused with their legal status. The use of standards remains voluntary, and, in cases of conflict between standards and legal requirements, the latter will always prevail.]

er fundamental aspects for all machinery, (ii) type B standards, which deal with safety and health aspects for a range of machinery, and (iii) type C standards, which cover a specific type of machine. An important section of type B standards deals with human physical performance (EN 1005 parts 1–4) (28–31), and prEN 1005-3 (30) "Recommended Force Limits for Machinery Operation" constitutes the third part of this section. [Part 1 (28) contains terms and definitions, while parts 2 (29) and 4 (31) deal with manual handling and work postures, respectively. Detailed descriptions of parts 2 and 4 can be found on pages 19–20 and 15–16, respectively, in this section.]

In contrast to other international standards, CEN standards issued in relation to the machine directive do not focus on employers or employees but, instead, address designers or manufacturers of machinery.

prEN 1005-3 (the prefix "pr" denotes that it is a draft standard) provides guidance for designers of machinery in controlling health risks due to machine-related muscular force exertion. Recommended force limits for actions during machine operation are specified and presented within the framework of a risk-assessment procedure based on the force-generating capacity of the intended users. The focus on the intended users is closely related to the standard objective of providing guidance to designers. Besides the general working population, potential machine users include very young and very old people when machinery for domestic applications is in question.

The risk assessment is structured into a three-step approach. In the first step, maximal isometric force-generating capacity is determined for the actions in question taking into account the characteristics of the specified target population. Maximal force values for domestic or professional use can be obtained from a table presenting precalculated isometric force capacity values for common actions [eg, hand work (one-hand power grip), arm work (sitting posture), whole-body work (pushing and pulling)]. Alternatively — if the target population can be more precisely defined and information on the distribution parameters of the maximal isometric force in the population is available — the 15th force percentile can be used as the basic force limit.

The second step reduces the basic force limit according to specific characteristics of force exertion (velocity, frequency, and duration of action) by introducing a set of multipliers. The velocity multiplier (0.8) reduces the basic isometric force if movement is required, while the frequency multiplier (values between 0.2 and 1.0) adjusts for fatigue effects on force-generating capacity with consideration for frequency of actions and their individual duration. Finally, the duration multiplier adjusts for cumulated fatigue effects and reduces force-generating capacity in proportion to the total number of workhours in similar actions (multipliers of 0.8 and 0.5 for 1–2 and 2–8 hours, respectively).

In the third step, the reduced force-generating capacity obtained in step 2 is further reduced with the tolerability and health risk taken into account. Three separate multipliers are introduced, each defining a different risk zone. Multiplying the reduced force limit from the second step by a value of 0.5 (a 50% reduction) defines a recommended force level for machinery use for which the risk of disease and injury is negligible. A risk multiplier between 0.5 and 0.7 defines a "not recommended zone", in which the risk of injury or disease cannot be neglected, while risk multipliers greater than 0.7 define unacceptable force levels involving obvious risk.

The preface of the standard indicates adherence to available scientific evidence concerning the physiology and epidemiology of manual work and emphasizes that the risk assessment approach used is based on the assumption that reducing fatigue during work is effective in reducing musculoskeletal disorders. It is, however, recognized that "the knowledge is scarce and the suggested limits subject to changes according to future research".

CEN prEN 1005-4: evaluation of working postures in relation to machinery

The fourth part (31) of the CEN standard (EN 1005) on human physical performance, issued in relation to the EU machine directive, concerns work postures in relation to machinery. [For the general characteristics of the CEN standards, see the description given at the beginning of the preceding section.]

The draft version prEN 1005-4 (31) presents guidance to the designers of machinery in assessing and controlling health risks associated with work-related postures and movements. The standard specifies recommendations for postures and movements with minimal external force requirements and is intended to reduce the risks for nearly all healthy adults. [In contrast to the other parts of EN 1005, no attempts are made to differentiate between different groups of intended users.]

A detailed risk assessment procedure for determining the acceptability of postures and movements constitutes the main part of the standard.

The risk assessment approach is based on a U-shaped model that proposes an increased health risk when the task exposure approaches either end of the curve (ie, if there is little or no movement, denoted "static posture", or if movement frequencies are high, >2/minute).

In three parts representing the trunk, upper arm, and head-neck regions of the body, the standard presents combinations of static postures and two levels of movement frequency (high ~ >2/min or low ~ <2/min).

Static work postures are categorized according to the procedure proposed in ISO/CD 11226 (32), in which different body regions are divided into intervals (eg, trunk flexion 0–20 degrees, 20–60 degrees, and >60 degrees).

For each postural interval, and each combination of posture and movement, a level of acceptance is given according to the following three categories: acceptable, conditionally acceptable, and not recommended. In general, small deviations from neutral postures (eg, 0–20 degrees) are characterized as acceptable regardless of the movement frequency, while moderate deviations (eg, 20–60 degrees) or marked deviations (eg, <60 degrees) are characterized as conditionally acceptable or not recommended. [The term conditionally acceptable indicates that health risk is acceptable if certain conditions are fulfilled (eg, moderately or markedly deviated static postures with trunk or arm support or moderately or markedly deviated postures in combination with a low frequency of movement and limited exposure time)].

ISO/CD 11226 : ergonomics — evaluation of working postures

ISO/CD 11226 is a draft for an international standard (32) (published in 1995) that contains an approach to determine the acceptability of work postures. Aimed at designers, employers, employees, and others involved in work, job, and product design, it specifies recommended limits for work postures with minimal force exertion and provides guidance for the assessment of health risks. The voluntary standard applies to the adult working population, with the purpose of providing "reasonable protection for nearly all healthy adults".

A two-step approach is used to determine the acceptability of work postures. The first step evaluates specific body segment or joint angles and classifies the results as "acceptable", "go to step 2", or "not recommended". [The criteria for classification are mainly based upon the risk of overloading passive body structures.] If a "step 2" approach is initiated, the duration of the work posture is taken into consideration (based upon endurance data) before a final judgment is made.

For step 1, evaluation tables are presented for trunk postures, head postures, shoulder and upper-arm postures, forearm and hand postures, and lower-extremity postures. In general, minor deviations from neutral positions (eg, trunk flexion 0–20 degrees, head inclination 0–25 degrees, upper-arm elevation 0–20 degrees) are considered acceptable. Moderate deviations (eg, trunk flexion 20–60 degrees, head inclination 25–85 degrees, upper-arm elevation 20–60 degrees) are classified as either acceptable — if full support of the body segment is present — or labeled as "go to step 2". Extreme deviations from neutral (eg, trunk flexion >60 degrees, head inclination >85 degrees, upper-arm elevation >60 degrees) are always evaluated as "not recommended".

The step 2 procedure requires the use of plots made to indicate the relationship between body position (eg, degrees of trunk flexion) and the maximum acceptable holding time (in minutes). Figures are available for all body segments, and, for assessments of moderate deviations from neutral joint positions, the actual holding time at the workplace is compared with the maximum acceptable holding time for the specific joint angle in question. The maximum acceptable holding time is used as a cut point, and only observed holding times below this value are classified as acceptable.

This ISO committee draft concludes with two informative annexes that provide information on methods to determine work postures and present examples of models for evaluating holding time — recovery time regimes. The latter is included to support a general recommendation in the standard advocating that adequate recovery times should be available also for holding times below the maximum acceptable limit.

GUIDELINES FOR MANUAL MATERIALS HANDLING

The standards presented in this section fulfilled the inclusion criteria for manual materials handling. See table 2 for a summary.

Guidelines based on the NIOSH lifting equation

A substantial number of guidelines addressing the manual lifting of loads is based on concepts originally proposed in the NIOSH lifting equation [published in 1981 and later revised in 1993 (33)]. The NIOSH model incorporates the following two primary components: (i) the computing of a recommended weight limit for a specific lifting job on the basis of a mathematical expression in which the maximum recommended weight for lifting under optimal conditions is reduced by a number of coefficients to compensate for the characteristics of the lifting task that differ from optimal conditions (the lifting equation) and (ii) the calculation of a lifting index, the ratio of the weight lifted over the recommended weight limit, used as a single number estimate to identify potentially hazardous lifting jobs.

The revised NIOSH equation and the ISO, CEN, and IEA guidelines grouped and presented in this section all adhere to this general model. The similarities are striking, and significant differences relate primarily to the establishment of a maximum recommended weight for lifting under optimal conditions (the load constant). This load constant represents a fixed value in the NIOSH equation, based on the strength and biomechanical limits for

Table 2. Guidelines for manual materials handling. [CEN = European Committee for Standardization, EEC = European Economic Community, EFTA = European Free Trade Association, EU = European Union, IEA = International Ergonomics Association, IEA TG = International Ergonomics Association Technical Group, ISO = International Organization for Standardization, NIOSH = National Institute for Occupational Safety and Health (in the United States)]

Standard	Aim	Domain	Type	Legal status	Basis	Level of accuracy	Category	Reference
Revised NIOSH equation for the design and evaluation of manual lifting tasks	Prevention of lifting-related low-back pain and disorders	Manual handling jobs	Guideline	Voluntary guideline	Biomechanical, physiological, psychophysical	Quantitative	Health-based	Waters et al, 1993 (33)
ISO/CD 1122-8: ergonomics – manual handling – part 1: lifting and carrying	Provision of ergonomic recommendations for manual handling tasks for designers, employers, employees	Manual handling activities; applies to the working and domestic population	ISO standard (committee draft)	International standard (if passed); no legal implications for labor market regulation	Epidemiologic, biomechanical, physiological, psychophysical	Quantitative	Health-based	ISO, 1995 (35)
CEN prEN 1005-2: manual handling of machinery and component parts of machinery	Provision of guidelines (safety requirements) for designers of machinery involving manual handling	Manual handling of objects in relation to machine operation (construction, use, disposal) Professional and domestic applications	Draft CEN standard (harmonized European standard)	If passed, implementation as national standard in EU/EFTA countries compulsory (standards subordinate to national labor market regulation)	Ergonomic design principles	Quantitative	Health-based	CEN, 1996 (29)
IEA TG manual material handling: methods of risk exposure assessment	Assessment of risk related to manual materials handling	Manual handling activities	Proposed IEA guideline	Voluntary guideline	The "NIOSH method"	Quantitative	Health-based	Colombini et al, 1996 (36)
EU council directive 90/269/EEC: minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back Injury to workers	Provision of health and safety requirements for the manual handling of loads with emphasis on employers' obligations	Handling of loads where there is a risk, particularly of back injury to workers	Directive	Minimum requirements regulatory	Not specified	Qualitative	Health-based	EEC, 1996 (37) (http://europa.eu.int/eur-lex)

the 75th percentile for females, but it may vary in the other guidelines depending on the characteristics of the intended user population. Additional differences mainly concern the interpretation of the lifting index or the use of slightly different, but comparable estimates of the risk prediction component of the lifting equation.

Revised NIOSH equation for the design and evaluation of manual lifting tasks

In 1993 NIOSH published the revised NIOSH lifting equation, a mathematical equation for determining the amount of weight that can be safely lifted by nearly any worker for a specific manual lifting task (33). Although advisory in nature, the guidelines are generally adhered to by industries in the United States (34).

The NIOSH lifting equation incorporates three criteria (biomechanical, physiological, and psychophysical) in order to determine a recommended weight limit for a specific task. Several criteria were used to develop the equation on the basis of the assumption that each lifting task imposes different types of requirements on the worker. The biomechanical criterion aims at limiting the effect of lumbosacral stress in infrequent lifting and defines a compressive force of 3.4 kN in the joint between the L5 and S1 vertebral segments as the level that defines an increased risk of low-back injury. The physiological criterion sets energy expenditure limits to

avoid metabolic stress and fatigue in repetitive lifting tasks and adopts a number of task-dependent energy expenditure limits based on a maximum aerobic lifting capacity of 9.5 kcal/minute. The psychophysical criterion limits the workload to an "acceptable" limit based on the workers' perceptions of their lifting capability.

Based on these criteria, the recommended weight limit (RWL) (ie, a load value that nearly all healthy workers can perform over a substantial period of time, eg, up to 8 hours, without an increased risk of developing lifting-related low-back pain) is defined in the equation as follows:

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM.$$

The equation includes two primary components, the load constant (LC) and the multipliers [the horizontal multiplier (HM), the vertical multiplier (VM), the distance multiplier (DM), the asymmetric multiplier (AM), the frequency multiplier (FM), and the coupling multiplier (CM)]. The load constant refers to the maximum recommended weight for lifting at a standard lifting location under optimal conditions. The load represents a fixed value of 23 kg and defines — with reference to the biomechanical and psychophysical criteria — a load, which, under ideal conditions, would be acceptable to 75% of female workers and about 90% of male workers and for which the disc compression would be less than 3.4 kN. The multipliers consist of six coefficients (≤1) used to reduce the load constant to compensate for the characteristics of the lifting task that differ from the standard or optimal conditions (ie, the geometry of the lift and the frequency and duration of the activity). [HM reduces the load constant with increasing horizontal distance of the load from the spine, VM reduces the load for lifts originating at floor or shoulder level, DM reduces the load constant when the total distance moved is >25 cm, AM compensates for asymmetric lifting (ie, lifting loads away from the saggital plane), FM reduces the load constant with increased frequency of lifting or work duration, CM finally reduces the load constant for lifting loads with less than optimal hand couplings.]

The NIOSH lifting equation was originally intended to be used as a job design or redesign tool capable of identifying the features of a lifting task that contributed the most to the hazard of low-back injuries. The equation has, however, gained widespread attention as a tool for estimating the risk of lifting-related low-back problems. In the revised lifting equation a lifting index is included as a single number estimate to identify potentially hazardous lifting jobs. The index is calculated as the ratio of the load lifted to the recommended weight limit, and an increased risk for lifting-related low-back pain for some fraction of the workforce is expected in lifting tasks with a lifting index of >1.

ISO CD 11228: ergonomics — manual handling — part 1 — lifting and carrying

The ISO committee draft on manual handling in lifting and carrying (ISO/CD 11228-1) was published in 1995 (35). [Draft versions of part 2 and 3 concerning pushing and pulling and repetitive handling at high frequency are under preparation.]

ISO standards are advisory standards, and part 1 of this manual handling standard targets designers, employers, employees, and others involved in work, job, and product design. The standard provides recommended limits for manual lifting by taking into account the intensity, frequency, and duration of the manual handling task and, therefore, allows the health risk for the working population to be evaluated. The recommended limits are based on the integration of data derived from four major research approaches, namely, the epidemiologic, the biomechanical, the physiological, and the psychophysical, and they apply to the adult working population. They provide "reasonable protection" for nearly all healthy men and two-thirds of healthy women.

The standard addresses all manual handling situations in which a load in excess of 3 kg is being lifted with the lifter in a standing position, but it does not include the holding of objects, pushing or pulling, lifting with one hand, or lifting by two or more people.

The ISO standard is similar in concept to the NIOSH equation, but it includes several modifications. In practical terms, the standard provides a step-by-step approach to estimate the health risk of lifting and carrying, each step presenting an increased level of complexity.

At the simplest level (level 1) the definition of an acceptable manual lifting task is the nonrepetitive lifting of a load with a mass of less than 25 kg under ideal (or optimal) circumstances. This mass constant corresponds to the load constant in the NIOSH equation, but it exceeds the NIOSH constant by 2 kg. Furthermore it is indicated in the ISO draft that this mass constant can be changed depending on the field of application and the intended user population. [Recommended mass constants are included in an annex to the draft and values of, for example, 15 kg — for the general working population including the young and the old — are given.] The next level of risk assessment reduces the recommended weight limits taking into account the frequency of lifting but still requiring ideal lifting conditions and a total duration of the lifting activity of less than 1 hour per day. The third level involves seven factors being considered and utilizes an equation to determine a recommended acceptable load level when the lifting conditions are not optimal. This approach and the equation used are identical to the revised NIOSH lifting equation. Finally the NIOSH approach is supplemented by recommended limits for the cumulative mass of manual

lifting or carrying (related to distance.) A cumulative mass is defined as acceptable if less than 10 000 kg per day is handled provided the carrying distance is between 1 and 10 meters and ideal conditions prevail. Under less than ideal circumstances, this recommended figure should be substantially reduced (at least by one-third).

The ISO committee draft concludes with several informative annexes providing recommendations for, for example, the avoidance of manual handling tasks, the design of the work (task, workplace and work organization), and the design of the handling of live objects.

CEN prEN 1005-2: manual handling of machinery and component parts of machinery

The draft version prEN 1005-2 (29) "Manual Handling of Machinery and Component Parts of Machinery", the second part of CEN standard EN 1005 "Human Physical Performance", issued in relation to the EU machine directive, specifies ergonomic recommendations for designers of machinery involving manual handling. [For the general characteristics of the CEN standards, see the beginning of the section on recommended force limits for machinery operation on pages 14—15.] Data are provided for handling loads in excess of 3 kg (without technical aids), and the standard describes a procedure to assess health risks in potentially hazardous manual handling activities. This part of EN 1005 does not include the holding of objects, pushing, or pulling, hand-held machines, or handling while seated. The design-oriented aspect of the draft is reflected in the fact that the standard does not aim at a "general working population" but, instead, requires the definition of an "intended user population" (implying that the target population could be either elderly people or children — domestic use — or a highly trained group of young male workers).

The presented risk assessment model consists of three methods, each based on the same primary elements, but different with respect to complexity, ease of use and precision. Method 1 is a quick screening instrument based on checklists. Method 2 includes some additional risk factors and relies on tables to calculate a recommended mass limit. And method 3 requires the use of a lifting equation and includes risk factors not present in the first two methods. The recommended approach is to begin the risk assessment with the simple screening method and proceed to the more advanced methods only if the risk level identified in the first method is not acceptable.

In practical terms the three methods adopt the following primary elements or methodological steps to be carried out: (i) establishment of the mass constant in relation to the intended user population, (ii) actual risk assessment using checklists, tables or formulas, and (iii) decision on the kind of action required (eg, no action, redesign, or use of a more complex risk assessment).

The first common step for all the methods — establishment of a mass constant taking into account the intended user population — represents an important modification of the NIOSH fixed-load constant, and the proposed constants are presented in table 3.

Based on the use of an appropriate mass constant, the checklist approach in method 1 includes assumptions to be met if the risk level is to be considered acceptable. The assumptions refer to different aspects of the handling situation, namely, the environment (eg, moderate thermal environment, handling by one person only, etc), the critical mass (eg, actual load not exceeding 70% of the recommended mass constant, load kept close to the body, etc), the critical vertical displacement (reduction in load demanded if vertical displacement required), and, finally, the critical frequency (indicating the required reduction of load if the frequency of lifting is increased).

In method 2, risk assessment is performed through an extensive use of tables. The index for the recommended mass limit (RMLI) is determined by framing the target population and defining the mass constant before

Table 3. Recommended mass constants taking into consideration the intended user population. [Reprinted from reference 29]

	Mass constant kg	F & M %	F %	M %	Intended user population	
Domestic use	5				Children and older population	Total population
	10	99	99	99	General domestic population	
Professional use	15	95	90	99	General working population including older and younger	General working population
	25	85	70	90	Adult working population	
	30 35 40	Data not available			Specialized working population	Specialized working population under special circumstances

F: Female
M: Male

the assigned values from the tables are inserted to complete the formula, as follows:

$$RMLI = MC \times VM \times DM \times HM \times AM \times CM \times FM,$$

where MC is the mass constant, VM is the vertical multiplier, DM is the distance multiplier, HM is the horizontal multiplier, AM is the asymmetric multiplier, CM is the coupling multiplier, and FM is the frequency multiplier. [Note that the formula and the table base approach represent a simplified version of the revised NIOSH lifting equation.]

The recommended mass limit (RMLI) is then used to calculate a risk index (RI) — equivalent to the NIOSH lifting index — as follows:

$$RI = \text{actual mass (kg)} / RMLI \text{ (kg)}.$$

To select the appropriate action, a rather detailed interpretation of the index is provided; it indicates that RI values of ≤0.85 denote an acceptable risk level. RI values between 0.85 and 1.0 require additional risk assessment by method 3 or redesign of the machinery or assurance by an ergonomics expert that the current risk is acceptable. If the RI is ≥1.0, redesign is obligatory.

The thorough risk assessment in method 3 involves the computing of an amended version of the NIOSH equation (again using reference values from table 3 as the mass constant), including three multipliers not included in the original equation. The result is a new recommended mass limit (RML) according to the following formula:

$$RML = RMLI \times 1HM \times 2PM \times NM,$$

where 1HM is a one-hand multiplier (if present = 0.6), 2PM is a two-person multiplier (if present = 0.85), and NM is a neighboring tasks multiplier (if present = 0.8).

The RML is used to calculate a risk index in the same way as in method 2, and the evaluation of it is identical, with the obvious exception that further risk assessment with a more complex method is not available for RI values between 0.85 and 1.0.

IEA TG manual materials handling: methods of risk exposure assessment

The IEA Technical Group on Musculoskeletal Disorders (IEA TG) developed a draft document in 1996 (36) with the purpose of proposing IEA guidelines for the assessment of risks associated with manual materials handling. The guidelines are closely modeled after the proposed CEN standard on the handling of machinery and component parts of machinery (29) and thus rely heavily on the revised NIOSH lifting equation.

The presented risk-assessment methods have been drawn from the CEN proposal, and therefore the modifications of the NIOSH equation include the same basic elements as prEN 1005-2 (29): (i) the ability to alter the load constant in the recommended weight lift equation while taking into account the intended user population [the recommended and differentiated mass constants are identical in the IEA guidelines (36) and prEN 1005-2 (29)] and (ii) the inclusion of additional multipliers for, for example, one-handed lifting or two-person lifting. In addition the IEA paper presents a method for assessing lifting tasks with sequential exposure (ie, workers rotate between various lifting tasks).

The risk assessment is carried out in two steps. First, a simplified assessment utilizes a procedure that checks for compliance with some essential prerequisites (eg, the adherence to national norms or guidelines) and compares the load lifted with a recommended maximum — or critical — weight value for a given lifting frequency. This recommended maximum value is obtained by reducing the recommended mass constants for the general working population using a few fixed multipliers and requiring a lifting index of <0.85 (acceptable level of risk). The multipliers have been chosen to mirror a normal, but not ideal lifting situation.

If this initial screening procedure is unable to confirm that conditions are fully acceptable, a second step that involves calculating a modified NIOSH lifting equation is required. The recommended weight limit (RWL) is calculated as in prEN 1005-2 (29) by inserting assigned values from tables to complete the formula as follows:

$$RWL = LC \times VM \times DM \times HM \times AM \times CM \times FM.$$

Again LC represents the specific load constant for the intended users (see reference 29 and table 3), VM is a vertical multiplier, DM is a displacement multiplier, HM is a horizontal multiplier, AM is an asymmetric multiplier, CM is a coupling multiplier, and FM is a frequency multiplier. The lifting index (LI) is used as a single number estimate of risk and is calculated as in prEN1005-2 (or NIOSH):

$$LI = \text{actual mass (kg)} / RWL \text{ (kg)}.$$

The interpretation of LI is however slightly different (less detailed) than that of the proposed CEN standard. An LI of ≤1 is suggested to be implicative of a very low risk. If LI is ≥1.0, the risk is higher, and the higher the indicator value, the greater the risk.

In special cases the IEA guideline suggests that other elements can be added to the equation, for example, a multiplier for one-handed lifting (0.6) or a two-person multiplier (0.85).

Finally a method assessing sequential exposures to lifting tasks with different LI values is included. In these situations a composite lifting index (CLI) can be calculated. This index is generally determined by the task with the greatest LI, plus a share that represents the LI values of the other tasks.

Other guidelines

EU council directive 90/269/EEC: minimum health and safety requirements for the manual handling of loads particularly involving the risk of back injury to workers

The manual-handling directive (90/269/EEC) issued by the Council of the European Communities in 1990 (37), is the fourth individual directive within the meaning of article 16 of EU council directive 89/391/EEC (38) on the introduction of measures to encourage improvements in the health and safety of workers at work. The directive lays down minimum requirements for the regulation of manual handling activities in order to protect workers against the risk of back injury and obliges member states to bring into force the national laws and regulations needed to comply with the directive not later than 31 December 1992.

In general, the directive emphasizes employers' obligations to initiate measures to avoid the need for manually handling loads. If manual handling cannot be avoided, the employer must adopt appropriate means to reduce the risk involved and organize the workstation in such a way as to make the handling as safe and healthy as possible. This adaptation implies mandatory considerations of several items listed in annex I of the directive (eg, the characteristics of the load, the physical effort required, the characteristics of the work environment, and the requirements of the activity).

The reference factors to be used in an analysis of the risk of back injury are specified in the annex. Load characteristics present a risk if, for example, the load handled is too heavy or too large or it is positioned in a manner requiring it to be held at a distance from the trunk. Physical effort presents a risk if, for example, it is too strenuous or only achieved through the use of a twisting movement of the trunk. The work environment imposes a risk if, for example, not enough room is available to carry out the activity, and, finally, the requirements of the activity present a risk if the activity entails, for example, overfrequent or overprolonged physical effort involving, in particular, the spine. It is emphasized that reference can be made simultaneously to the various factors to enable a multifactorial risk analysis.

Besides the obligation to take appropriate organizational measures, the directive requires the employer to provide information to workers on the weight of the load handled and the center of gravity of the heaviest side when a package is eccentrically loaded. In addition, employers are obliged to ensure that workers receive proper training and information on how to handle loads and the potential risk involved. Complementary individual risk factors are presented in a separate annex (annex II), which indicates an increased risk in situations in which the worker is physically unsuited to carry out the task, is wearing unsuitable clothing, or does not have adequate training.

GUIDELINES FOR REPETITION, FORCE OR POSTURE IN MONOTONOUS, REPETITIVE WORK

The standards included in this section fulfilled the inclusion criteria. See table 4 for a summary.

ANSI Z-365: control of work-related cumulative trauma disorders: part 1: upper extremities

In 1989 the National Safety Council in the United States initiated efforts to develop a "voluntary consensus" standard for the control of work-related cumulative trauma disorders through the accreditation of an American National Standards Institute (ANSI) committee. The proposed aim was the preparation of a technical standard specifying principles and practices for controlling work-related cumulative trauma disorders. The ergonomic considerations to be focused upon included work postures, work layout, force requirements, vibration, work rates, tool design, and the flexibility of the workstations.

Several draft versions have been issued representing the ongoing work of the ANSI committee. The fourth working draft, published in January 1996 (39), focuses mainly on upper-limb disorders, while specific recommendations for other parts of the body will be added as separate substandards.[2]

The working draft describes components and functions of a control process for cumulative trauma disorder that includes surveillance for affected workers and risk factors, the analysis and design of jobs, and the management of affected workers. Prerequisites for the recommendations presented in the drafts are outlined in a background section summarizing the position of the ANSI committee in relation to the scientific literature available. Tentative conclusions indicate that it " is possible to quantify exposure to work-related cumulative trauma disorders (CTD) risk factors and identify many work situations in which CTDs are likely to occur". At the same time, however, it is stated that, even though "it is possible to identify broad principles of design to reduce exposure to CTD risk factors, it is not yet possible to specify precise quantitative work design parameters for a given level of risk in a given population".

2 A new, shortened and revised version of ANSI Z-365 has recently been completed and was released for balloting and comments in October 2000.

Table 4. Guidelines for repetition, force or posture in monotonous, repetitive work. (ACGIH = American Conference of Governmental Hygienists, ANSI = American National Standards Institute, IEA = International Ergonomics Association, IEA TG = International Ergonomics Association Technical Group, TLV = threshold limit value)

Standard	Aim	Domain	Type	Legal status	Basis	Level of accuracy	Category	Reference
ANSI Z-365: control of work-related cumulative trauma disorders: part 1: upper extremities	Control of work-related cumulative trauma disorders with emphasis on management responsibilities	Manual lifting, assembly, manipulation of tools, machinery and other devices (industry-wide)	American national standard (draft)	Voluntary consensus standard	Review of available scientific literature	Qualitative	Health-based	ANSI, 1996 (39)
California State standard (repetitive motion injuries)	Prevention of repetitive motion injuries with emphasis on employers' obligation	Jobs where a repetitive motion injury has occurred	General industry safety order	Regulatory	Not specified	Qualitative (conditions for control quantitative)	Health-based	California, 1997 (40) (www.dir.ca.gov/title8/5110.html)
IEA TG: exposure assessment of upper limb repetitive movements: a consensus document	Provision of definitions, criteria and procedure to assess work conditions representing physical overload for the upper limbs	Repetitive work	Guideline	Voluntary guideline	Scientific literature, standards and pre-standards	Qualitative	Health-based	Colombini et al, 2001 (41)
Occupational and individual risk factors for shoulder-neck complaints: part 1 – guidelines for the practitioner (Winkel & Westgaard)	Prevention of work-related shoulder-neck complaints	All types of work	Guideline	Voluntary guideline	Epidemiologic	Qualitative (semiquantitative concerning exposure duration)	Health-based	Winkel & Westgaard, 1992 (42)
Repetitive work of the upper extremity: part 1 – guidelines for the practitioner (Kilbom)	Prevention of work-related musculoskeletal disorders of the upper extremities in association with repetitive work	Repetitive work tasks performed continuously for a minimum of 60 minutes	Guideline	Voluntary guideline	Epidemiologic, physiological, biomechanical, medical	Semiquantitative	Health-based	Kilbom, 1994 (44)
ACGIH proposed TLV for hand activity level	Control of musculoskeletal disorders of the hand, wrist and forearm	Monotask jobs performed for more than 4 hours a day	Proposed TLV (considered trial limit until 2001)	If passed ACGIH TLV (guideline not regulatory)	Epidemiologic, psychophysical, biomechanical	Quantitative	Health-based	ACGIH, 2000 (48)

On the basis of these conclusions, several mandatory requirements for control programs conforming to the standard on cumulative trauma disorders have been established. Basic requirements emphasize management responsibilities for the safety and health of employees, the need for a written program describing objectives and tasks, the provision of training for employees and managers, and the active involvement of employees in the program. Mandatory methods include the following five compulsory steps: (i) surveillance of affected employees and work-related risk factors, including employee reports, analyses of existing records (eg, employee compensation reports and absenteeism records), and job surveys using, for example, plant walkthroughs or risk-factor checklists (several sample checklists are provided in an annex to the standard); (ii) evaluation of affected employees (the early evaluation of employees' signs and symptoms, including diagnosis and the initiation of treatment, is believed to limit the severity of the conditions); (iii) development and implementation of medical intervention among employees, aiming at a systematic follow-up of symptomatic employees to document symptom improvement or resolution; (iv) job analysis (ie, detailed analyses of jobs identified in the surveillance process), including the evaluation of jobs for risk factors related to cumulative trauma disorder at a sufficient level of detail to identify potential work-related risk factors (adherence to such physical stresses as force, posture, motion, recovery, vibration, temperature, taking into account the magnitude, repetition and duration of each factor, is emphasized as being obligatory, and recommended methods for measuring and quantifying

risk factors are presented in an annex), and (v) evaluation of identified and analyzed jobs (job design and intervention). The objective of this step is to reduce or eliminate the identified risk factor. As "safe exposure limits are not available", it is emphasized that physical stress should be reduced as much as technically and practically feasible in order to reduce exposure to factors that increase the risk of cumulative trauma disorders. The job "redesign" procedure involves the implementation of solutions (eg, engineering controls) and a follow-up analysis.

California State standard (repetitive motion injuries)

Effective in July 1997, the General Industry Safety Order, Repetitive Motion Injuries (40) established a number of legal obligations for employers in the state of California in the United States.

The obligations apply to employers responsible for jobs in which a repetitive motion injury has occurred to more than one employee under the following conditions: (i) the repetitive motion injury was predominantly (ie, 50% or more) caused by a repetitive job, process, or operation (work-related causation), (ii) the employees incurring a repetitive motion injury were performing a job, process, or operation of identical work activity (same repetitive motion task, eg, word processing, assembly or loading), (iii) the repetitive motion injuries were musculoskeletal injuries identified and diagnosed by a physician, and (iv) the repetitive motion injuries were reported to the employer in the last 12 months since the effective date of the safety order.

If these conditions are fulfilled, employers are obliged to establish and implement programs designed to minimize repetitive motion injuries. Compulsory program elements include worksite evaluation, control of workplace exposures, and the training of employees. Control of workplace exposure requires the employer to implement measures capable of either preventing exposure to workplace risk factors or minimizing exposures to the extent feasible. Engineering and administrative controls to be considered are specified, for example, workstation redesign, adjustable fixtures or tool redesign, job rotation, and work pacing or work breaks.

Training obligations include information to employers on exposures associated with repetitive motion injuries, symptoms, and the consequences of injuries and methods used by the employer to minimize repetitive motion injuries.

In essence the California ergonomic regulation adapts some (not all!) of the mandatory requirements outlined in the ergonomic standard proposed by OSHA in 1995 (OSHA '95) (23), but it abstains from the voluminous nonmandatory sections describing how to perform risk analysis and implement control measures in the OSHA proposal.

IEA TG exposure assessment of upper-limb repetitive movements: a consensus document

A draft document on musculoskeletal disorders was prepared by Colombini et al and issued by the IEA TG in 1999, and later published in 2001 (41). The draft proposal presents guidelines for assessing risk factors for work-related musculoskeletal disorders in association with upper-limb repetitive movements. Aimed at professionals involved in the prevention of such disorders, the proposed advisory IEA guideline provides a set of definitions, criteria, and procedures "useful to describe and, wherever possible, assess" workplace exposure.

A general assessment model to evaluate the four main physical risk factors (ie, repetitiveness, high force, awkward postures and movements, and lack of recovery periods) constitutes the main part of the draft. Emphasizing the importance of the time aspect (duration of exposure), definitions and concepts are established for a detailed work organizational analysis, and procedures are suggested for subdividing worktasks into, for example, cycles, technical actions, and joint movements.

Methods are presented for the exposure assessment of each risk factor separately with the primary ambition of providing applicable tools easily that do not require sophisticated instrumentation, and, when possible, are built on observational methods. In the final section of the draft proposal a need for an overall exposure assessment, taking into account the interrelation between different risk factors (exposure indices), is expressed. The current lack of sufficient scientific data to support such a model is, however, at the same time recognized.

Given the consensus character of the document, the formal part of the proposed guidelines mainly clarifies definitions and describes procedures for the assessment of workplace exposure. Methods for evaluation and risk characterization are included in an annex of the guideline. The annex provides examples of methods that have proved useful in field studies, and it illustrates possible approaches to the analysis of workplace risk factors. It is however emphasized that numerous methods are available for the proposed workplace risk assessment, and the examples presented are not especially endorsed or recommended.

Occupational and individual risk factors for shoulder-neck complaints: part 1 — guidelines for the practitioner (Winkel & Westgaard)

In the early 1990s the *International Journal of Industrial Ergonomics* initiated the publication of a series of

ergonomic guidelines aimed at providing practitioners with practical and usable guidelines to enhance worker safety and productivity. The voluntary and informative character of the guidelines was defined in a general preface to the series. It emphasized that the recommendations presented were "neither intended to replace existing standards" nor should they "be treated as standards". A further common feature characterizing these ergonomic guidelines is the formal presentations of the scientific background underlying the proposed guideline in an independent and separate paper.

The guideline on risk factors for shoulder-neck complaints (42, 43) was published in 1992. Based on a literature review of documented exposure-response relationships for shoulder neck disorders, the guideline introduces a tentative general framework for the assessment of exposure and suggests a line of action for the regulation of physical workplace exposures.

Physical exposure assessment is conceptualized as a three-dimensional task requiring the assessment of level, repetitiveness, and duration. At the same time, it is assumed, however, that exposure levels in general are not harmful or injurious per se, with the exception of extreme physical exposure (ie, accidents). Only in combination with exposure times that are too long can adverse health effects result, and the implication is that "physical exposure should primarily be regulated by time limits, provided the design of the workstation and hand tool is optimal". It is recognized that exposure times that are too short (ie, inactivity) may cause negative physiological effects, but this possibility is considered of minor importance for the guideline, in which the emphasis is on setting maximal time limits.

The suggested line of action consists of three consecutive elements. First, the level of workplace exposure is classified as low, medium, or high. Low exposure levels for the shoulder-neck region are typically experienced when seated work is combined with "good" workstation design according to ergonomic textbooks. Medium exposure levels result from improper work postures (elevated shoulders or abducted or flexed upper arms or flexed or extended neck) in combination with minor force requirements. High exposure levels are characterized by the exertion of high forces in the shoulder or neck area (eg, using heavy hand tools with the upper arm or arms deviating from a vertical position).

Assuming that efforts to optimize workstation design to the extent possible has been initiated, the second step then defines maximal time limits according to the exposure classification. For low exposure levels in monotonous worktasks the exposure time should be less than 4 hours/day, for moderate exposure levels continuous work of ≤1 hour is acceptable, while high exposure levels require exposure times "shorter " than the time limit defined for moderate exposures.

The third and final program element suggests a "grouping" procedure on the assumption that an acceptable overall physical exposure of the shoulder-neck region can be obtained by optimizing the way worktasks belonging to different exposure groups are distributed and combined during the workday.

Repetitive work of the upper extremity: part 1 — guidelines for the practitioner (Kilbom)

The guideline on repetitive work of the upper extremity (44) appeared as part of the *International Journal of Industrial Ergonomics* series of ergonomic guidelines. Since its publication in 1994, the guideline and the accompanying scientific background paper (45) have been frequently cited, and the risk assessment models presented in the paper have exerted a noticeable influence on numerous contemporary guidelines (eg, the IEA TG guidelines and parts of OSHA's ergonomic protection standard).

Based on a literature review of experimental, field, and epidemiologic studies in ergonomics, work physiology, biomechanics and clinical science, the guideline aims to provide assistance in the primary and secondary prevention of work-related musculoskeletal disorders associated with repetitive work. Repetitiveness is used as a starting point in the risk assessment approach, but procedures to integrate other known risk factors for musculoskeletal disorders into the overall assessment of risk are included in the guideline.

The identification of a repetitive worktask or a potential problem job is the first level in the suggested risk assessment process. Prerequisites for identifying a problem job are (i) the job can be defined as repetitive (ie, work cycles are shorter than 30 seconds (or one fundamental work cycle constitutes more than 50% of the total cycle time) and the work task is performed continuously for a minimum of 60 minutes and/or (ii) a case of work-related musculoskeletal disorder of the upper extremity has been encountered at the workplace.

When a problem job or task has been identified, the assessment of exposure levels of known risk factors (eg, time, forces, posture, and speed characteristics) constitutes the next step in the process. In order to make the guidelines more usable for practitioners, quantitative input data are required for the time parameters only (repetitiveness expressed as the number of movements/minute for different joints). Exposure levels for all other risk factors are dichotomized into high or low exposure groups using subjective assessments (eg, posture parameters are dichotomized into postures with neutral/small deviation or postures with moderate/extreme deviation, while the speed parameters are dichotomized into static/slow movements or fast movements.

Table 5. Recommendations for risk assessment in repetitive work (44).

Body region	Type of exercise	Frequency of movement or contraction	Risk assessment	Risk modification — very high risk
Shoulder	Dynamic	>2.5 / minute	High	One of the following for *any category*: high external force, high speed, and high static load, extreme posture, lack of training, high demands on output, monotony, lack of control, long duration of repetitive work
	Intermittent, static		See Winkel & Westgaard	
Upper arm, elbow	Dynamic	>10 / minute	High	
	Intermittent, static		See Dul et al	
Forearm, wrist	Dynamic	>10 / minute	High	
	Intermittent, static		See Byström	
Finger	Dynamic	>200 / minute (?)	High	

The subsequent risk analysis — in which exposure levels are compared with acceptance criteria — requires the adherence to recommendations given in the guideline (table 5).

Emphasis is placed on repetitiveness as a risk factor (ie, cut points defining high risk are based primarily on the frequency of movement). [The epidemiologic evidence for an exposure-effect relationship between workplace risk factors and musculoskeletal disorders is considered to be the most valid for repetitiveness, especially when the outcome measure is tendon or nerve disorders.]

Exposure to the other dichotomized risk factors at high exposure levels (eg, high external force or extreme postures) is incorporated into the model, and simultaneous exposure to high repetition and one or more of the risk factors is associated with a very high risk.

Note that practical guidance concerning the actual evaluation of intermittent static contractions, for example, repetitive handgrips with small or negligible external movements, is not included in the guideline. Instead references are given to other guidelines or scientific papers [eg, those found in papers by Winkel & Westgaard (42, 43) and Byström (46)].

A final paragraph on solutions is influenced by the lack of quantitative data recognized in the guideline. It is emphasized that even though cut points defining an increased risk may, to some extent, be available, no data allow the identification of safe levels for either the maximal acceptable duration of repetitive work per day or the acceptable rate of movements or contractions. In consequence, the only approach available is to reduce critical exposure levels to the extent feasible. A tentative list of priorities is presented that primarily emphasizes the reduction of movements and total exposure time. Only secondly should intervention be directed against — in the following order — postures and static work, lack of control, and other risk factors (high speed, monotony, etc).

ACGIH proposed TLV for hand activity level

In 1999 ACGIH published its intent to establish a threshold limit value (TLV) for hand activity level (47). It is a quantitative guideline for the control of musculoskeletal disorders of the hand, wrist, and forearm in monotask jobs that are performed for ≥4 hours a day (48). It is accompanied by a paper describing the epidemiologic and experimental literature and the rationale used for its development.

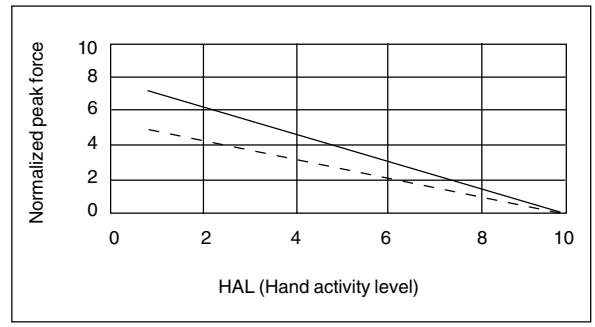

Figure 3. The threshold limit value (TLV) for the reduction of work-related musculoskeletal disorders based on "hand activity" or "HAL" and peak hand force. The top line depicts the TLV, and the bottom line is an action limit for which general controls are recommended. [Reprinted from reference 48]

This guideline gives threshold limit and action limit values for observed or measured hand activity levels and normalized peak force values (figure 3). A trained person is needed for the observation of hand activity level. The method of observation was developed and evaluated by Latko et al (49) and later used in an epidemiologic study on upper-limb musculoskeletal disorders (50). A dose-response relationship was found between repetitiveness in three levels and the prevalence of carpal tunnel syndrome. Hand activity levels can also be obtained from the frequency of exertion(s) and the percentage of duty cycle from a table in the TLV documentation. Peak hand force is assessed with a normalized scale from 0 to 10, corresponding to 0% to 100% of applicable population reference strength (dividing the force required to perform the job by the strength capability of the worker population for the activity). A representative set of complete work cycles should be observed or measured for the assessment.

VIBRATION STANDARDS

The standards included in this section fulfilled the inclusion criteria for vibration. See table 6 for a summary.

ISO 2631-1: mechanical vibration and shock — evaluation of human exposure to whole-body vibration: part 1: general requirements

The revised ISO standard on whole-body vibration was published in 1997 (51) following years of debate and discussion. This revised version of the 1985 vibration standard is a complicated document containing a set of alternative methods for evaluating whole-body vibration. [Apparently part of the complexity of the standard reflects discord within the committee responsible for its production and approval (52).]

The primary purpose of ISO 2631-1 is to define methods of quantifying exposure to whole-body vibration in relation to human health, comfort, and perception and the incidence of motion sickness. Methods for measuring and evaluating vibration constitute the proper standard, while guidance for the subsequent assessment of whole-body vibration with respect to health, comfort, or motion sickness is presented in informative annexes.

Measuring and evaluating exposure. The "basic evaluation method" recommended in the standard requires that the frequency-weighted root mean square (rms) acceleration be measured. Frequency weighting is essential when vibration exposure is evaluated because the way in which vibration affects health (or comfort, perception, motion sickness) is dependent on the vibration frequency content. The standard provides recommended frequency weighting for the different axes of vibration and incorporates a special frequency weighting for motion sickness emphasizing low-frequency vibration. For evaluating vibration with respect to health, ISO 2631-1 advocates frequency weighting W_d for horizontal vibration on a supporting seat surface, weighting W_k for vertical vibration on a supporting seat surface, and weighting W_c for evaluating seat-back measurements. [The fre-

Table 6. Vibration standards. (ISO = International Organization for Standardization)

Standard	Aim	Domain	Type	Legal status	Basis	Level of accuracy	Category	Reference
ISO 2631-1: mechanical vibration and shock — evaluation of human exposure to whole-body vibration: part I: general requirements	Provision of methods to measure and evaluate exposure to whole-body vibration in relation to human health	Vehicles, machinery, and industrial activities exposing people to periodic, random and transient mechanical vibration	ISO standard	International standard, no legal implications for labor market regulation	Epidemiologic, biodynamic	Quantitative	Technical measurement standard (annex health-based)	ISO, 1997 (51)
ISO 5349: mechanical vibration — guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration	Provision of methods to measure and evaluate human exposure to hand-transmitted vibration	Vibrating tools, vibrating machinery or vibrating work pieces transmitting vibration to the hands and arms of operators	ISO standard	International standard, no legal implications for labor market regulation	Epidemiologic	Quantitative	Technical measurement standard (annex health-based)	ISO, 1986 (53)

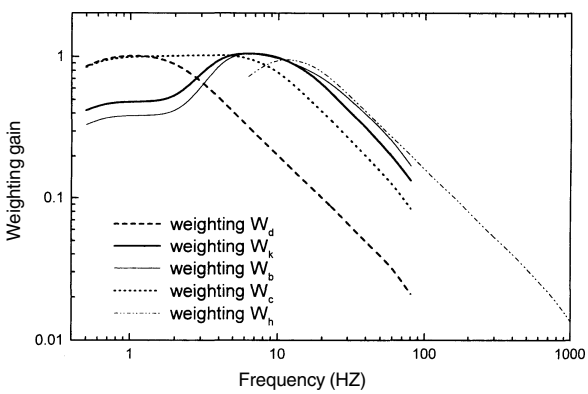

Figure 4. Frequency weightings used in ISO standard 2631-1. [Reprinted from reference 51]

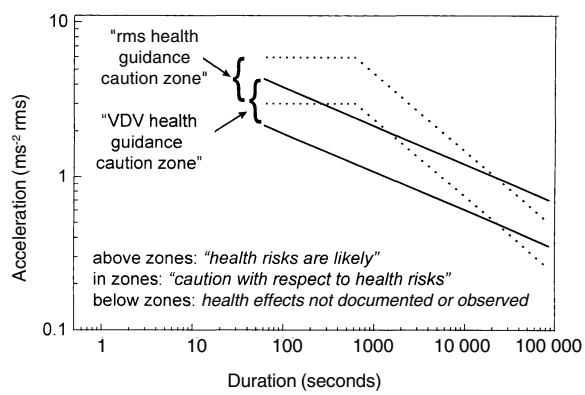

Figure 5. Health guidance caution zones presented in ISO standard 2631-1. [Reprinted from reference 51] (rms = root mean square)

quency weightings are new with respect to the 1985 ISO standard, and examples of frequency weighting curves are shown in figure 4].

In cases of vibration exposure characterized by substantial peaks, the rms procedure is considered inadequate for assessing adverse health effects, and additional methods are presented. The presence of high peaks is reflected in the crest factor (defined as the modulus of the ratio of the maximum instantaneous peak value of the frequency-weighted acceleration value to its rms value). For vibration with crest factors greater than 9, ISO 2631-1 advocates two alternative methods. These methods are called (i) the running rms method (takes into account occasional shocks and transient vibration by use of a short integration time constant) or (ii) the fourth power vibration dose "VDV" method (which is more sensitive to peaks than the rms method since it uses the fourth power (instead of the second power) of the acceleration time history as the basis for averaging). To determine whether the results obtained with the additional methods should be used in the subsequent risk assessment, the standard suggests that only if the ratio between the "alternative values" and the rms values exceed 1.5 (for the running rms) or 1.75 (VDV method) should the new value be taken into consideration.

Guide to the use of vibration evaluation methods. Three annexes provide differentiated information on the possible effect of vibration on health, comfort, and perception. The health guidance constitutes the main part of the annex section. It addresses adverse health effects to the lumbar spine and the connected nervous system due to long-term exposure to whole-body vibration and applies primarily to seated persons. The insufficiency of data showing a quantitative relationship between vibration exposure and the risk of health effects is recognized, but the guidance is "given in numerical terms to avoid ambiguity and to encourage precise measurements".

Based on the evaluation methods described in the standard, two different "health guidance caution zones" are presented (figure 5). The acceptability of exposure is judged by comparing the measured rms values of the frequency-weighted acceleration with the zone shown in the figure at the duration of the expected daily exposure. According to the standard exposures, below the zone should be acceptable with "no health effects have been clearly documented and/or objectively observed"; for exposure in the zone the rating is "caution with respect to potential health risks is indicated"; and for above the zone, "health risks are likely".

The "VDV caution zone" is defined by vibration dose values of 8.5 and 17 $ms^{-1.75}$. With the use of these dose values the corresponding rms accelerations for different durations of exposure have been calculated as shown on the figure. The "rms health caution zone" — also included in the figure — uses the weighted rms and suggests constant acceleration from 1 to 10 minutes and the acceleration falling in inverse proportion to the square root of exposure duration from 10 minutes to 24 hours. No mathematical definition for this "rms caution zone" is given, and precise values for the upper and lower boundary of the caution zone can hardly be discerned from the figure.

The standard emphasizes that the health guidance caution zones are identical for the two methods for durations from 4 to 8 hours, the range in which most occupational observations are made. It should however be noted that, for 10 minutes of exposure, the rms caution zone suggests that magnitudes less than 3.0 m/s^2 should be acceptable, while the "VDV caution zone" indicates that, at magnitudes above 2.45 m/s, health risks are likely. No explanation for this discrepancy is given, and there is limited guidance to indicate the preferred caution zone to be used in a risk assessment procedure.

ISO 5349 : mechanical vibration — guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration

The international measurement standard on hand-arm vibration was published in 1986 (53). The main body of this standard (ISO 5349) defines procedures for measuring and reporting hand-transmitted vibration exposure. Guidelines for the evaluation of vibration exposure are presented in an annex (not an integral part of the standard) describing a model for predicting the duration of vibration exposure necessary for the onset of vascular symptoms (ie, finger blanching).

Measuring and reporting exposure (frequency weighting and time dependency). General guidelines are given for the measurement of vibration from handheld power tools. All measurements are to be made on the tool handles in three mutually orthogonal directions defined in the standard, and the directional component with the largest measurement value is used to assess the exposure.[3] Acceleration levels (rms) are reported as frequency-weighted accelerations or as acceleration in octave or one-third octave bands. Frequency weighting is, however, compulsory for risk assessment purposes, and

3 ISO 5349 is now under revision. The proposed revision (ISO, 1998) requires the assessment of vibration exposure to be based on the root-sum of squares for all directions rather than the dominant direction, as a single-axis evaluation may underestimate the severity of vibration (54).

it constitutes an important part of the standard. The prescribed frequency weighting — based on vibration perception data — emphasizes theimportance of low frequencies and implies that, when the vibration frequency rises above 16 Hz, the potential harmful effects of hand-arm vibration decrease. Time dependency (ie, duration of exposure) is based on 4 hours of daily exposure. If the daily duration of exposure differs from 4 hours, the measured acceleration level must be recalculated — using an equation specified in the standard — and expressed as an "energy equivalent" frequency-weighted acceleration for a period of 4 hours. [Example: If the daily duration of exposure is 1 hour, the 4-hour equivalent is obtained by dividing the measured frequency-weighted value by a factor of 2.]

Evaluation of hand-transmitted vibration exposure. A model for the relationship between finger blanching (white finger) latency and the 4-hour energy equivalent daily acceleration is included in annex A of the measurement standard. The assumed "dose"-response relationship is presented as curves showing the time in years of daily vibration exposure before episodes of finger blanching occur in 10%, 20%, 30%, 40%, and 50% of exposed persons (figure 6). The model is based on the statistical and mathematical treatment of approximately 40 studies on white-finger prevalence and latency among vibration-exposed workers, but in recent years it has been heavily criticized for "scientific inadequacy" [eg, by Gemne & Lundström (55)]. No attempts are made in the annex to define the limits of safe exposure. Instead the ISO standard defers the choice of selecting the acceptable weighted acceleration levels to the national authorities in each country.

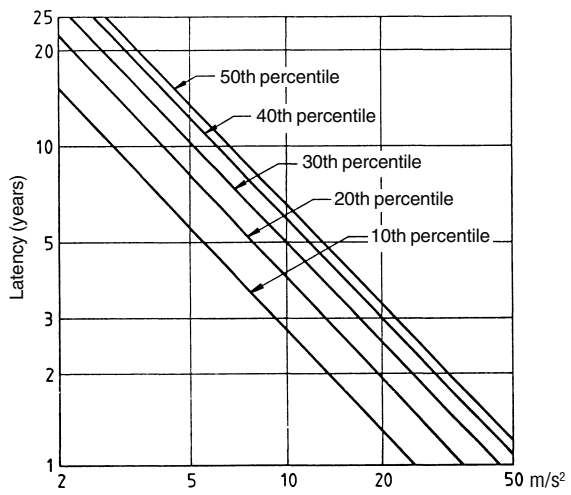

Figure 6. ISO model for the relationship between 4-hour frequency-weighted energy equivalent acceleration and the latency of white fingers. [Reprinted from reference 53]

GUIDELINES FOR ENERGY CONSUMPTION

The following standards fulfilled the inclusion criteria for energy consumption. See table 7 for a summary.

Job design for the aged with regard to decline in their maximal aerobic capacity: part 1 — guidelines for the practitioner (Ilmarinen)

The guideline on job design for the aged was published as part of the *International Journal of Industrial Ergonomics* guidelines in 1992 (56). [See the section on guidelines for practitioners with respect to occupational and individual risk factors for shoulder-neck complaints beginning on page 23 for more information on the *International Journal of Industrial Ergonomics* guideline series.] The main emphasis is on demographic changes in the workforce and the expected increase in relative workload for aging workers. Several general recommendations for maximal energy consumption during work and acceptable physical workload are, however, included in the guidelines and the accompanying scientific background paper (57).

In an attempt to meet the ambitious aims — to prevent premature aging, improve job satisfaction and productivity, and reduce early retirement — the guidelines present a stepwise procedure for identifying workplace problems and introduce measures for problem solving.

The procedure for identifying workplace problems or health risks at work is primarily concerned with the verification of situations in which "Physical demands on the cardiorespiratory system are too high" (ie, the identification of situations with an imbalance between physical work capacity and physical job demands). Maximal oxygen consumption is used as a measure of individual physical work capacity, and different submaximal tests to determine maximal oxygen consumption are described and recommended in the guidelines. Recommendations for the assessment of work or job demands are given on a "two-level" basis. The practitioner is advised to assess physical activities during work using a simple observation technique classifying job activities according to energy requirements (expressed as multiples of basal metabolic rate — the "Edholm scale"). For the actual measurements of workload (ie, oxygen consumption during work) the practitioner is referred to specialists.

The final step in the "problem identification procedure" requires the assessment of relative aerobic strain by relating measured (or estimated) oxygen consumption during work to the maximal oxygen consumption of the same subject. [An alternative — and simpler method — using individual heart rate during work as

Table 7. Guidelines for energy consumption.

Standard	Aim	Domain	Type	Legal status	Basis	Level of accuracy	Category	Reference
Job design for the aged with regard to decline in their maximal aerobic capacity: part 1 – guidelines for the practitioner (Ilmarinen)	Prevention of premature aging, improved job satisfaction and productivity, and reduced early retirement	Jobs with high physical demands	Guideline	Voluntary guideline	Physiological	Semiquantitative	Performance and health-based	Ilmarinen, 1992 (56)
Energy expenditure: ILO encyclopedia (Bonjer)	Prevention of fatigue	All types of work activities (industry-wide)	Guideline	Voluntary guideline	Physiological	Semiquantitative	Performance and health-based	Bonjer, 1971 (12)

an overall measure of physiological strain is also briefly described in the guideline.]

In the problem-solving part of the guideline, the measured relative aerobic strain is to be compared with the accept criteria or limit values for maximal acceptable oxygen consumption during work. The main part of this section consists of figures and tables to be used in the determination of acceptable workload, all based on the following two general recommendations valid for prolonged work (8 hours): (i) relative aerobic strain should not exceed 50% on the presumption that rest pauses are available and (ii) relative aerobic strain should not exceed 33% on the presumption that rest pauses are not available.

If heart rate during work is used as a single number measure of strain during work, additional tables are provided to allow the practitioner to determine acceptable or not acceptable mean heart rates on the basis of gender, age, and maximal oxygen consumption.

The main reason for the suggested limits is specified in the scientific background paper (57) as a measure "to avoid the tiring effects of anaerobic metabolism during work". No attempts are made to suggest or document adverse health effects when these values are violated. At the same time, the premature nature of the recommendations given is emphasized, and the values presented are described as "in most cases illustrative in nature".

In a concluding section, the guideline suggests the following two lines of action when acceptable levels are surpassed: (i) reduction of workload by cutting peak loads or introducing effective rest schedules or (ii) improvement of worker fitness through aerobic exercise training. In case of the first alternative, a figure is included to assist the practitioner in choosing the appropriate rest periods. The figure, however, merely illustrates that the recommended time for work periods decreases while the recommended rest time is prolonged at increasing levels of relative aerobic strain.

Energy expenditure: ILO encyclopedia (Bonjer)

Published as a part of the *ILO Encyclopaedia of Occupational Health and Safety* in 1971, Bonjer's paper (12) is — strictly speaking — not a guideline. It has, however, gained wide acceptance as a sort of unofficial ILO position on energy requirements and is frequently cited.

The potential benefits of knowing the energy expenditure in different tasks are specified in a preface to the paper. Knowledge of energy expenditure (or oxygen consumption) is considered a prerequisite for (i) determining the degree of fatigue to which the worker is exposed, (ii) estimating the length of time during which he or she can be expected to work during a shift, and (iii) calculating the number, frequency, and length of required rest periods. Methodological considerations and practical recommendations related to these topics constitute the three main sections of the paper.

The first section, "On-the-job Measurement", recommends methods for the direct measurement of oxygen consumption during work (eg, the Douglas bag technique or measurement with the Kofranyi-Michaelis portable gas meter). Indirect measures of oxygen consumption (eg, heart rate, pulmonary ventilation, or energy expenditure tables) are mentioned as potential methods, but their use is discouraged due to the high uncertainty inherent in the methods. The attractiveness of continuous heart rate recordings during work is, however, recognized, but their use is only recommended in connection with intermittent measurements of oxygen consumption.

In the second section, on acceptable levels, criteria are presented to help determine the acceptability of the measured mean energy expenditure during work. Bonjer states that it is not "physiologically justifiable" to require equal energy expenditure for different workers and therefore recommends that 33% of maximum energy expenditure be considered the maximum allowable

level of energy expenditure for an 8-hour workday. The main objective is to avoid "undue fatigue", and, in practice, the determination of acceptable levels requires measuring the aerobic capacity for each individual worker.

In order to establish the maximum levels of energy expenditure for worktimes that differ from an 8-hour day, a rectilinear relationship between oxygen uptake and the logarithm of endurance (or work) time is assumed. With the use of two fixed points on the curve — maximal oxygen uptake can be sustained for 4 minutes, and energy expenditure for 480 minutes (8-hour) should not exceed 33% of the maximal level — individual curves for persons with different maximal oxygen uptake can be drawn, and examples are included showing levels of oxygen uptake considered allowable for different worktimes.

The third main section, on rest periods, shows how the described curves can be used to determine the amount and length of the rest periods needed to keep the mean oxygen uptake at an acceptable level. In addition the following formula — "based on an invariable figure of 4.2 kcal/min for net energy expenditure" — is presented to calculate the recovery time needed as a function of worktime:

$$t_r = (M / 4.2 - 1) \times t_w,$$

where t_r = recovery time, M = net energy expenditure during work, and t_w = worktime.

GUIDELINES FOR SPECIFIC INDUSTRIES

The following standards fulfilled the inclusion criteria for specific industries. See table 8 for a summary.

Ergonomics program management guidelines for meatpacking plants

Guidelines were issued in 1990 by OSHA (58) in response to the very high incidence rates of cumulative trauma disorders reported in the meatpacking industry. [In the late 1980s incidence rates in meatpacking plants (ie, slaughtering, processing, and packaging) were approximately 75 times than that of industry as a whole.] The guidelines were intended to aid employers in implementing ergonomic programs, and the advisory and nonregulatory nature of the guidelines was strongly emphasized.

In three sections the guidelines provide (i) information on management commitment and employee involvement, (ii) a description of recommended program elements, and (iii) detailed guidance and examples for the program elements. [By highlighting and describing four key elements in an ergonomic program (ie, worksite analysis, hazard prevention and control, medical management, and training and education), the meatpacking guidelines established a general framework for ergonomic programs to be adopted later in a number of successive guidelines in the United States.]

The commitment of top management and the involvement of employees are defined as basic requirements for a successful ergonomic program. Worksite analysis then constitutes the first major program element with the objective to "recognize, identify, and correct ergonomic hazards". A three-step procedure is described; it involves the gathering of information on incidence rates for upper-extremity disorders or back injuries, screening surveys to identify potential "problem" jobs, and an ergonomic job-hazard analysis of identified jobs.

The methods recommended for screening surveys include the use of ergonomic checklists (references included in the guideline) with adherence to some

Table 8. Guidelines for specific industries. [EEC = European Economic Community, EU = European Union, NIOSH = National Institute for Occupational Safety and Health (in the United States), OSHA = Occupational Safety and Health Administration (in the United States)]

Standard	Aim	Domain	Type	Legal status	Basis	Level of accuracy	Category	Reference
Ergonomics program management guidelines for meatpacking plants	Prevention of work-related cumulative trauma disorders and related injuries and illnesses	Meatpacking plants	Guideline	Voluntary guideline	Available scientific evidence, advice from NIOSH, medical literature, practical experience	Qualitative	Health-based	OSHA, 1990 (58) (available on ErgoWeb)
EU council directive 90/270/EEC: minimum safety and health requirements for work with display screen equipment	Provision of health and safety requirements for work with display screen equipment with emphasis on employers' obligations	Work with display screen equipment	Directive	Minimum requirements regulatory	Not specified	Qualitative	Health-based	EEC,1990 (59) (http://europa.eu.int/eur-lex)

specified generic risk factors (eg, repetitive activities, forceful exertions, prolonged static postures, excessive vibration, lifting or moving objects of excessive weight or asymmetric size). Special emphasis is placed on the need to identify, not only "problem jobs", but also "restricted activity or light duty jobs". The "indepth" analysis of ergonomic hazards in identified high-risk jobs includes the direct measurement and assessment of repetitiveness, posture, vibration, force, and the calculation of maximum weight limits in accordance with the NIOSH lifting equation, and it should be "performed and documented by a qualified person".

The second program element — hazard prevention and control — describes measures to prevent or control hazards identified through systematic worksite analyses. Separate recommendations are available for engineering and work practice controls, personal protective equipment, and administrative controls. Detailed information on engineering controls achievable in the meat industry constitutes an important part of the program guidelines. Examples of workstation or work method redesign measures aimed at reducing excessive force demands, high repetition rates, or awkward postures are presented together with criteria for the selection and design of appropriate tools. The methods proposed for work practice controls include training and practice times for employees with respect to proper work technique (proper cutting techniques, good knife care, correct lifting techniques), while examples of personal protective equipment focus on gloves and protection against extreme cold. In the administrative control section, examples of administrative measures to reduce the duration, frequency, and severity of exposures are presented (eg, decreased production rates and limited overtime work, the provision of rest pauses to relieve fatigued muscle-tendon groups, and the use of job rotation or job enlargement).

Implementation of a medical management system constitutes the third program element in the guideline. Proper medical management is considered essential to the success of ergonomic programs, and several issues are highlighted (eg, injury and illness record keeping, early recognition, conservative treatment, conservative return to work, and adequate staffing and facilities). The general aim of a medical management program is defined as the ability "to ensure early identification, evaluation, and treatment of signs and symptoms." and a full description is provided of a recommended program for the medical management of cumulative trauma disorders in meatpacking establishments.

The fourth program element addresses issues related to training and education. The main purpose of this final program element is to ensure information about ergonomic hazards for employees. Proper information on ergonomic hazards for potentially exposed employees is emphasized as a prerequisite for the active involvement of employees in their own protection. Recommendations are given for both general training (formal instruction on hazards associated with jobs and equipment) and specific job training (initial orientation and hands-on training) for affected employees. In addition some recommendations are presented to establish procedures for educating supervisors, managers, and health care providers about ergonomic issues.

EU council directive 90/270/EEC: minimum safety and health requirements for work with display screen equipment

The Council of the European Communities issued its directive on video display units (90/270/EEC) (59) in 1990, as the fifth individual directive within the meaning of article 16 of EU council directive 89/391/EEC (38) on the introduction of measures to encourage improvements in the health and safety of workers at work. The directive lays down minimum safety and health requirements for work with display screen equipment and obligates member states to introduce the national laws and regulations needed to comply with the directive not later than 31 December 1992.

In general the directive emphasizes employers' obligations to analyze computer workstations to evaluate safety and health conditions. Special emphasis is put on possible risks to eyesight, physical problems, and problems of mental stress, and employers are required to take appropriate measures to remedy the risks found.

The actions required are specified in the directive as the employers' obligation to (i) provide workers with information on all aspects of safety and health related to their workstation (including information on any actions taken by the employer in compliance with the directive), (ii) secure appropriate training in the use of the workstation, (iii) plan the workers' daily work routine in such a way that the work is "periodically interrupted by breaks or changes of activity reducing the workload at the display screen", (iv) protect workers' eyes and eyesight by offering appropriate tests (eg, ophthalmological examinations) and provide special corrective appliances if necessary, and (v) ensure that workstations meet the minimum ergonomic requirements laid down in an annex of the directive.

The minimum ergonomic requirements outlined in the annex concern equipment, the environment, and operator-computer interface. Some general equipment requirements are given for the display screen, keyboard, desk, and chair. It is specified that, for example, the display screen should be adjustable and free of flicker and reflection, keyboards should be tiltable and separate from the screen, desks should be sufficiently large to

allow for a comfortable working position, and chairs must be equipped with adjustable seats and seat backs.

The minimum environmental requirements (spacing, lighting, noise, reflections, heat, radiation, humidity) and the requirements for operator-computer interface and application software are described in broad qualitative terms (eg, "an adequate level of humidity shall be established and maintained" or software "must be suitable for the task and easy to use").

ACUTE OVERLOAD GUIDELINES

The following guideline fulfilled the inclusion criteria for guidelines for acute overload. See table 9 for a summary.

The reduction of slip and fall injuries: part 1 — guidelines for the practitioner (Leamon)

The guideline on the reduction of slip and fall injuries (60) appeared as part of the *International Journal of Industrial Ergonomics* guidelines in 1992 (60, 61). [See the section on guidelines for practitioners with respect to occupational and individual risk factors for shoulder-neck complaints, on pages 23–24 for more information on the *International Journal of Industrial Ergonomics* guideline series.] Aimed at reducing the incidence of slips, the guideline is intended for use in "any area where people walk", and the scope is thus extended beyond the area of occupational health. Focus is on walking and problems "caused at the heel during foot touchdown". It is however anticipated that improving the walking or slipping environment will benefit other related activities (eg, pushing and pulling or load carrying while walking).

The main body of the guideline presents a two-step approach in the actions to prevent problems related to slipping and falling. Problem identification (data collection and surveillance) is followed by a catalogue of practical solutions. [The seriousness of the problems is stressed by figures showing that 17.5% of all industrial injuries involve falls and 12.5% of all industrial fatalities are due to falls.]

Surveillance systems are emphasized as important tools in the process of problem identification. It is strongly recommended that specific reporting requirements should be included in all accident reporting systems to reveal the possible role of slipping and falling, highlighting factors such as footwear, levels of the floor, load carrying, lighting, and the like. In certain cases (eg, the increased number of slipping and falling injuries of delivery drivers), a more proactive surveillance strategy is suggested to determine the true reason for the reported incidents. The approach involved would include questionnaires and structured interviews among drivers.

In the practical solutions part of the guide, the following five approaches are listed:

1. Regular walkthroughs at industrial plants are recommended as an important part of industrial safety practice capable of detecting and reporting contaminating spills, slippery conditions, loose components, or discarded tools.
2. Janitorial audit (ie, the evaluation of the janitorial process of floor finishing) is considered equally significant. The organizational responsibility to support janitors in choosing the correct material and applying the appropriate methods when using floor finishers is stressed.
3. Job analysis is suggested as a way to reveal tasks in which excessive frictional requirements at the feet occur, and "hence when solutions should be sought".
4. The importance of visually recognizing slippery surfaces is stressed and measures (eg, appropriate light levels or changes of floor coloring in order to avoid hidden "discontinuities" in the frictional properties of the walking surface) are recommended.
5. Floor surface specification is considered important, and it is recommended to maintain the legally determined standard defining a static coefficient of friction greater than 0.5 (measured on a James machine) as associated with a "nonslip" surface. It is however emphasized that there is conflicting evidence on the level of protection provided by such a measurement during normal movement. The recommendation is thus mainly included in the guidelines due to the advantage of having a legal defense in case of fall injuries and not because a coefficient of friction of >0.5 is considered to be a particularly useful tool in producing safer workplaces.

Table 9. Acute overload guidelines.

Standard	Aim	Domain	Type	Legal status	Basis	Level of accuracy	Category	Reference
The reduction of slip and fall injuries: part 1 – guidelines for the practitioner (Leamon)	Prevention of slip and fall injuries during walking	All areas where people walk	Guideline	Voluntary guideline	Epidemiologic (accident statistics), experimental	Qualitative	Health-based	Leamon, 1992 (60)

Standards and regulations are potentially powerful tools in preventive efforts to control musculoskeletal disorders at the workplace. Despite their high degree of social and economic impact, only sporadic attempts have been made to evaluate the effectiveness and scientific credibility of existing and proposed standards and guidelines (62).

In a review on ergonomic standards by Dul et al (7) [see Selection of Standards and Guidelines, p 9]), 700 standards were retrieved in a database search using the key word "ergonomics". A repeated search in the same database 4 years later resulted in more than 2000 standards. A large proportion of this rapidly increasing number of standards is apparently being accepted and approved by national authorities and responsible bodies without much public debate, with limited involvement of labor market partners and with the scientific community as more-or-less passive bystanders.

The potential benefits of physical workload standards should not be questioned — a summary of possible "pro's", as suggested by Griffin (63), follows:

- They encourage unification of methods.
- They increase awareness of problems.
- They emphasize the need for health monitoring.
- They emphasize the need for further research.

However, the costs involved in "letting through" a considerable and the probably increasing number of standards that are "confused, internally inconsistent, and contain errors [p 911]" (52) tend to outbalance the benefits. In the current priority planning published by OSHA, a 5-point regulatory strategy was outlined for the development of "standards that make sense to reasonable people". A key point in this regulatory strategy is to focus on the need to eliminate or fix confusing or out-of-date standards. To do so and — even more important — to avoid the continued passing and implementation of new erroneous standards, a code of practice for the evaluation of physical workload standards is strongly required.

It is the aim of the present section of this document to establish a framework of criteria for identifying scientifically "good" and practically efficient physical workload standards and to test the applicability of the criteria by evaluating the standards presented in the preceding section (Presentation of Standards).

EVALUATION CRITERIA

The following three key or core areas in the evaluation procedure were identified: scientific coherency, effectiveness, and usability.

First of all, scientific coherency denotes the degree to which standards are related to scientific knowledge on the causes of the injuries or diseases in question. Standards do not conform to the principles of published scientific work, and the relation to the perceived state of knowledge is frequently unspecified. The first item in the criterion for scientific coherency (item 1) thus addresses the question of whether the scientific basis is described in the standard and if the description is sufficient. It is considered desirable that the accuracy of the guidance in a standard be specified (ie, the coherency between science and the content of standards should be made apparent within the standard). Griffin (63) specified this requirement by stating: "It may be reasonable for standards to define methods that are not supported by scientific data but it is desirable that the basis of the recommended methods is stated. It is unreasonable for standards to imply that they are based on scientific data without giving sufficient information for such claims to be checked [p 57]." Items 2 and 3 in the criteria for coherency evaluate the actual concordance between scientific knowledge and recommendations given in the standard. In item 2 the degree of coherency with the factual basis available (ie, the interpretation and application of scientific knowledge presented in the standard) is assessed. The final item in the coherency criteria (item 3) evaluates the theoretical potential for the type of guidance presented in the standard and assesses whether or not the scientific knowledge — interpreted correctly — is sufficient for the level of accuracy chosen in the standard.

Second, the effectiveness of an occupational safety and health standard concerns the impact of the standard with regard to the prevention of occupational diseases and injuries. The following questions are thus under consideration: (i) is workers' exposure being adequately controlled at the level required by the standard and (ii) are adverse health effects being prevented as a result of the standards (64). The information needed to evaluate the effectiveness of a standard consists of exposure and disease surveillance and — ideally — prospective studies designed to elucidate how the risk of disease is modified by the introduction of a given standard. Exposure surveillance is an important part of the process, mainly because it cannot be assumed a priori that workers' exposure is actually controlled to the level required in a regulatory standard. Unfortunately there are substantial limitations in the information currently available for evaluating the effectiveness of physical workload standards. In order to extend the operational applicability of an effectiveness criterion, even circumstantial information has been included (ie, the

Table 10. Summary of criteria for identifying "good" and practically efficient physical workload standards.

Criteria	Item
Scientific coherency	• Description of scientific basis • Degree of coherency with factual basis • Sufficiency of factual basis with respect to chosen level of accuracy
Effectiveness	• Identification of risk factors • Reduction of exposure levels • Reduction of adverse health effects
Usability	• User friendliness

ability of a standard to identify high-risk jobs or risk factors correctly). In this way, the effectiveness criterion consisted of three single items considering the ability of standards to (i) identify risk factors and high-risk jobs correctly, (ii) reduce exposure levels, and (iii) reduce adverse health effects.

Third, the usability criterion evaluates the potential of the standards for practical implementation and takes into account the potential "user friendliness" of the standards, emphasizing guidelines and recommendations that are easy to read and use. Information concerning employers' and employees' awareness of standards and regulations — and their responses to and interpretation of the guidance presented — is considered to be of major importance. When available, this type of information was incorporated in the single-item criterion for usability.

An overview of the framework for the criteria used in the identification of scientifically "good" and practically efficient physical workload standards is summarized in table 10.

EVALUATION

The 26 physical workload standards reviewed in the section Presentation of Standards were evaluated using this framework of criteria. So that the evaluation procedure could be simplified, the standards were subdivided into groups according to their approach prior to the actual evaluation. The following two rather distinct groups could be identified: (i) standards presenting quantitative-type guidelines for specific exposures with precise and numerical accept criteria and (ii) process-type standards or guidelines presenting mainly qualitative guidelines and focusing on a program approach. Twelve quantitative standards and fourteen process-type standards were identified as follows:

Quantitative standards (Q-type)

- OSHA proposed ergonomics protection standard (OSHA'95) (23)
- Washington State ergonomics rule (27)
- CEN prEN 1005-3: recommended force limits for machinery operation (30)
- CEN prEN 1005-4: evaluation of working postures in relation to machinery (31)
- ISO/CD 11226 ergonomics — evaluation of working postures (32)
- Revised NIOSH equation for the design and evaluation of manual lifting tasks (33)
- ISO/CD 11228-1: ergonomics — manual handling — part 1: lifting and carrying (35)
- CEN prEN 1005-2: manual handling of machinery and component parts of machinery (29)
- IEA TG manual materials handling: methods of risk exposure assessment (36)
- ACGIH proposed TLV for hand activity level (48)
- ISO 2631-1: mechanical vibration and shock: evaluation of human exposure to whole-body vibration: part 1: general requirements (51)
- ISO 5349: mechanical vibration — guidelines for the measurement and assessment of human exposure to hand-transmitted vibration (53)

Process-type standards (P-type)

- Fitting the job to the worker: ergonomics program guideline (State of Washington) (24)
- British Columbia ergonomics requirements (25)
- OSHA ergonomics program standard (OSHA'2000) (26)
- EU council directive 90/269/EEC: minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers (37)
- ANSI Z-365: control of work-related cumulative trauma disorders: part 1: upper extremities (39)
- California State standard (repetitive motion injuries) (40)
- IEA TG exposure assessment of upper limb repetitive movements: a consensus document (41) [4]
- Occupational and individual risk factors for shoulder-neck complaints: part 1 — guidelines for the practitioner (Winkel & Westgaard) [4] (42)

4 These standards are not "clear-cut" process-type (P-type) standards. They constitute an intermediate variant often characterized by a broad exposure definition (taking into account different kinds of exposure) or emphasizing individual risk factors.

- Repetitive work of the upper extremity: part 1 — guidelines for the practitioner (Kilbom) [4] (44)
- Job design for the aged with regard to decline in their maximal aerobic capacity: part 1 — guidelines for the practitioner (Ilmarinen) [4] (56)
- Energy expenditure: ILO encyclopedia (Bonjer) [4] (12)
- Ergonomics program management guidelines for meatpacking plants (58)
- EU council directive 90/270/EEC: minimum safety and health requirements for work with display screen equipment (59)
- The reduction of slip and fall injuries: part 1 — guidelines for the practitioner (Leamon) (60)

The two groups were evaluated separately, and the results are presented in two different sections (partly because minor modifications in one of the evaluation criteria were judged necessary before the process type standards could be evaluated. See the section on process-type standards (pp 39–42) for additional information.

Each standard was assessed for each item of scientific coherency, effectiveness, and usability by the authors of this document, and the results were classified into one of the following categories: +, ++, and +++ to indicate that the standard fulfilled the requirements specified in the criterion, the number of + signs showing the degree of adherence (ie, + = weak, ++ = moderate, +++ = and full adherence); – to indicate that the standard was unable to fulfill the requirements specified in the criterion; and · to denote that the information available was found insufficient to permit a conclusion regarding the criterion in question.

Quantitative standards

Table 11 presents the evaluation results for the quantitative standards.

Scientific coherency

Description of the scientific basis. Only the Washington State ergonomics rule (27), the revised NIOSH equation (33), and the ACGIH proposed TLV for hand activity levels (48) fulfilled all the requirements specified in the criterion for scientific basis. They provided a detailed and sufficient description of the basis of the methods recommended and allowed sources of information in the standards to be traced. For example, the "Concise Explanatory Statement" in the Washington State ergonomics rule presents a comprehensive list of references of the data supporting the risk factors and reference values.

The OSHA draft standard (OSHA'95) (23) and the prEN 1005-3 (30) on force limits contain general lists of references or bibliographies, with no possibilities for tracing the specific background for the different recommendations made. The adherence of the two standards to the criterion was thus rated as weak.

Similar scores were obtained for ISO/CD 11228-1 (35), prEN 1005-2 (29), IEA TG (36) and the two vibration standards (51, 53). The ISO/CD 11228-1 (35), the prEN 1005-2 (29) and the IEA TG manual handling (36) standards do not contain a description of their scientific basis. Instead a general reference is made to the NIOSH guideline (33). This approach rules out, however, the possibilities for the users of the standards to check the important modifications and supplements to the NIOSH guideline proposed in the standards. The ISO 2631-1 whole-body vibration standard (51) only presents general references, and in the ISO 5349 standard (53) on hand-arm vibration no specific references are given to the background papers for the "dose"-response model presented in the annex. [They can however be traced through scientific papers published independently of the standard.]

The standards on work postures (31, 32) failed to meet this criterion in that there was a complete lack of references or information concerning the background for the standards.

Degree of coherency with factual basis. The criterion concerning factual basis considers the degree to which the recommendations and acceptance criteria presented in the standards are related to scientific knowledge on the causes of the injuries or diseases in question. The evaluation and the classification results shown in table 10 are based on contemporary reviews of the epidemiology of work-related musculoskeletal disorders. [As an example see reference 1.]

In general, the Washington State ergonomics rule (27) was considered to be in reasonable concordance with scientific knowledge. The "Concise Explanatory Statement" issued in connection with the rule gives a detailed analysis of the relevant epidemiologic literature supporting the exposure levels specified in the rule. The suggested criteria for assessing the combinations of risk factors and exposure duration remain, however, partly unsupported and the degree of fulfillment of the rule was classified as moderate.

Similar results were obtained for the NIOSH equation (33) and the ACGIH-proposed TLV for hand activity levels (48). The NIOSH equation (33) — and the NIOSH derived guidelines — use three criteria (biomechanical, physiological, and psychophysical) to define recommended weight limits and identify hazardous

Table 11. Evaluation of quantitative standards. (ACGIH = American Conference of Governmental Hygienists, IEA TG = International Ergonomics Association Technical Group, ISO = International Organization for Standardization, NIOSH = National Institute for Occupational Safety and Health (in the United States), OSHA = Occupational Safety and Health Administration (in the United States), TLV = threshold limit value, + = weak, ++ = moderate, +++ = full adherence, (+) = information based on case studies, – = unable to fulfill the requirements specified in the criterion, · = information available found insufficient to permit a conclusion regarding the criterion in question)

Standard	Scientific coherency			Effectiveness			Usability
	Description of scientific basis	Degree of coherency with factual basis	Sufficiency of factual basis with respect to chosen level of accuracy	Identification of risk factors	Reduction of exposure levels	Reduction of adverse health effects	User friendliness
OSHA proposed ergonomics protection standard (OSHA'95) (23)	+	+	+	(+)	(+)	(+)	+
Washington State ergonomics rule (27)	+++	++	+	·	·	·	++
CEN prEN 1005-3: recommended force limits for machinery operation (30)	+	+	–	·	·	·	+
CEN prEN 1005-4: evaluation of working postures in relation to machinery (31)	–	–	+	·	·	·	–
ISO/CD 11226, ergonomics — evaluation of working postures (32)	–	–	+	·	·	·	–
Revised NIOSH equation for the design and evaluation of manual lifting tasks (33)	+++	++	+	+ (+)	·	·	+
ISO/CD 11228-1: ergonomics — manual handling — part 1: lifting and carrying (35)	+	+	+	·	·	·	+
CEN prEN 1005-2: manual handling of machinery and component parts of machinery (29)	+	+	+	·	·	·	+
IEA TG manual materials handling: methods of risk exposure assessment (36)	+	+	+	·	·	·	+
ACGIH proposed TLV for hand activity level (48)	+++	++	+	(+)	·	·	+
ISO 2631-1: mechanical vibration and shock: evaluation of human exposure to whole-body vibration: part 1: general requirements (51)	+	+	+	+ (+)	+	·	–
ISO 5349: mechanical vibration guidelines for the measurement and the assessment of human exposure to hand transmitted vibration (53)	+	+	+	+ (+)	++	·	+

lifting tasks. The validity of the biomechanical and physiological criteria has met some criticism (65), and it is evident that some biomechanical risk factors have not been taken into consideration in the lifting equation (66). The main objection is, however, that the rationale for building a model combining physiological, biomechanical, and psychophysical data into a single number estimate of acceptability has a somewhat limited basis in scientific knowledge. The model expresses a valuable "common sense" approach and may result in "reasonable" weight limits, but the degree of coherency with scientific knowledge was considered moderate.

In the ACGIH proposed TLV (48), the recommendations for exposure thresholds are based on repetition and peak hand force, and, while there is some support for the repetition criterion, the quality of the data supporting the force specifications remains controversial. In addition, there appears to be limited scientific basis for the assessment of highly specific combinations of force and repetitiveness and the associated risk for musculoskeletal disorders, and the result of the rating could be no more than moderate.

The degree of adherence to the criterion was considered weak for the OSHA'95 draft (23), mainly due to the lack of scientific knowledge to support the composite scores in the risk-factor checklists. A similar score was obtained for the prEN 1005-3 on force limits (30). The standard deviates from scientific knowledge with respect to the following important ways: the isometric force capacity values can be questioned and the numerical values of the different multipliers are merely "qualified guessing". The limited lack of coherency with scientific knowledge is recognized in a preface to the standard, admitting the "scarcity of knowledge".

The NIOSH-derived guidelines — ISO/CD 11228-1 (35), prEN 1005-2 (29) and IEA TG (36) — were also

classified as weak, indicating that they fulfilled the criteria less well than the original NIOSH equation (33). Several additional items introduced in these standards (eg, guidelines for pushing and pulling, cumulative weights, and the differentiated load constants) have little basis in scientific knowledge.

The scientific basis for the vibration standards (51, 53) has been a matter of intense debate, showing, at best, a weak association between scientific knowledge and recommendations given in the two standards.[5] The frequency weighting used in ISO 5349 for hand-arm vibration (53) relates to acute sensory effects rather than to chronic peripheral vascular functions, and, therefore, its relevance for risk assessment is questionable (67, 68). At the same time, essential inadequacies and lack of scientific documentation for the risk prediction model in the annex of ISO 5349 have been pointed out (55, 63). In a review on the whole-body vibration standard, Griffin (52) summarized the problems in respect to health guidance, emphasizing major deficiencies in the scientific knowledge base for the standard and concluding that the standard would "cause unnecessary confusion [p 883]".

The degree of coherency with factual basis was considered even more critical for the guidelines on work postures (31, 32). The detailed risk-assessment procedures, combining either frequency of movement or maximal holding times and work postures to determine health risks, appeared more or less coincidental with only a marginal relation to epidemiologic evidence for work postures as a risk factor.

Sufficiency of factual basis with respect to chosen level of accuracy. In general, the ability of the standards to meet the criterion on the chosen level of accuracy was classified as weak. The classification results reflect the evaluators' interpretation of the state-of-the-art of the epidemiologic evidence for work-related musculoskeletal disorders, implying that it is difficult to turn scientific information concerning even well-established generic workplace risk factors into quantitative guidelines. The rating for the prEN 1005-3 on force limits (30) (ie, unable to fulfill the requirements) indicates minor differences between the different physical load factors and therefore suggests that the potential for making quantitative guidelines was considered slightly higher for lifting, posture, repetition, and vibration than for force.

Effectiveness

Identification of risk factors. For most quantitative standards the available information regarding their ability to identify workplace risk factors was considered insufficient to permit conclusions. The OSHA'95 draft (23), the NIOSH lifting equation (33), the ACGIH proposed TLV for hand activity level (48), and the two vibration standards (51, 53), however, partly fulfilled the criterion.

The association for the NIOSH guide (33) was classified as weak to moderate. A number of studies has examined the effectiveness of the guide in terms of its ability to associate jobs with risk of low-back disorders correctly. Marras et al (69) reported that the lifting equation identified high-risk jobs with a reasonable sensitivity, while a large proportion of low- and medium-risk jobs were misidentified, the misidentification indicating marginal specificity. The guideline seems to identify most jobs as being risky, and this apparent bias in the NIOSH method was confirmed by Lavender et al (70) in a study comparing five different methods used to assess the risk of low-back disorders.

The ability of the vibration standards (51, 53) to identify workplace risk factors was also rated weak to moderate. The frequency-weighting procedures of both standards have been criticized. Moreover, the absence of guidance on differential aspects of different axes of vibration or the effect of contact force and posture (hand-arm vibration) strongly affects the correct identification of workplace risk factors (63, 71).

The OSHA'95 draft (23) has not been thoroughly validated. A report on workers' protection from the US General Accounting Office (72) does, however, give some evidence of successful identification of high-risk jobs in five specific ergonomic programs adapting the principles outlined in, for example, the meatpacking guideline (58). Although classified as a quantitative guideline, the OSHA'95 draft (23) does incorporate the main program elements from the meatpacking guideline (58). When the limitations inherent in a case study were taken into consideration, the degree of adherence to the criterion for the draft standard was classified as weak. [The result is placed in parentheses in the summary table (table 11) to indicate that the information was based on case studies.]

The ACGIH-proposed TLV (48) was rated in a similar way. A recent epidemiologic study (50) evaluated the repetition — but not the force — criterion used in the TLV proposal and found an association between

5 Health guidance does not constitute an integral part of the vibration standards. The health guidance presented in the annexes to the vibration standards is, however, considered in the evaluation procedure due to the major impact the recommendations have had on the practical evaluation of vibration exposure.

hand activity level and the prevalence of carpal tunnel syndrome.

The available information was considered insufficient for the newly adopted Washington State ergonomics rule (27), the prEN 1005-3 on force limits (30), and the posture guidelines (31, 32). A similar lack of information was found to exist for the NIOSH-derived lifting guides. The ISO/CD 11228-1 (35), prEN 1005-2 (29), and IEA TG (36) are all preliminary or draft standards, and their ability to identify biomechanical risk factors correctly has not been tested. Minor but potentially significant differences between these guidelines and the original NIOSH equation (33), at the same time, hinder the assumption that the positive association found for the NIOSH guideline a priori can be expected to exist for these guidelines.

Reduction of exposure. With the exception of the OSHA'95 draft (23) and the two vibration standards (51, 53), no information indicating a reduction in exposure levels after the introduction of the standards was available.

Regarding hand-arm vibration there is a considerable amount of information indicating a reduction in vibration levels from handheld power tools manufactured after the passing of the ISO standard (67). The degree of adherence to the "exposure reduction" item was classified as moderate, mainly because a simultaneous increase in exposure time — and possibly cumulative exposure — after the introduction of new tools cannot be ruled out on the basis of current data. Information on trends for whole-body vibration exposure is scarce. There are some indications of a reduction in whole-body vibration levels during the operation of contemporary motor vehicles (73), but the results are less convincing and the association between the standard and reduced exposure could, at best, be classified as weak.

The case study published by the US General Accounting Office (72) describes a reduction in exposure in five facilities adapting the main principles outlined in the meatpacking guideline (58) and incorporated in the OSHA'95 draft (23). Although circumstantial in nature this information was taken as indicative of a weak association (a plus sign in parentheses in table 11) between the program elements in the OSHA draft and reductions in exposure.

Reduction of adverse health effects. In general, there is no valid information showing that the quantitative occupational safety and health standards meet their objectives. Time trends in disease occurrence may actually, in some cases, indicate an increase in disease following the acceptance of the standards. In, for example, Australia the incidence of manual handling injuries has increased since the introduction of a national standard on manual handling (NIOSH-type guideline) and its associated codes of practice (74). This trend could imply that, for some of the standards, the classification should indicate a negative association between the standard and the requirements specified in the criterion. Interpreting time trends in disease occurrence is, however, complicated and may be subject to biases related to changes in administrative practices or disease reporting systems.

It was considered that, regarding most standards, there was insufficient information for a rating. However, some information was available concerning the OSHA'95 draft (23) and the ISO hand-arm vibration standard (53). The US General Accounting Office report (72) found reductions in overall injury and illness incidence rates after the main core elements of an ergonomic program had been implemented. Measurement problems were, however, recognized, and the degree of adherence of the OSHA'95 draft (23) was again classified as weak (in parentheses in table 11) to indicate the uncertainty involved. A general decline in the prevalence of vibration-induced white fingers has been reported in, for example, Sweden, the United Kingdom, Japan, and Finland (67), and this trend indicates a positive association between the introduction of the hand-arm vibration standard and reduced adverse health effects. The association was, however, only reported for vascular disorders. Primarily due to the lack of information considering, for example, neurological or articular disorders, the available information for the hand-arm vibration standard was considered insufficient.

Usability

The usability or "user friendliness" of the standards was rated as rather weak. The standards are often complicated documents that are difficult to use and interpret. The current evaluation of the implementation of the manual handling regulation in the United Kingdom (75) and Australia (74) indicates major problems with the technical terminology and the usability of the differentiated numerical regulations. [In Australia only 50% of the businesses addressing manual handling issues used the code of practice for manual handling, and, of those which did use the code, 50% had modified the code to simplify the content.]

The best rating was given for the Washington State ergonomics rule (27). This new rule combines a straightforward approach with a number of easy-to-use models and an attempt to clarify complicated risk assessment models. This approach was acknowledged in the classification result indicating moderate adherence.

The degree of adherence to the criterion was considered weak for the majority of the standards, mainly

due to the level of complexity inherent in the standards. Despite similar scores, it should be noted that there is a difference in practical usability between, for example, the NIOSH equation (33) and the NIOSH-derived guidelines. The risk assessment procedures and the number of alternative methods described in the ISO/CD 11228-1 (35), prEN 1005-2 (29), and IEA TG (36) manual handling standards complicate the documents, while the "easy-to-use" tables and checklist included in the standards, on the other hand, may benefit the practitioner.

The two guidelines on work postures (31, 32) and ISO 2631-1 on whole body vibration (51) failed to meet the requirements specified in the usability criterion due to conspicuous problems with the interpretation of the standards.

Process-type standards

The evaluation results for the process-type standards are summarized in table 12.

Note that one item — coherency with factual basis — in the criteria for scientific coherency was modified. The item was considered of minor relevance for standards

Table 12. Evaluation of process-type standards. (ANSI = American National Standards Institute, IEA TG = International Ergonomics Association Technical Group, ILO = International Labour Organization, OSHA = Occupational Safety and Health Administration (in the United States), + = weak, ++ = moderate, +++ = full adherence, (+) = information based on case studies, – = unable to fulfill the requirements specified in the criterion, · = information available found insufficient to permit a conclusion regarding the criterion in question)

Standard	Scientific coherency			Effectiveness			Usability
	Description of scientific basis	Adequacy of program elements	Sufficiency of factual basis with respect to chosen level of accuracy	Identification of risk factors	Reduction of exposure levels	Reduction of adverse health effects	User friendliness
Fitting the job to the worker: an ergonomics program guideline (State of Washington) (24)	+	++	+++	(+)	(+)	(+)	+
British Columbia ergonomics requirements (25)	Not relevant	++	+++	·	·	·	+
OSHA ergonomics program standard (OSHA'2000*)* (26)	+++	+++	+++	·	·	·	+
EU council directive 90/269/EEC: minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers (37)	Not relevant	++	+++	(+)	·	·	+
ANSI Z-365: control of work-related cumulative trauma disorders: part 1 — upper extremities (39)	+++	+++	+++	(+)	(+)	(+)	++
California State standard (repetitive motion injuries) (40)	Not relevant	++	+++	·	·	·	+
IEA TG exposure assessment of upper-limb repetitive movements: a consensus document (41)	++	Not relevant	++	·	·	·	+
Occupational and individual risk factors for shoulder-neck complaints: part 1 — guidelines for the practitioner (Winkel & Westgaard) (42)	+++	Not relevant	++	·	·	·	+
Repetitive work of the upper extremity: part 1 — guidelines for the practitioner (Kilbom) (44)	+++	Not relevant	++	(+)	(+)	(+)	++
Job design for the aged with regard to decline in their maximal aerobic capacity: part 1 — guidelines for the practitioner (Ilmarinen) (56)	+++	Not relevant	+	·	·	·	+
Energy expenditure: ILO encyclopedia (Bonjer) (12)	–	Not relevant	+	·	·	·	+
Ergonomics program management guidelines for meatpacking plants (58)	+	+++	+++	(+)	(+)	(+)	++
EU council directive 90/270/EEC: minimum safety and health requirements for work with display screen equipment (59)	Not relevant	++	+++	(+)	(+)	(+)	+
The reduction of slip and fall injuries: part 1 — guidelines for the practitioner (Leamon) (60)	+++	++	+++	·	·	·	+

emphasizing process-type guidance rather than quantitative-type criteria. Instead the ability of the standards to cover main core areas in an ergonomic program (ie, management commitment and employees' involvement, hazard identification, job hazard analysis and control, training, and medical management) was evaluated (criterion item labeled "adequacy of program elements"). For some of the standards certain items in the evaluation criteria were considered irrelevant. These exceptions are specified in the discussion that follows and in thesummary table.

Scientific coherency

Description of the scientific basis. The OSHA ergonomics program standard (OSHA '2000) (26) and the ANSI draft standard (39) fulfilled all the requirements specified in this criterion by providing a detailed and sufficient description of the scientific knowledge base for the methods and procedures recommended.

In the series of guidelines published in the *International Journal of Industrial Ergonomics* the scientific basis for the practical recommendations is presented in separate and independent papers. This division occasionally causes minor difficulties in tracking the specific sources of information for recommendations made in the standards. Nevertheless, the procedure was approved and the guidelines in this series [ie, the shoulder-neck guidelines (42), the repetitive work guideline (44), the energy consumption (job design for the aged) guideline (56), and the slip and fall guideline (60)] were classified in a similar way, indicating full adherence to the criterion.

In the IEA document (41), references to the literature supporting the recommendations and suggestions presented are, in general, available. In some cases, however, the scientific background remains obscure and the degree of adherence in the standard to the criterion was considered moderate.

The State of Washington guideline (24) and the meatpacking guideline (58) present a general list of references with no direct link to recommendations made in the standard or guideline. The number and the quality of the references differ slightly, but the ability of the two standards or guidelines to adhere to the criterion was rated as weak.

Five standards – the British Columbia ergonomics requirements (25), the EU directive on manual handling (37), the California State standard (40), the "ILO" energy expenditure guideline (12), and the EU directive on work with video display units (59) — had no (or only anecdotal) references for their scientific basis and failed to meet the criterion. The British Columbia ergonomics requirements (25), the EU directive on manual handling (37), the California State standard (40), and the EU directive on work with video display units (59) are "formal" or legally binding texts, however, which normally do not contain references. The criterion was thus considered "not relevant" for four out of the five standards.

Adequacy of the program elements. The criterion program element adequacy requires the standards to adhere to core elements in an ergonomics program (ie, management commitment and employee's involvement, hazard identification, job hazard analysis and control, training, and medical management). The OSHA'2000 standard (26), the ANSI draft standard (39), and the meatpacking guideline (58) cover all the program elements, and this coverage was recognized in the classification results indicating full adherence to the criterion. In some of the standards one to two core elements were either missing or inadequately described [eg, management commitment and employees involvement in the State of Washington guideline (24) or medical management programs in the British Columbia ergonomics requirements (25), the EU directive on manual handling (37), the California State standard (40), and the EU directive on work with video display units (59)]. The degree of adherence to the criterion was classified as moderate for these standards. A similar score was obtained for the slip and fall guideline (60). Although the guidelines differ from the more general program type of standards, a relatively high proportion of the core elements was incorporated in the guidelines, and this step was considered sufficient for a classification indicating moderate adherence.

The remaining standards focus mainly on exposure or risk assessment and differ conceptually from the "clear-cut" process or program type of standard. [See the list presented at the beginning of the Evaluation section, pp 34–35.] The "adequacy of program elements" criterion was considered irrelevant for the following standards: the IEA TG (41), the shoulder-neck guideline (42), the repetitive work guideline (44), and the two energy consumption guidelines [one by Ilmarinen (56) and the other by Bonjer (12)].

Sufficiency of factual basis with respect to chosen level of accuracy. In general, the classification results for the process-type standards show a relatively high degree of adherence to the criterion for sufficient factual basis as to the chosen level of accuracy. The criterion considers the degree of concordance between verified scientific knowledge and the level of intended accuracy in the standard. As there is ample epidemiologic evidence for an association between certain physical workplace factors and musculoskeletal disorders, but insufficient knowledge with which to establish safe exposure levels, standards presenting merely qualitative guidelines and practical control procedures were rated high.

For the following nine standards the rating indicated full concordance between scientific knowledge and the level of accuracy presented in the standards: the Washington State guideline (24), the British Columbia ergonomics requirements (25), the OSHA'2000 standard (26),[6] the EU directive on manual handling (37), the ANSI draft (39), the California State standard (40), the meatpacking guidelines (58), the EU directive on work with video display units (59), and the slip and fall guidelines (60).

The degree of adherence was classified as moderate for the IEA TG (41), the shoulder-neck guideline (42), and the repetitive work guideline (44). The classification results reflect a varying degree of unsupported quantitative elements and acceptance criteria in the standards. [It should be noted that the classification of the IEA document (41) recognizes that the main part of the quantitative recommendations given is placed in an annex that is not formally a part of the document.]

The degree of adherence was rated as weak for the two energy consumption guidelines [one by Ilmarinen (56) and the other by Bonjer (12)] due to the limited amount of verified scientific evidence linking violations of the suggested threshold limit values for relative aerobic strain to adverse health effects.

Effectiveness

Identification of risk factors. Information concerning the ability of the process-type standards to identify high-risk jobs correctly is mostly circumstantial. The epidemiologic evidence for the association between physical workplace factors and musculoskeletal disorders is, however, generally more convincing when workers are exposed to several risk factors simultaneously than the evidence for single generic risk factors (eg, force, repetition) (1). This difference implies that process-type standards that take into consideration a wide scope of workplace exposure should have the potential to identify high-risk jobs. When this theoretical potential was verified by case studies, the adherence to the criterion was rated as weak. Parentheses were used in the summary table (table 12) to indicate that the information was based on case studies. This was the case for several standards presenting a broad view of workplace exposure [ie, the State of Washington guideline (24), the ANSI draft (39), the repetitive work guideline (44), and the meatpacking guideline (58)]. [The report from the US General Accounting Office (72) gives circumstantial evidence for the successful identification of high-risk jobs in facilities implementing integrated ergonomic programs adapting the principles outlined in these specific guidelines.]

The directives issued by the Council of the European Communities were considered efficient in identifying workplace risk factors associated with manual handling (37) and work with video display units (59), but again the association was classified as weak mainly due to inconclusive data.

The OSHA'2000 standard (26) was officially repealed in April 2001 and was only effective for a period of approximately 2 months. No data are thus available to document or evaluate the effectiveness of the standard. The classification results for all items in the effectiveness criterion indicate that the information available was insufficient to permit conclusions. It should, however, be noted that the injury-based approach represents a potential problem for the expected or "would have been" effectiveness of the standard. For a injury-based standard, the effectiveness of the standard is based on injuries and illnesses among the workforce being adequately reported. As there is ample evidence of a substantial underreporting of work-related musculoskeletal disorders in OSHA logs (76, 77), the ability of any injury-based standard to reduce exposure levels and adverse health effects is markedly affected. [See the discussion for further details.]

For the British Columbia ergonomics requirements (25), the California State standard (40), Ilmarinen's (56) and Bonjer's (12) guidelines on energy consumption, and the slip and fall guideline (60), the information was considered insufficient for the purpose of drawing conclusions. It was considered likely that the energy consumption guidelines by Ilmarinen (56) and Bonjer (12) could identify situations in which the energy consumption during work exceeded the levels recommended in the guidelines. The potential risk to human health posed by these situations has, however, not been sufficiently substantiated or documented.

Reduction of exposure. The case study review published by the US General Accounting Office (72) describes a reduction in exposure and a successful implementation of controls in five facilities trying to adapt some of the main principles in, for example, the meatpacking

6 The evaluation of the OSHA'2000 standard (26) concerns only the performance-based approach and the identification of potentially hazardous jobs in the basic screening tool. Although some optional, but highly quantitative methods for job hazard analysis have been included in a mandatory appendix, this now historical standard is still predominantly a process type of standard. In addition, some of the methods included in the OSHA appendix have been specifically evaluated in the "quantitative standards" section [eg, the NIOSH lifting equation (33)].

guideline. When the limitations inherent in a case study was taken into consideration, the information was considered indicative of a weak, but positive association between the standards incorporating main core elements in an ergonomic program and a reduction in exposure [the State of Washington guideline (24), the ANSI draft (39), the repetitive work guideline (44), and the meatpacking guideline (58)]. A similar rating, indicating weakadherence to the criterion, was used for the directive on work with video display units (59). This rating was based on a case study reporting reduced levels of mechanical exposure after intervention in concordance with the principles outlined in the directive (78).

No information was available that confirmed a reduction in exposure as a result of the remaining standards being implemented. It should be recognized, however, that the decision to use the category "information insufficient to draw definite conclusions" for these standards represents a somewhat conservative approach. It was considered likely that a large proportion of these standards has had little — if any — impact on work environment issues. Results from the Second European Survey on Working Conditions (79) indicate that the percentage of the workforce exposed to the handling of heavy loads actually increased from 31% to 33% during the time period (1991–1996) that the manual handling directive (37) was put in force in Europe.

Reduction of adverse health effects. In general, there is limited direct information showing that the process type of occupational safety and health standards are meeting the objectives. The US General Accounting Office (72) reported reductions in overall injury and illness incidence rates and reductions in workers' compensation costs in facilities implementing ergonomic programs. However, measurement problems were recognized, and the association between the five standards incorporating main core elements in an ergonomic program and a proved reduction in health effects was considered uncertain. The State of Washington guideline (24), the OSHA'2000 standard (26), the ANSI draft (39), the repetitive work guideline (44), and the meatpacking guideline (58) were, however, classified into the category representing a weak case-study-based degree of adherence to the evaluation criteria. The same degree of adherence was considered to exist for the directive on work with video display units, based on a single case study indicating reductions in pain and musculoskeletal symptoms subsequent to an implementation of the workstation design principles outlined in the directive (78).

For all the other standards, the available information was considered insufficient to permit a positive or negative conclusion to be drawn.

Usability

In general, the usability or "user friendliness" of the process-type standards was rated as weak or moderate. Empirical data concerning the practical implementation of the standards are scarce and — when available — indicative of a difficult process.

The best classification results were obtained for the ANSI draft (39), the repetitive work guideline (44), and the meatpacking guideline (58) (from a usability point of view the focus on a specific industry seems advantageous). Their degree of adherence to the usability criterion was rated as moderate.

Vogel et al (13) described the implementation of the EEC directive on manual handling (37) and emphasized that the process had not been too successful. Similar experiences have been reported for the implementation of the directive on work with video display units (80), and the adherence of the two directives to the usability criterion was classified as weak.

The evaluation results for the other standards reflect that they — as a general rule — are either voluminous and rather complicated documents, or the text is so general and diluted that the practical information value is limited. Their degree of adherence to the criterion was thus considered weak (ie, indicating a somewhat limited "user friendliness").

DISCUSSION

In general, the evaluation was most favorable for the process-type standards. The development of quantitative standards appears more demanding, and efforts to construct scientifically "good" and practically efficient quantitative standards have not been very successful. When the different elements in the evaluation criteria are compared (see tables 11 and 12), the most conspicuous difference between the two types of standards was found in the "scientific coherency" criteria. As emphasized in the introduction, the dilemma for the quantitative standards is a conflict between the intention of providing numerical acceptance criteria differentiating between hazardous and safe jobs and the paucity of scientifically well-founded data allowing such quantitative risk estimates to be established. This dilemma is visualized in the low scores obtained for all the quantitative standards of the last item in the "scientific coherency criterion" (ie, the sufficiency of factual basis with respect to chosen level of accuracy). It is worth noting that the general inability of the quantitative standards to fulfill this criterion item reflects the limitations in our knowledge on work-related musculoskeletal disorders rather than criticizes the standards themselves.

To solve this problem in an optimal way, better designed epidemiologic studies using good exposure and outcome assessment methods are needed. A failure to consider epidemiologic data involves the risk of developing standards that are inconsistent and of limited scientific credibility. It should, however, be recognized that traditional epidemiologic studies — providing at best rough estimates of low, medium, and high exposure levels — will be insufficient to provide numerical accept criteria based on valid dose-response relationships. Acknowledging that traditional epidemiologic cohort studies alone will be unable to provide the knowledge base needed, research into the mechanisms of the disorders with a view to establishing exposure dose, as well as dose-response relationships, should be given high priority. These two sources of data, epidemiologic and experimental, should be maximally utilized in the design of standards.

It is worth noting that, while the "insufficiency of factual basis" is currently an inherent problem in the development of quantitative standards, the two other items in the scientific coherency criterion can be solved given the prerequisites of today. Although most of the quantitative standards received a low rating on the description of scientific basis and the interpretation of the available scientific evidence, the recently adopted Washington State ergonomics rule (27) demonstrates that these issues can be dealt with satisfactorily.

The results from our evaluation and the unfavorable rating for the majority of the quantitative standards provide some support for the use of performance-based, process-type standards in regulatory initiatives against work-related musculoskeletal disorders. It should, however, be recognized that the absence of specific criteria and numerical acceptance criteria in the performance-based standards pose problems for the end users. Compliance with requirements in a regulatory performance-based standard may be obscure and difficult to understand for companies with limited expertise and resources. In the public hearing of the OSHA ergonomics program standard (OSHA'2000) (26), some small or medium-sized companies expressed strong concern about the lack of clear and specific instructions, and, in the final proposal, OSHA responded to this criticism by including simple screening tools and specific compliance end points.

Basically, however, the performance-based approach seems to be in line with current ideas on how to regulate and promote health and safety at work. Recent years have witnessed a transition from a predominately specification approach (with a strong reliance on exposure limits) to a performance or systems approach, emphasizing functional demands on management activities and the overall process of improvement and development (81). At the same time, the results presented in this section concerning the effectiveness of standards indicate that future regulatory actions against work-related musculoskeletal disorders will be the most successful if an integrated ergonomic program approach is adopted. The US General Accounting Office report (72) on several companies with ergonomic programs gives strong — although indirect — support for the belief that well-managed ergonomic programs with high commitment on the part of the stakeholders can be efficient.

On the whole, however, knowledge or documentation of the effectiveness of legislation or standards in reducing work-related musculoskeletal disorders is limited. In a thorough review on ergonomic intervention research, Westgaard & Winkel (82) were unable to find any formal studies on the effect of legislative initiatives. A need for the development of the instruments required for a thorough survey and evaluation of the effectiveness of the regulatory actions is thus obvious. In Europe, the Trade Unions Technical Bureau for Health and Safety has initiated some projects to monitor the transposition and application of European directives on health at work, and these attempts should be encouraged.

Several case studies indicate that intervention directed towards decreasing exposure to single mechanical load factors may have a positive effect on musculoskeletal health. The quality of the studies is however, in general, low, and definite conclusions regarding the beneficial effects of reduced exposure levels are difficult to draw (82, 83). It is thus not possible or meaningful to interpret this type of information as circumstantial evidence in favor of the effectiveness of, for example, standards presenting force limits or guidelines for work postures.

A specific and important issue in the effectiveness question is represented in the OSHA ergonomics program standard (OSHA'2000). This important "benchmark" document presents a strong and well-documented integrated ergonomic program approach that would have had all possibilities for a positive impact on the frequency of work-related musculoskeletal disorders. Due to the repeal of the standard, its true effectiveness will never be known. In retrospect, however, the injury-based (injury-triggered) methodology proposed in the standard calls for some concern.

An injury-based regulation contradicts the general tradition in Europe and the Nordic countries emphasizing the preventive — or proactive — aspects of regulation focusing on employers' responsibility for "avoiding workers' exposure to risk agents". The substantial underreporting characterizing work-related musculoskeletal disorders further aggravates the potential problems with effectiveness. In the economic analysis that was published in a preamble to the standard in the *Federal Register,* the current underreporting rate was estimated to be as high as 50%. OSHA expected that the passing of the standard would have doubled the number

of reported cases due to a combination of incentives for employees to report musculoskeletal disorders inherent in the standard and the obligation to include "persistent signs and symptoms" among the recordable cases. However, the standard might also have created several of important incentives for employers to discourage employee reporting of disorders. A reported case of work-related musculoskeletal disorder was thus the initial trigger that eventually would have required the implementation of all elements — and costs — involved in a full ergonomic program. The net result of these opposing effects is difficult to foresee, but most likely the de facto level of underreporting would have remained substantial.

Underreporting is a major problem for any injury-based standard because it invalidates the effectiveness of the standard a priori and affects its ability to reduce exposure levels and adverse health effects. Although the OSHA ergonomics program standard may, in this respect, have been overly conservative and prone to limitations on effectiveness, the passing of the standard marked an important first step in a long-needed regulatory effort to reduce work-related musculoskeletal disorders, and the subsequent repeal of the standard calls for concern.

A final aspect concerns the usability of the standards. It is evident from the evaluation that efforts are needed to improve the usability and "user friendliness" of future guidelines and enhance the process of implementation through the involvement of labor market partners. In Europe the Trade Unions Technical Bureau for Health and Safety advocates the incorporation of workplace experience in the process of standard making and emphasizes the importance of organized, systematized feedback of users' experience in the revision of existing standards.

In summary, the results from the present evaluation should not be interpreted as an argument against practical recommendations and quantitative suggestions. An official comment from the American Industrial Hygiene Association on ergonomic standards provides strong support for a performance-based approach and acknowledges the inadequacy of dose-response data for specific thresholds. At the same time, however, arguments are presented for the use of quantitative exposure triggers identifying jobs at extreme high (or low) risk. The implication is that quantitative guidelines may be appropriate and useful in some cases but that epidemiologic evidence is needed when such recommendations are presented as threshold limit values capable of eliminating the risk of health impairment to workers.

The CEN standards (the prEN 1005 series) represent a special case in this context with a general inability to meet the suggested evaluation criteria. From originally technical standards with a limited scope, the CEN standards have developed — with the best intentions from the CEN working groups — into health-based standards with a strong commitment to health and safety issues at work. The result appears as an unfortunate combination of very specific numerical accept criteria, limited and undocumented epidemiologic or other scientific basis, and an opaqueness in the standardization process.

The use of regulatory actions in the prevention of musculoskeletal disorders is based on rather identical principles in the Nordic countries with strong adherence to the common European rules on occupational safety and health established in the EU directives. The framework directive (38) and its individual directives have been integrated into the national legislation of all the Nordic countries [7] with only minor amendments to the minimum requirements set at the European level.

In general, the individual directives [eg, the manual handling directive (37), the video display unit directive (59), and the work equipment directive (84)] have been transposed with limited modifications. The mere transliteration of EU statutory principles is, however, as a general rule, supplemented by an important extensive framework of additional implementation measures and transposing instruments (eg, labor inspectorate guidance or national codes of practice). These instruments are, in general, nonmandatory — focusing on qualitative guidelines on how to comply with the general requirements — and highly informative, providing risk assessment models, checklists, and monitoring instruments.

A high level of conformity exists for nonmandatory guidelines in the Nordic countries. This congruence can partly be ascribed to a project of the Nordic Council of Ministers initiated in 1992 with the aim of harmonizing risk assessment models for physical workplace factors between the ergonomists of the Nordic boards of occupational health and safety. The results were published in the *TemaNord* series (85), introducing a methodological approach to risk assessment defining three zones of acceptability using a red-yellow-green rating system ("traffic light"). Conditions (eg, manual materials handling situations, work postures, or monotonous, repetitive worktasks) are considered either unacceptable (action required, red zone), conditionally acceptable (evaluation required, yellow zone) or acceptable (no action required, green zone). This approach has inspired other current European and international standards and guidelines and has markedly influenced the design and layout of labor inspectorate guidelines in the Nordic countries.

SWEDEN

In Sweden, a general ergonomic standard, Ergonomics for the Prevention of Musculoskeletal Disorders, was passed in 1998 (86). It is aimed at designing and arranging workstations, jobs, and work environment conditions in such a way that physical loads implying a risk for health or unnecessary fatigue are averted It requires employers to ensure that work postures and movements, manual handling and other exertion of forces, and physically monotonous, repetitive, closely controlled or restricted work is avoided, and it identifies ways of redesigning work so that these exposures are reduced. It also requires the employer to ensure that the employee has the opportunity to influence the organization of work so that variation and recuperation from fatigue can take place. The employer must also ensure that the employee has sufficient knowledge concerning unsuitable postures and movements, manual handling, proper use of technical equipment and aids, and early indicators of overload. The monitoring of workers' health and the building of health and safety systems in general is focused on separately in the Internal Control provision. The employee is required to be attentive to the employers' instructions and to notify the employer if loads dangerous to health occur. Demands are also made on manufacturers, importers, suppliers, and providers to ensure that technical devices and the like do not impose loads that are dangerous to health or unnecessarily fatiguing. A special section gives equal responsibility to the employers and commissioners of building work and coordinators of common worksites, partnerships, and others engaging chartered labor.

The paragraphs in the provision are nonquantitative and then further commented on in an attachment, "General Recommendations … on the Implementation of the Provisions on Ergonomics for the Prevention of Musculoskeletal Disorders". In the attachment detailed advice is given on methods to design work so that unsuitable postures, movements, manual handling, and other exertion of force are avoided. Contributing factors such as mental strain, unsuitable climate, work surfaces, and personal protective equipment are discussed, as are work organizational factors such as job decision latitude and incentive pay systems contributing to the risk of musculoskeletal symptoms.

Two appendices present a checklist and models for the assessment of work postures, manual handling, and physically monotonous, repetitive work. The models have been further developed from the *TemaNord* publication (85). In these models, work postures, manual handling, and repetitive work are subdivided into the

7 Through the Agreement on the European Economic Area (EEA), Norway is a part of the EU internal market and is obligated to incorporate EU legislation on work environment issues.

following three fields of acceptability: red = unsuitable conditions, yellow = evaluate more closely, green = acceptable conditions. The model for assessing postures has no quantitative limits, the model for lifting combines two types of limits (maximum 25 kg under optimal conditions, further reduced to 3 kg in the green field and lifting within three-fourths of an arm's length), and the model for pushing and pulling has limits for forces according to definitions for red, green, and yellow. The model for repetitive work defines the frequency of work cycles (several times per minute for at least half the shift), and their distribution over the workshift in the red, yellow and green fields are defined in a similar way. When repetitive work is assessed, postures and movements, job decision latitude, and the training or competence demands of the task are also considered. This new ergonomic provision came into force on 1 July 1998 and was followed by a large media campaign.

In order to ensure full implementation of the EU manual handling directive, a supplementary provision was issued in April 2000. This provision on manual handling (87) transposes the detailed text of the EU manual handling directive, and employers are obligated to fulfill all the requirements specified in this supplementary provision when they apply the general ergonomic provision.

NORWAY

The Norwegian authorities have issued two regulations in the field of ergonomics, Heavy and Monotonous Work (88) in 1995 and Work with Display Screen Equipment (89) in 1994, with an implementation period up to 1 January 1999. These regulations implement EU council directives 90/269/EEC (37) and 90/270/EEC (59), respectively. In the regulation on heavy and monotonous work, monotonous and repetitive work is included as well. Some elements of the regulation on work with display screen equipment go further than the minimum requirements of the corresponding EU council directive.

According to the Norwegian regulations the employer can freely choose the preferred means, as long as the demands of the regulations are fulfilled. The regulations are only qualitative and give no limit values. Primary prevention is advocated. In accompanying guidelines, the regulations are explained, and advice is given on how to implement the regulations.

Heavy and monotonous work

The regulation on heavy and monotonous work deals with all kinds of manual work, including heavy work and monotonous, repetitive work. The regulation gives general advice on how to avoid work-related health complaints. It further states that risk factors should be evaluated in the planning, outlining, and implementing phases of work.

The accompanying guideline states the risk factors that should be included in the evaluation. Recommendations concerning weight limits and work postures for lifting are given. The guideline also includes models for assessing work postures during sitting, standing, walking, squatting and lying, work postures relative to weight when lifting, carrying and lowering, force limits in pushing and pulling, and monotonous repetitive work. The models for the assessments were taken from the *TemaNord* publication (85).

Work with display screen equipment

The regulation on work with display screen equipment applies to all employees who regularly use display screen equipment in their daily work. Requirements are given on the function of the screen, keyboard, table, and chair of the workplace and on the lighting, reflection, dazzle, noise, heat, radiation, and air humidity. Requirements are also given for planning and organizing work, preventive measures, and software and hardware. A separate paragraph deals with vision and needs for special glasses. Finally, demands for education, information, and worker involvement are outlined. The extensive accompanying guideline explains the requirements given in the regulation and describes preventive measures.

FINLAND

The EU directives on manual handling (37) and work with visual display units (59) were both translated into Finnish and have been effective in Finland since 1994 (90, 91). Thereafter, manuals have been written to accompany both of these directives, consisting of the government decision themselves and guidelines for their implementation. Both manuals contain a risk analysis and management method with which to assess the activities at workplaces. These manuals are available on the internet at http://fi.osha.eu.int. A checklist for workstations with video screens conforming to the requirements of the directive has been written in Finnish and in Swedish. The Finnish version is available also in electronic form at the home page of the Finnish Institute of Occupational Health (www.ttl.fi).

In the Act on the Protection of Young Employees, work consisting of continuous lifting of weights exceeding 20 kg for men and 15 kg for women is considered hazardous for young workers (< 18 years) (92). Monotonous repetitive work that may cause repetition strain injuries

for an unaccustomed worker is also considered hazardous for young workers. Recently, a paragraph about considering "ergonomic principles", the work environment, and work posture in association with tool and other instrument acquisition and use was included in the Act (93). A manual to clarify further the ergonomic principles is in preparation. The *TemaNord* publication (85) that presents the Nordic evaluation model of physical risk factors at work is being translated into Finnish.

DENMARK

The Danish Working Environment Act adheres to the common European rules on safety at work established in the EU directives. The framework directive (38) and its individual directives have been incorporated into Danish law by a set of executive orders.

The executive orders are accompanied by guidelines and other information aimed at the practical implementation of the regulations (working environment authority guidelines and working environment authority information). The guidelines are nonmandatory and advisory in nature and provide either information on possible ways to apply the regulation or information concerning the code of practice adopted by the work environment authorities.

Manual handling is the subject of several guidelines. The general principles in the manual handling directive (37) and its corresponding executive order have been outlined in a publication called Manual Handling (94), while the guideline Assessments of Lifts (95) presents a criteria model for the assessment of lifting tasks. Taking into account primarily the weight lifted and the horizontal distance to the body, three zones of acceptability (acceptable, conditionally acceptable and not acceptable) are defined in the model in concordance with the approach used in *TemaNord* (85). The maximal acceptable weight to be lifted under optimal conditions is set at 50 kg and is allegedly based on the scientific background documentation for the original NIOSH lifting equation from 1981 (96). In addition limits for carrying or the cumulative mass of manual lifting (maximum 10 000 kg/day for lifts originating close to the body) are included. Recommended force limits for pushing and pulling are incorporated into the guideline Manual Handling and Waste Collection (97), which gives maximum acceptable initial and sustained push and pull forces of 400 N and 200 N, respectively.

The display screen guideline Work with Display Screen Equipment (98) adheres to the regulation in the EU directive (59) and its corresponding executive order. The different paragraphs in the directive are explained, and qualitative recommendations on how to meet the terms specified are given (eg, concerning equipment, environment, and daily work routines).

An executive order and some guidelines bear direct reference to the framework directive and especially article 6.2d emphasizing employers' responsibility for "adapting the work to the individual, especially as regards the design of work place, the choice of work equipment and the choice of working and production methods, with a view, in particular to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health" (38).

The guideline Monotonous Repetitive Work (99) thus provides general information on monotonous, repetitive work while Mapping and Assessment of Monotonous, Repetitive Work (100) presents a model aimed at the identification of jobs implying a high risk of musculoskeletal disorders. The model contains quantitative limits for repetition (a critical exposure level is defined by work cycles of less than 30 seconds or by the same movement patterns being performed more than 50% of the cycle time). Additional risk factors in the model — force, posture, cognitive demands, and organizational factors — are described and characterized in qualitative terms (101).

The guideline Assessment of Working Postures and Movements (102) gives qualitative recommendations for work postures using the same traffic-light approach (red-yellow-green) as the *TemaNord* and the Swedish provision on ergonomics to define levels of acceptability. In addition the guideline Workplace Assessment (103) outlines ways to comply with the requirements given in the framework directive (38) for the implementation of "measures to encourage improvement in the safety and health of workers at work".

Finally, two guidelines Whole-body Vibrations (104) and Hand-arm Vibrations (105) have been issued in relation to the framework directive (38), the individual directive on work equipment (84) and the corresponding executive orders. The guidelines are, with only minor modifications, based on corresponding ISO vibration standards (51, 53).

Conclusions and recommendations: what should be implemented?

There is unquestionably a need for regulatory actions in the prevention of work-related musculoskeletal disorders. Voluntary prevention or nonregulatory efforts have proved to be insufficient, and musculoskeletal disorders remain the most frequent work-related health problem in the European Union (79).

The results presented in this report provide some support for the view that regulatory actions against work-related musculoskeletal disorders will be the most successful if a performance- or process-type approach is adopted. A substantial number of case studies indicates that integrated ergonomic programs can be efficient in protecting workers against work-related musculoskeletal disorders.

In contrast to this positive picture, the potential benefits of quantitative guidelines or numerical threshold limits remain to be proved. The conflict between the intention of providing numerical accept criteria differentiating between hazardous and safe jobs and the paucity of scientifically well-founded data allowing such quantitative risk estimates to be established has not been solved in an optimal manner. Despite remarkable efforts by a large number of individual researchers and scientists involved in the process of standardization — and some promising elements in the new Washington State ergonomics rule — too many quantitative guidelines are still inconsistent and have limited scientific credibility. It should be recognized that quantitative guidelines identifying jobs at extreme high (or low) risks may be appropriate and useful in some cases. The limited amount of epidemiologic evidence, however, calls for concern when such recommendations are presented as "safe" thresholds capable of eliminating the risk of health impairment to workers.

In the Nordic countries the combination of adopting the process-oriented EU directives and the use of nonmandatory, mainly qualitative guidelines and provisions seems to constitute a consistent and sound approach to regulatory action. The nonmandatory guidelines frequently represent a valuable compromise. They have been successful in covering many aspects of risk assessment and have avoided unsupported quantitative recommendations without appearing diluted. At the same time, the emphasis on a process or system approach — focusing on performance and risk-assessment procedures rather than on specific rules — represents a flexible approach well adapted to address the complicated and rapidly changing hazards of today's workplaces.

It should be noted, however, that efforts are strongly needed to develop the instruments required for a thorough survey and evaluation of the effectiveness of the regulatory actions. The implementation of a performance-based approach relies heavily on governmental enforcement policies and the instruments available for inspection (control) and partnership or dialogue with employers and employees. The efficiency of these transposing instruments needs constant evaluation, and current trends in the Nordic countries to prioritize the monitoring of the practical impact of regulatory actions should be encouraged and supported. At the same time, it is of major importance to improve the usability and "user friendliness" of future regulatory actions and enhance the process of implementation through the involvement of labor market partners. The newly established Topic Center for good practice information on work-related musculoskeletal disorders at the European Agency for Safety and Health at Work may be expected to play a key role in this development.

A future challenge to the consistency of regulatory actions in the Nordic countries can be anticipated from the voluntary technical standards, which give new products a presumption of conformity with the machine directive. A series of draft CEN standards — addressing aspects directly related to musculoskeletal disorders and presenting highly quantitative recommendations (see the Evaluation section for further information, p 33) — are currently in a stage of public hearing. If adopted these CEN proposals will become national standards in all the Nordic countries.

Although the technical standards address machine manufacturers and designers and not the safety and health of workers in occupational settings, this distinction is difficult to comprehend for end users. The main problem is not on a formal level, since CEN standards are subordinate to national labor market regulation, and, if conflict exists, national law prevails. The potential problem relates to the confusion of having two sets of standards covering the same musculoskeletal risk factors with an entirely different approach and paradigm.

Currently the problem is not recognized in the Nordic countries. Efforts have so far been directed towards improving minor details in the prEN 1005 series (28–31). The more principal and fundamental questions (ie, the pros and cons of the standards) have received little attention. The preventive benefits of technical standards and requirements for ergonomic design principles must be outweighed with the potential drawbacks of introducing

an element of confusion in the national work environment policies by accepting these CEN standards. It is recommended that this debate be initiated and completed before the voting procedure for the draft standards terminates.

A final aspect in the implementation issue concerns the legislative framework of the European Union. The fact that EU legislation on safety and health at work forms the basis for regulatory actions in all the Nordic countries emphasizes the obligations of the Nordic countries to promote initiatives to improve this framework.

There is, at the moment, a need for new regulations at the community level and a stocktaking of existing directives. The European Trade Union Confederation and the European Trade Union Technical Bureau for Health and Safety are currently demanding community initiatives to ensure that directives "are fully applied and revised to cover the different types of MSD risk properly" (106). Probably the most pertinent problem today is the need to add to the number of individual directives within the meaning of the framework directive (38). The framework directive provides a general outline for risk identification and prevention that is further specified in the following three individual directives with special relevance to work-related musculoskeletal disorders: the manual handling directive (37), the directive on work with video display units (59), and the work equipment directive (84). At present monotonous, repetitive work is not the subject of an individual directive, and it is only referred to in general terms in the pleas of the framework directive for efforts to alleviate "monotonous work and work at a predetermined work-rate and to reducing their effect on health [p 4]". A directive on monotonous, repetitive work to supplement the manual handling directive (37) could thus be an important and appropriate new initiative.

In the Nordic countries (eg, Norway, Sweden, and Denmark) repetitive work has been put on equal footing with manual handling in the legislative and regulatory framework despite the lack of an individual directive. This approach is, however, not the general picture in Europe. The results of an information "request" from the European Agency for Safety and Health at Work (107) demonstrates marked differences between the countries in policies, definitions, and approaches to repetitive work. A repetitive work directive — providing unification in definitions and risk assessment procedures and preventive approaches — would be potentially beneficial for all member states and would, at the same time, transfer momentum to preventive efforts in the Nordic countries.

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