# **Risk Estimation** for Musculoskeletal Disorders in Machinery Design - Integrating a **User** Perspective

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*"Designing is a dynamic social process: a process of negotiation at times, of barter, exchange and trade-offs among all these different interests."*

Bucciarelli (1990)*

* BUCCIARELLI, L.L., 1990. Ethnographic study and simulation of engineering design process. In: HELANDER, M. and NAGAMACHI, M., (Eds.), *Design for manufacturability and Process Planning*, Taylor & Francis, London.

# Foreword

Musculoskeletal Disorders (MSD) is the catch-all term used to describe all work-related injuries and disorders of the back, upper and lower limbs that result in pain and impairment problems for workers. The phenomenon has been variously branded as the 'workplace epidemic' or even the 'occupational plague of the future' in a bid to spotlight the extent of this major and growing occupational problem in industrialised countries.

The findings of the recent *3rd European Survey of Working Conditions*[1] on the increasing prevalence of risk factors and reported health problems involving musculoskeletal disorders, do not bode well for the future.

Work intensity has risen sharply in Europe. Five years ago, 54% of workers worked at very high speed, and 56% worked to tight deadlines. In the latest survey, those figures have risen to 56% and 60% respectively. Despite the predictions of the 1980s that repetitive work would increasingly be automated, 15% of the tasks in Europe's workplaces have highly repetitive work cycles of less than five seconds.

The most common work-related health problems are back pain (33% of workers), stress (28%) and muscle pains (23% of workers complain of neck and shoulder pain, 13% upper limbs and 12% lower limbs). A comparison with the corresponding figures in the last European survey carried out in 1995 shows that self-reported MSD problems have risen sharply by an average of 4% (specifically, a 3% increase in back pain and 6% for muscle pains).

There is a similar worrying increase in risk factors for MSD. The percentage of workers who have painful tiring positions or carry heavy loads for more than a quarter of their time has risen over the last 5 years by an average 3% (47% and 37%, respectively).

The European institutions have made some moves on the issue. The European Agency for Health and Safety at Work on behalf of DG Social Affairs and Employment has published a special report on work related upper limb disorders[2]. This informed the Luxembourg Advisory Committee's MSD Ad Hoc Group debate and subsequent draft opinion on Commission MSD prevention initiatives. The Advisory Committee adopted the opinion in September 2001. Regulatory and non-regulatory actions will be envisaged to raise the level of primary MSD prevention at workplaces in Europe[3].

MSD was also the topic of the Bilbao Agency's European Week 2000. The closing European symposium held in Bilbao in November 2000 concluded that more action is needed to combat work-related musculoskeletal disorders. Both legislative and voluntary measures were discussed.

We look on all these as a first tentative move towards better working conditions in Europe and stronger European legislation on MSD prevention.

1. Merlie and Paoli, Dublin Foundation, 2000.
2. Buckle, P. and Devereux, J., *Work-related neck and upper limb musculoskeletal disorders,* 1999.
3. See Opinion on MSD: An impulse for initiatives from the European Commission, Koukoulaki, Th., *TUTB Newsletter* N° 17, June 2001, p. 38.

In the current body of European legislation, both working environment Directives under the old Article 118 A and product Directives under the old Article 100 A include some ergonomic provisions related to MSD prevention.

Article 6 of Framework Directive 89/391/EEC lays a broadly-worded obligation on employers to adapt the work to the individual, especially as regards the design of work places, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating and reducing the effect of monotonous work and work at a predetermined work-rate.

The Work Equipment (89/655/EEC), Manual Handling (90/269/EEC) and VDU (90/270/EEC) Directives set general minimum requirements for employers to assess ergonomic risks and take appropriate prevention measures. Even so, other than the specific MSD issue addressed by the Manual Handling Directive, no other ergonomic provision sufficiently covers all types of MSD, particularly upper limb disorders (ULDs). A proposal for a Vibration Directive is currently going through the conciliation process.

Product directives like Machinery Directive 98/37/EC give manufacturers a duty to take ergonomic requirements into account at the design stage of work equipment. But these are general requirements intended only to avoid operator fatigue and discomfort; they have no direct bearing on the potential health effects.

In neither case, however - equipment use or design – have any specific common methodologies to *estimate* or *evaluate* risks for MSD been framed at European level. A European consensus on these matters is needed in order to lay down effective guidelines for machinery designers and improve the existing legislation.

The issue is whether, with the current scientific knowledge on MSD pathologies and relevant dose-effect relationships, appropriate indicators and valid methodologies can be set for risk estimation leading on to preventive measures. More research into work-related MSDs is certainly needed to clarify mechanisms and exposure-dose-response relationships (Kilbom, 1999). Improvement of regulation and technical standards development, however, cannot wait on better information. Even using the existing knowledge on MSD, with all its limitations, could bring enormous health benefits to European workers. For example, the number of European workers that already have or will develop cancer before the effects of the asbestos ban in Europe filter through 30 years hence are estimated in the millions.

The Bilbao Agency's report (P. Buckle, 1999) shows that methodologies for estimating the main upper limb risk conditions do exist, and an impressive set of data exists for the prevention of several types of MSD. Manual handling guidelines exist in a number of countries (Italy, Spain, Sweden, Norway, the UK, etc.), but only Sweden, Norway and Denmark have regulations and guidelines that address the prevention of all MSDs in the round. On other continents - like the USA (Washington and California), Canada and Australia - ergonomic regulations for the prevention of back and upper limb disorders are in effect.

The TUTB has always argued that ergonomic aspects cannot be divorced from product design and use. Ergonomics is one thing that cannot be tacked on after a machine has been manufactured, but must be designed-in at the earliest stages. There is much scientific evidence on the close linkages between ergonomic factors and the development of MSD. Also, neither collective protective measures nor personal protective equipment can attenuate MSD hazards. A first step in primary prevention is to eliminate risks at the equipment design stage, so development of technical standards is vital here to plug the yawning gap in technical documents on compliance with the Machinery Directive's ergonomic essential safety requirements. CEN/TC122 Working Group WG 4 "Biomechanics" is currently developing the prEN-1005: Parts 1-5[4] series of standards on machinery-related MSD risks under a Machinery Directive mandate.

Notwithstanding the consensus among the working group experts, the national standards bodies have not yet approved all parts of the series[5].

The debate, in fact, is still open on the relationship between science, technological change and regulations, between national responsibilities and European harmonisation.

The ETUC Executive Committee decided back in 1997 to mount a Europe-wide campaign focused on the prevention of musculoskeletal disorders as a priority for European occupational health and safety policies and to bolster action by its national trade union and European industry federation member organizations.

The campaign was a mass information mix of seminars, information brochures, and technical publications giving more focused guidance on MSD-related issues. The TUTB devised a campaign "tool box"[6], as well as providing scientific support for the seminars and overall coordination.

This guide aims to add a technical tool to the ETUC campaign on musculoskeletal disorders, and especially to the debate on machine safety standards. It is devised as a first follow-up to a previous TUTB publication, *Integrating Ergonomic Principles into C-Standards: TUTB Proposals for Guidelines* (A. Ringelberg, P. Voskamp, 1996) and is mainly addressed to machinery designers.

This document offers up a collection of estimation methods selected from a range of sources that we believe may prove helpful in estimating MSD risk factors in machinery design. It does not claim to be a "quick-fix" problem-solver for evaluating every single risk factor. We want to set a debate rolling among affiliated unions and experts on the different national practices and methodologies in a quest for a European consensus on better ways of preventing MSD.

Initially, the aim is to help inform the framing of standards that maximally reflect the current state of scientific knowledge and state of the art, and exercise positive leverage on the European debate on work-related MSD without undermining the existing directives.

We see the machinery design process as being part of a closed loop with its actual workplace use. Where MSD risks are concerned, the interaction is heightened in that operators physically experience and literally feel in their body the effects of poor design on a daily basis. So our second aim is to feed knowledge from the actual use of machines back to designers' and manufacturers' drawing boards. We mean to factor the end users' perspectives into the design process by showing how workplace knowledge can be channelled into the conceptual stage of machinery design. We strongly believe that end-users can contribute to improved machinery design by informing the process with their real-life experience of interacting with machines and the problems they have met.

As things stand, user information plays little part in machinery design. One or two manufacturers may have their own data sources from customer feedback, but we have no idea how representative they are for user-machine interaction, and the process is not systematic enough to be applied on a wider scale. So, because there

4. EN 1005-1: Safety of machinery - Human physical performance – Part 1: Terms and definitions.
   - prEN 1005-2: Part 2: Manual handling of machinery and component parts of machinery.
   - EN 1005-3: Part 3: Recommended force limits for machinery operation.
   - prEN 1005-4: Part 4: Evaluation of working postures and movements in relation to machinery.
   - prEN 1005-5: Part 5: Risk assessment for repetitive handling at high frequency.
5. See also Standards on biomechanics: close to formal vote, Koukoulaki, Th., *TUTB Newsletter* Nº 17, June 2001, p.36.
6. Other relevant TUTB publications:
   - *Europe under strain* (O'Neill, R., 1999) that describes the general MSD debate and presents a series of case studies on trade unions' actions in Europe and in the rest of the world.
   - A special report on MSD in Europe in the *TUTB Newsletter*, nº 11-12, 1999.
   - *Musculoskeletal disorders and work organisation in the European clothing industry*, Hague, J., Oxborrow, L. and McAtamney, L., 2001.

is no formal method for collecting it via the standardization procedure, that knowledge tends to be lost.

EN-1050: Safety of machinery/Principles for risk assessment, para. 4.2 "Information for risk assessment" requires machinery designers to use a variety of data. Very few of these relate to end users. User characteristics like anthropometric and biomechanical data should be used in the initial stage of setting the machine's limits. Passive data that result from a poorly-designed operator/machine interface (e.g., accident and ill-health data) should also be included in pre-design input. Data that reflects users' experiences are not mentioned. We think that CEN should promote a procedure for feeding back user data into existing standards. More specifically, EN 1050 should include information derived from actual use of machinery in the information for machinery designers. We hope and expect that this handbook will go some way to getting these data incorporated in machinery standards in the future.

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Marc Sapir,
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# Contents

# Authors' Preface
## How to use this guide

This booklet offers guidance on how to identify and estimate MSD risk factors when designing machinery. It also brings the end-user perspective into the design process. It is aimed at machinery designers and occupational health & safety experts. Although quite technical and focused on machinery design, it can also provide helpful pointers on MSD risk factors for machine operators and workers' representatives.

**Section 1** gives background information on MSD definitions and recent statistics in Europe.

**Section 2** outlines different types of user data relevant to machinery design, and techniques for collecting it.

**Section 3** is the core of the book. It provides guidance to designers on screening and estimating MSD risks based on the EN 1050[7] step-by-step approach. It makes no pretence to offer a full risk assessment or solutions for hazardous situations or products. Instead, it gives quantitative and qualitative pointers to the existence of risks.

Two indicative checklists are suggested for the first steps of MSD risk assessment (problem definition and hazard identification). The hazard identification checklists cover 8 different hazard classes (A - H). "Methods" A – G[8] give estimations for each risk in turn. A selection of 18 specific models, sets of reference data and methods for estimating MSD risks are provided in figures, tables and worksheets. *The general heading "Method" is used throughout to systematize the different types of scientific procedures and make them easier to assimilate.*

In this section, different types of user-related data and appropriate ways of collecting them are presented for the different phases of the risk assessment process. The user data proposed here are not exhaustive.

Section 3 is followed by a flowchart illustrating the design phases for MSD risk assessment and the corresponding data, along with collection procedures and techniques. Because this guide does not go into the risk evaluation phase of risk assessment, this is shown with dotted lines in the flowchart.

**Section 4** rounds off the overview of available methods with three fairly complex, *integrated* approaches for assessing *a combination of risks* for upper limbs.

Finally, a questionnaire on MSD-related strain actually felt is included as an **annex** for information purposes. This was originally designed as a tool to determine the physical strain on operators working with existing machinery, but can equally be used by designers to collect information about problems with existing machines for a redesign.

7. EN 1050: 1996, Safety of machinery – Principles for Risk Assessment.
8. Risk estimation methods for hazard H (local stress) and added risk factors like cold are not included as they are dealt with in the integrated estimation methods in Section 4.

The *Step by Step Approach* for machinery designers is explained in more detail below:

**STEP 1 Defining the problem**

The first step in the risk assessment process is to define the problem in terms of the "limits of the machinery" and the "limits of the workplace": what are the main aspects of the intended "life" of the machinery, and what are the key tasks and conditions at the workplace.

Use the specific checklist:
- *Checklist 3.1* "Limits of the machinery". Once *Checklist 3.1* has been filled in, *Step 1* is complete. *Go to Step 2.*

**STEP 2 Hazard Identification**

There is a range of risk factors for MSD (referred to later as factors A – H). Checklist 3.2 offers specific questions for each factor which enable the hazard to be identified.

If the answer to any of the questions in the Checklist is affirmative (usually "yes"), that factor is a *relevant hazard*, and a further risk estimation must be carried out. *Go to Step 3.*

If all the answers are negative (usually "no"), the factor is *not a relevant hazard*. The step-by-step approach is therefore *completed at Step 2.*

**STEP 3 Risk Estimation**

The risk estimation procedures for each factor (A – H) identified as a *relevant hazard* are given in Section 3: Risk estimation, in the corresponding "Methods" (A - G).

The risk estimation procedures give a reasonably comprehensive overview of the state of the art. Some newly-developed methods are also included.

The outcome of *Step 3* may be described in terms of the "three-zone model", *green, yellow* and *red*, meaning that the risk is *acceptable, conditionally acceptable* or *not acceptable*, accordingly.

If the outcome is that the risk is *acceptable*, then the risk assessment is complete.

If the outcome is *conditionally acceptable*, ways must be found of making improvements to the design of the product. Experts may carry out a more detailed risk evaluation. If the outcome is that the risk is *not acceptable*, then appropriate steps must be taken to change the machine design (then start over from *Step 1*).

It is not within the scope of this booklet to propose such measures or solutions. Nor does it aim to present a complete risk assessment. It is merely a proposed guide for screening and estimating MSD risk factors. However, some of the more sophisticated methods for carrying out a risk evaluation are also given.

The criteria used to select estimation methods were: validity, percentage of male/female population covered, applicability and usability. Specific methods are included for risk factors for which no other established methods exist. Other grounds for inclusion were the body which devised the method, the existence of a minimum scientific consensus, and the general applicability of the method (i.e. some methods were mentioned in national legislation, while others were issued by national and European standardization bodies). Finally, recent methods were also included to demonstrate scientific advances in the field of MSD.

The checklists and choice of methodologies for MSD risk estimation were discussed in a European experts select group set up by the TUTB, comprised of Ms A. Ringelberg (Chair), B. Indesteege (INRCT, Belgium), E. Occhipinti (EPM, Italy), M. Sapir (TUTB), G.A. Tozzi (TUTB), Th. Koukoulaki (TUTB), A. Zieschang (KAN, Germany).

All figures and tables extracted from standards have been published in this book with the consent of the relevant standardisation bodies.

Section 1
# Introduction

## 1.1 Background

MSD have been defined in many ways. We have gone with Asa Kilbom's definition of musculoskeletal disorders as "a wide range of inflammatory and degenerative diseases and disorders that result in pain and functional impairment"[9].

The terminology of musculoskeletal disorders also varies within Europe and across the world. Overuse syndrome (OOS), Repetitive Strain Injuries (RSI), Cumulative Trauma Disorders (CTD) are just some of the terms used to name work-related MSD.

These disorders can affect the back, muscles, tendons, nerves and joints of the upper and lower limbs. Their cause is multifactorial. They mainly occur where operators are exposed to a series of risk factors at the workplace. Some factors act in isolation, others in synergy. All result in overload for the operator or user. The external load is transmitted internally to the exposed worker's body tissues and joints.

The risk factors that can lead to MSD include:

**Physical factors:**
- Poor posture
- Repetitive movements
- Force
- Loads
- Vibration
- Direct mechanical pressure on body tissues

Other environmental factors like cold can be aggravating factors.

**Organisational and psychosocial factors:**
- Exposure duration
- Pace of work
- Breaks
- Payment systems
- Job content and control over work
- Mental workload
- How workers perceive work organisation

Risk estimation can inform a preventive strategy on how to improve equipment design, existing workplace conditions and work organisation by lowering the risk of MSD.

9. Kilbom *et al.*, 1996.

A prevention strategy should therefore include load-reducing measures. A good strategy for general MSD prevention should include the following aspects:
- adapting the work to the individual;
- reducing the repetitive pattern of work;
- good ergonomic design of products and workplaces;
- work task and workplace interventions;
- management of workers' complaints;
- appropriate medical surveillance and diagnosis of musculoskeletal disorders as public and occupational health responsibilities;
- a multidisciplinary (covering all risk factors) and participatory approach to risk assessment and prevention measures;
- education and training programmes.

Specific ways of preventing overload or underload of body regions in particular include:
- varying postures and movements;
- avoiding excessively strenuous or long duration muscle force, high frequencies of movements and handling;
- avoiding work in restricted, awkward postures;
- avoiding or reducing exposure to vibration;
- providing sufficient rest breaks for recovery.

## 1.2 Musculoskeletal disorders in Europe

Musculoskeletal disorders affect over 40 million European workers – more than 30% of the workforce. Estimates in various Member States suggest that the total cost of work-related MSDs may vary between 0.5% - 2% of Gross National Product, which is a significant drain on the EU economy. The Eurostat study done for the Commission to achieve comparability of data on recognised occupational diseases in Member States in 1995 (EODS) put MSD among the ten most frequent diseases in the EU. Specifically, Upper Limb Disorders ranked sixth and seventh in the list.

The social cost and suffering caused by disabling (occupational) diseases related to musculoskeletal disorders (MSD) are very high all over Europe. Recent data[10] put the estimated medical costs of MSD in Finland at around 2% of expenditure on publicly-funded health services. Also, the likelihood of WRMSD resulting in lost working days was 3 times greater where there was no ergonomic intervention than where there was. These findings add further weight to the need for manufacturers to design ergonomic machines to minimize MSD risk at a very early stage.

## 1.3 Dilemmas and practical approach - Limitations

The first thing to say is that the science of prevention, diagnosis and action on MSD is far from fully developed. No clear 'dose-effect' relationship for safe exposures has been shown for some risk factors. So far, data on human capabilities has often been used to describe the level of risk. But capability has no direct bearing on the risk of injury. By using epidemiological data on the incidence of MSD, experts have reached a consensus on correcting capability data by including the risk of injuries (i.e., diminishing the capability data by applying a factor)[11].

10. Inventory of socio-economic information about work-related musculoskeletal disorders in the Member States of the European Union - European Agency for Safety and Health at Work, *Fact sheet* number 9: 2000.

11. EN 1005-3: Safety of machinery- Human physical performance - Part 3: Recommended force limits for machinery operation, CEN 2002.

Hands-on research is necessary to improve our knowledge and evidence (causes of infectious or allergic origin are not considered in this report).

But even with the available knowledge, immediate action can be taken to identify, estimate and then eliminate the major risks. This guide should be seen in that context.

The present document is addressed to machinery designers who have no control at the design phase over most of the workplace organizational and psychosocial factors that affect machinery operation. Therefore, only the physical risk factors will be dealt with here. That said, there is no denying the difficulty of separating the machine as such from its intended operating environment. Physical factors cannot be distinguished from time parameters, like frequency and duration, that are taken into account in the proposed methods. Also, the information for use supplied by manufacturers to employers should include all the warnings and preconditions that need to apply in a work environment for other MSD risk factors that interact with the physical ones.

Finally, we acknowledge that some of the methods and data presented here were intended mainly to be applied in the workplace for evaluating existing work equipment, and not specifically for new machinery design. However, they can provide useful risk assessment benchmarks for machinery design.

Moreover, very few machines are designed from scratch. Technology may move on, but new designs are often refinements of an existing conceptual machine design. So evaluating existing machines is often a necessary first step in the machinery design process.

# Section 2
# Integrating a User Perspective in Machinery Design

In this guide, **"user"** means the end user of a machine, i.e., the person whose job it is to install, operate, adjust, maintain, clean, repair, or transport machinery as described in the Machinery Directive[12] as an **operator**.

This section describes the different types of user-related data that are usable for risk assessments at the different stages of the design process, and appropriate procedures for collecting them.

## 2.1 Types of user-related data and collection procedures

A first basic distinction must be made among user requirements and user data stemming from the operator-machine interaction. The first category comprises all the basic data that designers following ergonomic design principles should take into account in designing a machine suited to all intended operators. These data include, for example, anthropometric[13] and biomechanical[14] requirements providing information on operators' body dimensions, physical abilities like strength and other matters.

The other category comprises data derived from a previous operator/machine interaction, i.e., "objective" or "passive" data like accident and health data, and "subjective" or "active" data like users' opinions, complaints or assessments of this interaction. Different data require different data collection methods and techniques. A more detailed outline is given below.

### 2.1.1 User requirements

Users' requirements are data that exist in population databases. When designing a machine to meet the expected operation population requirements, at least the $5^{th}$ to $95^{th}$ percentiles should be covered. Where health and safety aspects are important, wider percentile ranges must be used, at least to the $1^{st}$ and/or $99^{th}$ percentiles (EN 614-1). Work equipment should be designed for both men and women, so the relevant percentiles for female and male populations must be used (EN 614-2)[15]. Although operator requirements are compulsory in machinery design standards, manufacturers do not always make use of these data. Anthropometric misfit can force workers to adopt awkward postures or exert great force, thus exposing themselves to MSD risks.

12. 98/37/EC, Annex I, 1.1.1 (under revision).
13. EN 547-3 and prEN ISO 14738 deal with anthropometric data.
14. The series prEN 1005 deals with biomechanics.
15. EN 614-2:2000- Safety of Machinery-Ergonomic design principles-Part 2-Interactions between the design of machinery and work tasks.

## 2.1.2 User - machine interface data

### Passive data

The passive data referred to in this guide are existing national or European statistical records and data on accidents or occupational diseases. They are data that have been mainly collected for another purpose. The passive data are mostly quantitative, and seldom provide qualitative information. They are useful in giving designers a rough idea of what types of machines are responsible for MSD injuries. The problem is that these types of data are not representative, because accidents and injuries are underreported. Where MSD are concerned, little or no information on ergonomic issues with the machinery which are the main causes of MSD can be extracted from existing accident information systems and compensation records.

Data on accidents related to the safety features of machinery show a discernible cause-effect relationship (causal link). Useful information for alterations to machinery safeguards can be derived from them. On the other hand, it is less easy to extract information on risk factors from MSD records, let alone turn it into prevention provisions. The relationship is less clear-cut. Data on the tasks involved with the disorder are inadequate. So, while occupational disease statistics are immensely valuable in their current form, they are less useful as a ready source of information on MSD risk factors related to one specific type of machine. In the case of MSD, the aetiology is multifactorial, so the cause-effect (risk-disease) is not always one-track like other diseases. In a compensation record, for example, the job description "assembler" conveys no information on the intensity or other aspects of the work from which to extract MSD risk exposure. Such records seldom include production data that might be a pointer to frequency. Whatever else, failings in the structure and fields of the databases available which describe an incident or disease can affect the quality of extractable data.

Very few national systems enable a detailed analysis to be performed on the causes of an accident. **One possible improvement would be for national information systems to be more descriptive and give information on ergonomic factors that can lead to accidents[16] as well as MSD development.**

That is why, useful as the passive data may be, active data can be of more proven effectiveness in designing machinery to prevent MSDs.

### Active data

By "active data", we mean data sourced from users on an ongoing basis. It involves designers actively seeking out information on actual work, complaints of discomfort or pain associated with the machinery, identified risks and opinions, and suggestions for potential machinery improvements derived from users' experiences. This is a proactive approach to machinery design. One manufacturer looks not only at historical facts like accidents, but also takes into account the dynamics of potential hazards that are not properly guarded against in the initial design.

As mentioned in the foreword, important post-construction user-machine interaction information is lost and seldom reaches manufacturers. There must be an information flow between workplaces and manufacturers if machinery design is to be improved. Users of machines both benefit from ergonomics and suffer from the lack of it, so their opinions should be integrated into the design process. They also know about general workplace layout and the way a machine operates, which

16. In some European countries, acute back pain is considered an accident.

makes them more aware of the systemic consequences of machine alterations and more likely to propose sound solutions which take into account the workplace as a whole. Manufacturers may run a financial risk from withdrawing a defectively-designed machine, but operators run the risk of accident or disabling injury.

The Machinery Directive could set a framework for manufacturers to collect such data and factor user comments on their interaction with the machine into the design or improvement process. The General Product Safety Directive[17] requires manufacturers to take measures to inform themselves about whatever risks their products present in actual use. This includes investigating customer complaints.

Users' opinions can be collected during machinery design in two main ways: carrying out focused studies on a specific machine, or using existing national data on users' opinions (where such exist), or by combining the two. One example of the latter would be shop floor data on operators' complaints about machines. The first option would involve constituting a representative population of operators to take part in analysing existing problems in similar machinery using different methods. Industry unions could play a significant role here.

The second possibility involves an ongoing process of data collection at plant level where issues and complaints arise with specific machines before accidents happen and well before the onset of a disease. Here, manufacturers can factor relevant data into the design of a specific machine. Such data are being experimentally collected in France by the local authorities (the alarm sheet project). Similar schemes are thin on the ground in Europe (Italy, Portugal).

Different types of information need to be collected in different ways. Operator groups can be set up for task analysis[18]. Interviews with operators are more suitable for problem analysis – e.g., hazard identification, pinpointing specific latent-risk activities. Questionnaires are a good way of collecting quantitative data about a machine to form a general idea of where improvements can be made[19]. Ideas for alterations to machinery can be elicited through an in-depth survey. Here, focus groups of operators or decision design groups can yield valuable results. Suggestions on suitable techniques for the different phases of risk assessment are presented in Table 1, page 21.

A selection of techniques for collecting user data is given below.

**Controlled studies on a specific machine:**

Different methods can be used to study a specific type of machine:

- User questionnaires
- Operator interviews
- Operator focus groups

S. Caplan (1990) describes how focus groups can be used to address ergonomics problems. Machinery design, and especially MSD risk estimation, requires ergonomic techniques to be informed by operators' experience. Group dynamics and cross-fertilization between participants' knowledge and experience are beneficial to data collection. For MSD risks, homogeneous[20] groups of operators should meet in order to discuss the problems and risks experienced with the same type of machine.

17. Directive 2001/95/EC of the European Parliament and the Council of 3 December 2001 on general product safety.
18. Kirwan & Ainsworth, 1992.
19. Report on data collection project, TUTB-LO Sweden by Soderqvist, A. and TUTB, 1996.
20. Groups of workers that are exposed to the same machine and so to the same risk factors.

• Virtually-transmitted user experiences

Other innovative, technology-driven ways of sourcing user experience can also be found in the literature. Videoconferencing is a way of collecting opinions without having to have users physically present. "Telepresence" (Noro, 1996) is another means of network communication closer to face-to-face conversation.

**Shop floor data collection:**

• Worker participation in ergonomic risk assessments

Framework Health & Safety Directive 89/391/EEC lays a duty on all employers to perform a risk assessment for all the risks at the workplace. Even CE-marked machinery still needs to be evaluated in the working environment. Ergonomic risks should also be included in the assessment process. Workers have the right to participate in risk assessment. The results of MSD risk assessments on specific machines could inform new designs or improvements to machines. Trade unions have an important potential role here.

• Alarm Sheet (Fiche d'alerte) - An example of shop floor data collection

The French Labour Inspectorate is working with AFNOR (French standards institution) on a project in which remarks and comments on machinery-related problems are periodically reported by shop floor operators and collected by the authorities in order to detect potential hazards. Ergonomic problems that could lead to accidents or the development of MSD are also included. The project is an early screening scheme for operator/machine misfits before accidents occur or diseases develop. The idea is less to put manufacturers in court than to inform relevant C-standard development and improved machinery design.

• Discomfort and health complaints questionnaires

The Machinery Directive requires manufacturers to design machinery taking ergonomic principles into account in order to reduce discomfort, fatigue and psychological stress of the operator to the minimum possible. For this, manufacturers have to be able to collect information about the impact of their machine in the working environment. Data like operator discomfort and fatigue are rarely collected at enterprise level, and even where they are, it is for health surveillance purposes and no linkage is made with the machinery responsible for MSD. An analysis of existing records is needed to pinpoint the hazards inherent in machinery that are related to complaints.
Experienced levels of discomfort and fatigue are known predictors for the onset of MSD. These risks can be estimated in users' groups by means of standardised questionnaires. Borg (1990)[21] introduced a psychophysical scaling method. The Nordic questionnaire (Kuorinka *et al.*, 1987)[22] is designed to glean information from musculoskeletal symptoms located in specific regions of the body. A sample of a questionnaire that determines physical strain developed by IAD Darmstadt University of Technology in Germany is given in the Annex.
At this level, manufacturers can improve the quality and comfort of their products by taking users' experiences into account. This information can be gathered for specific machinery. Operators, workers and consumers can give input to improved product design. This creates better products and is a win-win game.

21. Borg., G., Psychophysical scaling with applications in physical work and the perception of exertion. *Scan. J. Work Environ. Health*, 1990, 16, 1:55-58.

22. Kuorinka, I., Jonsson, B., *et al.*, Standardised Nordic questionnaire for the analysis of musculoskeletal symptoms. *Applied Ergonomics*, 1987, 18, 3:233-237.

TABLE 1 **Examples of methods or techniques that can be useful in user experience data collection**

| Method or technique | Primary Purpose | Reference |
|---|---|---|
| Task analysis, functional task decomposition | Problem analysis | Kirwan and Ainsworth, 1992<br>McNeese *et al.*, 1995 |
| Focus groups | Idea generation and concept development | Caplan, 1990 |
| Shared Experience events | Idea generation | O'Brien, 1981 |
| Interviews, Questionnaires | Problem analysis, idea generation | Oppenheim, 1992 |
| Design Decision Group | Idea generation and concept evaluation | Wilson, 1991 |

**Issues around participatory design**

It has to be said here that the success of participatory design and the validity of user-related data are very dependent on how the data is collected. The first thing is to distinguish between voluntary and enforced end-user participation in the design process. Enforced participation and quality circles, for example, where ongoing suggestions for improvement are compulsory and part of the workers' job description, have been viewed with suspicion by trade unions. It is arguable whether such enforced participation is truly participatory and a constructive help in improving a product or a process[23]. In some cases, too, participation was seen as a way of "appropriating" operators' knowledge, and so benefiting only the company[24].

## 2.2 User-related data provisions in technical standards for machinery design

Although the Machinery Directive does not make the harmonized standards mandatory, manufacturers sometimes use them to perform the risk assessment. EN 1050 is the basic standard for risk assessment.

As stated in the foreword, EN 1050[25] as it stands makes no reference to data drawn from users' experience. Expert opinions on qualitative data reached through consensus-building methods like the Delphi technique are optional. Data on users' experience could probably be indirectly derived from such a process, but it is not certain how.

EN 292[26] refers to user input into the design process, but this is in the context of the New Approach Directives, where the user is the buyer of the machine, (the employer).

In other words, the standards provide no channel for users' opinions. **There is a break in the chain between manufacturers and workplace information.**

The only – and that general and non-mandatory - reference to a proactive input by the end-user (operator) comes in standard EN 614-1 (Ergonomics tasks during the design process) in regard to task analysis, and evaluation of a machine mock-up. Specifically, it says that operators can give valuable input to task specification, but does not spell out how (Perform a task analysis: EN 614-1: Safety of Machinery-Ergonomic design principles-Part 1).

The same standard also says that end-users should be involved in the design process when absolutely necessary in the trialing of a model/prototype of a

23. *Handbook of Human Factors and ergonomics*, Gabriel Salvendy, John Wiley & Sons, 1997.
24. Garrigou, A., Daniellou, F., Garballeda, G., and Ruaud, S., 1995, Activity analysis in participatory design and analysis of participatory design activity, *International Journal of Industrial Ergonomics* 15, pp. 311-327.
25. EN 1050: 1996: Safety of machinery-Principles for risk assessment.
26. EN 292: Safety of machinery-Basic concepts, general principles for design Part 1: (under revision).

machine (Evaluate with the operators). In other words, user experience can be called on at the very start or end of the risk assessment process. But data from user's experience can also be extremely useful in other stages of risk assessment on machinery design, like hazard identification and risk estimation. There are many examples of successful participatory approaches in equipment and workplace design. In the specific case of MSD risks, users have a greater impact, since their experience of strains and discomfort can give valuable insights into machinery design flaws.

Section 3

# Guidance for MSD Risk Estimation

The Machinery Directive (98/37/EC) requires designers and manufacturers to take ergonomic aspects into account. The first three steps of the risk assessment based on standard EN 1050[27] are outlined in more detail below.

## 3.1 Step 1 Problem definition – Limits of the machinery

In the design process, the manufacturer has first to define the limits of the machinery, including intended uses and foreseeable misuse *(use Checklist 3.1).*

The machinery design must incorporate known aspects of use and foreseeable misuse. The target population and tasks to be performed with the machine must be defined. The work tasks actually performed with a machine may constitute an MSD hazard to operators. Body characteristics and physical abilities differ between individuals in a working population. Good ergonomic design[28] should meet the needs of 90% of the user group population from the $5^{th}$ to the $95^{th}$ percentile.

The next steps in the design process are to make a rough design, hazard identification and risk analysis. Any hazards should be designed-out as far as possible at this stage.

### 3.1.1 User data input in problem definition

One part of the problem-definition phase of design is to define the intented user group, so information about user requirements needs to be compiled. User requirements obviously have to be included when setting the limits of the machinery, but even so, not all machines are designed taking these data into account.

#### Actual work

In the design process, it is important to take into account foreseeable types of use and misuse of the machine. Designers start the work task specification (EN 614-2[29]) by gathering information on comparable existing tasks and evaluating the workload that each task imposes on the operator. But operators may not always actually work on a machine in the way specified. They may deviate from the assumed working practice to compensate for inherent design defects. Working postures different to those assumed may be adopted in practice, too. Also, not all tasks or technical actions[30] are systematically taken into account in work task specification, so some phases of work with a machine may remain hazardous even after a

27. See also the Diagram: Risk estimation process for MSD risk factors on Machinery design – User input.
28. EN 614-1:1995- Safety of machinery- Ergonomic design principles - Part 1: Terminology and general principles (under revision).
29. EN 614-2:2000- Safety of Machinery- Ergonomic design principles - Part 2: Interactions between the design of machinery and work tasks.
30. Within each cycle several technical actions may be identified. These are elementary manual actions required to complete the operations within the cycle. They imply activities such as holding, pushing and cutting, (Gillbreth and Barns, ANSI).

## Checklist 3.1 **Problem Definition - Limits of the machinery**

| | Life cycle phases | | | |
|---|---|---|---|---|
| **Intended use** | **Construction and installation** | **Operation** | **Maintenance** | **Dismantling** |
| Work tasks | | | | |
| User groups | | | | |
| Space limits | | | | |
| Time limits<br>▪ Duration<br>▪ Frequency | | | | |
| Environmental<br>▪ Climate<br>▪ Noise<br>▪ Lighting | | | | |
| Use of Personal Protective Equipment | | | | |
| Foreseeable misuse | | | | |

From Ringelberg, J.A. and Voskamp, P., *Integrating ergonomic principles into-C-standards for machinery design - TUTB proposals for guidelines*, TUTB, 1996.

risk assessment. That is why designers must explore how machines are actually used in real-life working conditions.

The difference between what really happens and what designers have in mind seems to be one big cause of inefficiently or dangerously designed production facilities (Daniellou, 1987). A participatory approach to design will aim to change the representations of work on which designs are based[31].

## 3.2 Step 2 Hazard identification

This step involves identifying all the potential MSD hazards of the machine's operation. The machine designer can check for each hazard using the relevant questions in Checklist 3.2.

If the answer to a Checklist 3.2 question is affirmative ("yes"), move on *to the next Step2: Risk Estimation (3.3)*. If in doubt, answer "yes". If all answers for any hazard (A-H) in the Checklist are negative ("no") that is *not a relevant hazard* and can be set aside.

The Checklist questions are based on the TUTB report "Integrating ergonomic principles into C-standards for machinery design"(1996)[32], the OSHA checklist[33] and a Checklist on Physical Load[34].

The following are MSD hazards:

### A. Static postures and body movements

Postures and movements can be hazardous and present a risk if they are awkward and strenuous and performed over a long period. A posture can be defined as the position of the body, body segment(s), or joint(s). To prevent MSD, it is important that working postures are such that joints move within a small range of their possible mobility, close to what is called the "neutral position of specific joints". By doing so, the "local strain" for the structures is kept relatively low. It is important to understand that different joints and muscles in the human body have their "own" characteristics and respond differently under external load.

*Postures are static* if maintained for longer than four seconds[35].

The risk of MSD is increased where:
- postures are maintained for longer than 2 minutes;
- there is a high level of force exertion (this means relatively high, related to the abilities of specific muscle groups);
- there is no opportunity for alternating between static postures and movements;
- specific postures are directly related to the work task to be performed (like maintenance of machinery);
- no alternation of tasks is available within a work task (like combining sitting at a control panel with walking to perform inspection).

### B. Manual handling of loads (above 3 kg)

*Manual handling of loads* can be a hazard because of the (high) mass, (high) frequency, poor grip, or awkward posture in relation to a machine.

31. Garrigou, A., Daniellou, F., Garballeda, G. and Ruaud, S., 1995, Activity analysis in participatory design and analysis of participatory design activity, *International Journal of Industrial Ergonomics* 15, pp. 311-327.
32. Ringelberg, J. A. and Voskamp, P., TUTB, 1996.
33. OSHA' s Ergonomics Protection Standard, 2000. The standard was repealed on March 2001 and is no longer in effect.
34. Checklist Physical load, Information brochure (title: *Rug aan rug bij het bestrijden van fysieke belasting*) of the Ministry of Social Affairs and Employment, The Netherlands, 1993.
35. EN 1005-1 Safety of machinery - Human physical performance - Part 1: Terms and definitions, CEN 2001.

### C. Force exertion

*Force exertion* like pushing and pulling with the whole body or pushing a pedal can be a hazard for MSD. Both the initial forces to be delivered and/or the frequencies of muscle force exertion can cause harm.

### D. Repetitive movements

*Movements that have to be repeated frequently* over a long period of time can lead to MSD mainly (but not only) in the upper limbs as a result of overload injuries/reactions of the inflicted tissues. These diseases and complaints are called Work Related Upper Limb Disorders (WRULD).

### E. Hand-arm vibration

*Hand-arm vibration* can cause different upper extremity disorders, like "white finger syndrome", a vascular insufficiency of the hand and fingers (Gemme *et al.*, 1987). Vibration may also contribute to the development of other MSD in the hand-arm-shoulder system, like osteoarthrosis or carpal tunnel syndrome.

### F. Whole-body vibration

*Whole-body vibration* is related to a specific lumbar back disorder, called Hernia Nuclei Pulposi (HNP) and lumbar pain.

### G. Energetic load

*Energetic overload* can be a hazard. Fatigue can lead to a diminishing of muscle co-ordination and so to an increased risk of muscle and joint damage.

### H. Local mechanical stress

*Localized mechanical stresses* are caused by physical contact between soft body tissues and an object or tool in the work environment. Exposures to these stresses occur during work activities where a body part is in contact with a hard or sharp object or when a body part is used as a striking tool (Keyserling *et al.*, 1991[36]). Tools or parts which produce high pressure on the base of the palm can compress the median nerve and cause carpal tunnel syndrome (Tichauer 1966[37], Phalen 1966[38], Hoffman *et al.*, 1985[39], Szabo *et al.*, 1987[40]).

## 3.2.1 User data input in hazard identification

All the potential hazards for MSD disorders are analysed in the hazard identification phase of the design process. It is important here to gather information on registered musculoskeletal diseases related to the use of specific machinery or products. The manufacturer should keep a database on reported diseases (the "passive data" mentioned in Section 2) in relation to the life cycle phase of a machine. Registration and diagnosis[41] of musculoskeletal diseases[42] have to be improved across Europe. It is outside the scope of this document, but seems an essential task for the future, both for Member States and the European Commission.

36. Keyserling, W. M., Armstrong, T. J. and Punnett, L., 1991, Ergonomic job analysis: a structured approach for identifying risk factors associated with overexertion injuries and disorders, *Applied Occupational and Environmental Hygiene*, 6, pp. 353-363.
37. Tichauer, E., 1966, Some aspects of stress on the forearm and hand in industry, *Journal of Occupational Medicine*, 8, pp. 63-71.
38. Phalen, G., 1966, The carpal tunnel syndrome, *Journal of Bone Joint and Surgery*, 48A, pp. 211-228.
39. Hoffman, J. and Hoffman, P. L. 1985, Staple gun carpal tunnel syndrome, *Journal of Occupational Medicine*, 27, pp. 848-849.
40. Szabo, R. M. and Gleberman, R. H. 1987, The pathophysiology of nerve entrapment syndromes, *Journal of Hand Surgery*, 12A (Part 2), pp. 880-884.
41. See also: Sluiter, J. K., Rest, K. M. and Pr. Frings-Dresen, M. H. W., *Criteria document for Evaluation of the work-relatedness of Upper Extremity Musculoskeletal Disorders*, SALTSA, 2000. (It includes a list of ICOH for Upper Limb Disorders.)
42. See also: Hagberg, M. *et al., Work Related MSD's: A reference book for prevention*, Taylor and Francis, 1995.

The experiences of users who have interacted with similar machines is invaluable. The following active data can be used in this phase of the design process:

- **Subjective hazard identification**

Workers interact with machines on a day-to-day basis. They know what risk factors are associated with a machine and can also identify which phases of the production process and specific activities most endanger them. This kind of data derived from operators' experience must be used to prevent MSDs related to machinery by designed-in safety.

- **Experienced strain, discomfort, fatigue and pain information**

Most workers find out that they have MSD only after "receiving" the first signs like discomfort, fatigue and even pain. Experimental studies show that these kinds of symptoms can be precursors of the disease[43]. A questionnaire for sampling users' experienced strain is given in the Annex.

43. *Work Related Neck and Upper Limb Musculoskeletal Disorders*, European Agency for Safety and Health at Work, report prepared by University of Surrey.

# Checklist 3.2 **Hazard Identification**

If any answer is affirmative[44], the designer should move on for that hazard item (A/H) to the following step 3.3 Risk Estimation and the respective Methods A - G. This "will" involve him making assumptions - based on the task specification done in the previous step – about the future machine workstation and subsequent working actions and positions.

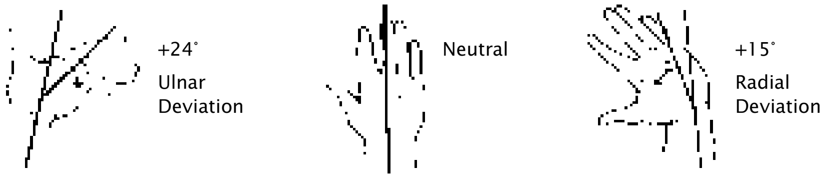
**A. Static postures and body movements**

A.1 Will the operator be standing for more than 1 hour during the work shift?

A.2 Will the operator be seated for more than two hours continuously?

A.3 Will the operator have to use restricted postures like twisting, bending, and kneeling?

A.4 Will joint positioning be involved at more than the neutral position?




A.5 Will the operator need to stretch his arm?

A.6 Will the operator need to work at shoulder height or above?

A.7 Will the operator need to work with knees bent?

A.8 Will there be too little space to maintain a comfortable posture?

A.9 Will the operator be able to change his/her posture? *"No" counts as an affirmative answer to this question.*
(Example: unable to adjust the height of a chair in the machine cab; unable to adjust the height of the machine inlet or outlet.)

A.10 Will the operator have to perform precision work without arm support (e.g., working with keyboards, buttons, and controls or in maintenance work)?

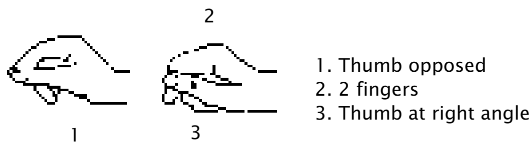
A.11 Will the operator have to read a panel inside or outside the cab?

A.12 Will the operator's feet be supported when seated?

A.13 Will the operator have to press a foot pedal whilst standing?

A.14 Will the operator have to perform a hand/pinch grip?

*Pinch actuation*




**B. Manual handling of loads (above 3 kg)**

B.1 Will handling devices be integrated in the machinery design? *"No" counts as an affirmative answer to this question.*

B.2 Will the operator have to perform manual handling tasks?

**C. Force exertion**

C.1 Can the actions requiring force exertion be performed in an optimal position?
a) as regards body and limb postures;
b) as regards the direction of force application (e.g., the hand-grip of a tool not correctly positioned).
*"No" counts as an affirmative answer to this question.*

C.2 Can movements and force exertion be varied? *"No" counts as an affirmative answer to this question.*

44. "No" may be an affirmative answer to some questions (where indicated).

C.3 Will the operator have to exert:
- pedal force (leg action)
- hand-arm force
- forces with fingertips

C.4 Will the operator have to exert rapidly increasing forces?

C.5 Will the operator have to push or pull with the whole body?

C.6 Will the operator have to push or pull by hand/arm?

C.7 Will the operator have to push or pull with feet/legs?

C.8 Will the operator need to wear gloves or other PPE? (If "yes", the force exerted by the operator will be increased.)

**D. Repetitive movements**

D.1 Will the operator be able to influence the operating sequences or pace of the machine? *"No" counts as an affirmative answer to this question.*

D.2 Will the operator have to perform repetitive movements during more than one hour of a work shift?

D.3 Will the repetitive movements performed last more than 30 minutes in a row?

D.4 Will the cycle time be short (less than 90 seconds)?

D.5 Will there be ergonomically adjusted or adjustable tools available when performing the repetitive movements?
*"No" counts as an affirmative answer to this question.*

D.6 Will the tools be too heavy (i.e., more than 1.0 kg)? Will there be a balancer available? *"No" counts as an affirmative answer to this sub-question.*

**E. Hand-arm vibration**

E.1 Will the machine produce hand-arm vibrations on the operator?

E.2 Will the machine transmit shocks (kick-back) to the operator?

**F. Whole-body vibration**

F.1 Will the machine produce vibrations on the whole body of the operator?

**G. Energetic load**

G.1 Will the operator need to climb a ladder or stairs?

G.2 Will the operator have to perform heavy work with the whole body during more than ten minutes in a work shift?

G.3 Will the operator have to perform light work with the upper limbs during more than one hour?

**H. Local compression**

H.1 Are there sharp edges in the machine, that could cause local compression of the operator's body parts?

## 3.3 Step 3 Risk estimation

In this step, all MSD hazards identified in the previous step must be estimated for potential risks.

This Step 3 presents the estimation of the risk. The outcome will be:
• the risk is estimated to be *acceptable*[45]: green
• the risk is estimated to be conditionally acceptable: yellow
• the risk is estimated to be not acceptable: red

Yellow and red risks need to be further evaluated by subsequent steps in the risk assessment, or preferably removed by redesign.

### 3.3.1 User data input in risk estimation

In this phase, the following passive and active user data can be used:
• MSD and injury statistics
• Discomfort and complaint surveys
• Risk assessment results

#### A. Risk estimation for static postures and body movements

For this hazard, examples of static postures and body movements are given in **Methods A.1-A.3.** *Figure A.1.1* presents a screening method described in prEN 1005-4[46]. It is relevant to both static postures and body movements[47] and can be used in the design process of machinery.

*Figure A.2.1* presents additional information "The estimated acceptable duration for 19 static standing postures" (Dul *et al.*). Table A.3.1 can be used for a quick estimation of acceptable postures taking into account work duration, rest and weight of the objects handled.

45. When concluding that a risk is acceptable, the reader should be aware of the fact that these statements and methods are based on the current state of the art and may well change in the future. It should be clear that risk estimation is only a "rough" screening instrument. If more definite conclusions are needed, a complete risk assessment performed with the help of experts will have to be performed.

46. prEN1005-4: Safety of Machinery – Human physical performance – Part 4: Evaluation of working postures in relation to machinery, CEN 2001.

47. One of the sources: MIEDEMA, M. C., DOUWES M. and DUL J., Recommended maximum holding time for static standing-up working postures. *Dutch Journal of Ergonomics*, 1993.

## Method A.1
## Health risks for static postures and movements

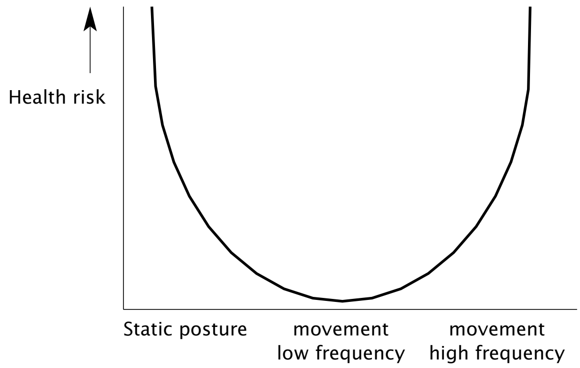
**Variables:**
Health risk, frequency of movement

In prEN 1005-4 the health risks for static postures and movements are described as:

- *acceptable:* the health risk is considered low or negligible for nearly all healthy adults. No action is needed.
- *conditionally acceptable:* there is an increased health risk for some or all of the user population. The risk must be analysed together with contributing risk factors, followed as soon as possible by risk reduction (i.e. redesign) or if that is not possible, other suitable measures.
- *not recommended:* the health risk is unacceptable for any part of the user population.

The prEN 1005-4 risk assessment procedure is based on the U-shaped model, where health risks increase when there is little or no movement or when there is highly frequent movement.

FIGURE A.1.1 **A model of the health risks associated with postures and movements**




Source : prEN 1005-4, 2001.

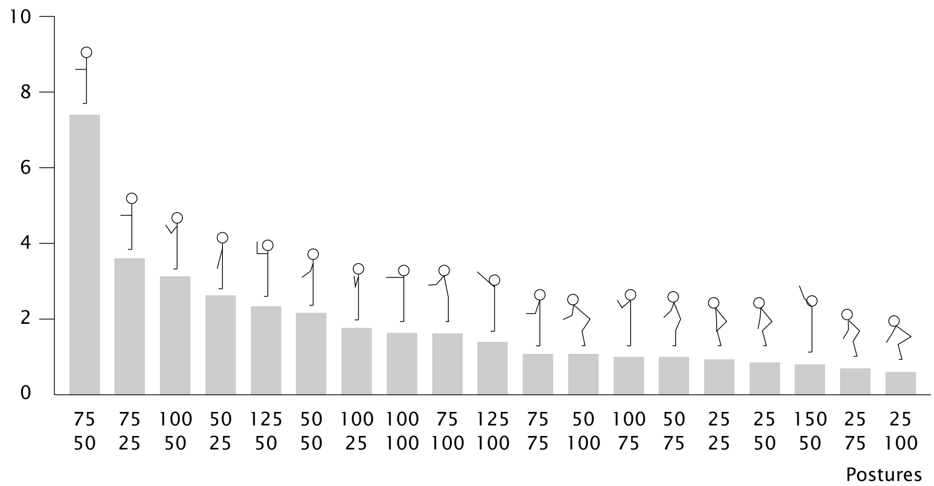
## Method A.2
## Acceptable duration for static postures

**Variables:**
Static standing postures (body angles), duration

**Population covered:**
95% of the population

Estimated maximum acceptable duration (20% MHT – Maximum Holding Time) of 19 static standing postures without rest to avoid "strong discomfort" (individual Borg-score 5, see reference 4, also Section 4.2: OCRA method, Table 4.2.2) in 95% of the population. A posture is defined by the vertical hand position (working height expressed as the percentage of shoulder height in upright standing position) and the horizontal hand position (working distance expressed as the percentage of arm reach). For example, posture 75-50 means that the working height is 75% of the shoulder height, and the working distance is 50% of the arm reach.

FIGURE A.2.1 **Estimated acceptable duration for 19 static standing postures**




Source: Dul, J., Douwes, M. and Miedema, M., A Guideline for the prevention of discomfort of static postures in: *Advances in Industrial Ergonomics and Safety.* Edited by R. Nielsen and K. Jorgensen, Taylor and Francis, London, 1993.

## Method A.3 Acceptable working postures

**Variables:**
Reach distance, reach height, force, relationship between work and rest

Source: Vink, P. and Dul, J. (Red.), *Lichamelijke belasting tijdens arbeid: Wetgeving en oplossingen.* Kerckebosch, Zeist, 1994.

TABLE A.3.1 **Work-related physical strain: regulations and solutions**

| | | **Total working hours / 8h working day** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **3 - 30 min** | | **30 min - 4h** | | **4 - 8h** | |
| | | work-rest quotient/cycle | | work-rest quotient/cycle | | work-rest quotient/cycle | |
| Joint angle | Weight (kg) | <1 | >1 | <1 | >1 | <1 | <1 |
| Neutral | ≤ 0 kg | safe | safe | safe | safe | | |
| | 0 - 1 kg | safe | safe | safe | | | |
| | 1 - 4 kg | safe | safe | | | | |
| Slight | ≤ 0 kg | safe | safe | | | | |
| deviation | 0 - 1 kg | safe | | | risk | | |
| | 1 - 4 kg | safe | | | evaluation | | |
| Extreme | ≤ 0 kg | | | | is needed | | |
| deviation | 0 - 1 kg | | | | | | |
| | 1 - 4 kg | | | | | | |

*Always unsafe: weight of more than 4 kg working in unsupported extreme joint deviations for longer than 30 minutes.*

## B. Risk estimation for manual handling of loads

Assessment methods exist for this hazard that incorporate many parameters of manual handling performance. Variables like distance from the body, distance to be covered with the load, awkward postures adopted while lifting, as well as the reference mass for loads (in Kg) for the intended user population and the frequency of lifts are taken into account.

Estimation of manual handling of loads is presented in **Methods B.1. - B.4.**

*Methods B.1-B.3* present three complicated methods from prEN 1005-2[48]. The first method is a screening tool. The designer is provided with worksheets *(Worksheets B.1a, B.1b)* to fill in. If this simple method reveals a risk, he must move on to the next two methods. The second *(Worksheets B.2a and B.2b)* and third *(Worksheets B.3a and B.3b)* methods incorporate additional risk factors and apply more complicated calculation formulae to evaluate the risk index for manual handling operations. The basic method initially selects a reference load for the intended population from a reference table (Table 1) in the standard. Then, several parameters - including environmental factors, postures, load distance from the body, coupling between hands and feet and frequency of lifts - are evaluated and the reference load can be reduced accordingly. The reference mass for professional use for 85% of the male and female adult population in optimum working conditions, is 25 kg.

The methods in prEN 1005-2 have a common basis with the NIOSH[49] method (1981, 1994), with some adjustments for mass constant and other influencing factors.

*Method B.4.* presents a simple screening model for manual handling from Swedish regulations.

**General remarks on prEN 1005-2:**

Standard prEN 1005-2 will help meet the acknowledged want of a harmonized standard for a Machinery Directive risk assessment of manual handling risks. But there is still room for improvement. The frequency of lifting is much too high in the present version, where operators could be lifting up to 18 tons a day. To illustrate the potential effect of this provision, Denmark's national compensation system provides that lifting more than 15 tons a day constitutes special circumstances, and operators exposed to these working conditions can take their pension after **5 years.** Also, while the Machinery Directive does not distinguish between men and women operators, the standard covers only part of the female population. Specifically, the reference mass of 25 kg in the standard refers only to 70% of the female population. Finally, despite the absence of evidence for the percentage of population covered, there is an exception where the reference mass can exceed 25 kg and be up to **40 Kg.**

48. prEN 1005-2: Safety of machinery- Human physical performance- Part 2: Manual hand-ling of machinery and component parts of machinery, CEN 2000. *(The tables presented here correspond to documents that were in discussion at CEN the period of this publication and can be subject to change.)*
49. Work practices guide for manual lifting. NIOSH, 1981. Applications manual for the revised NIOSH Lifting Equation. CDC, NIOSH, Cincinnati, OH 45226, USA, 1994.

## Method B.1
## Quick screening for manual handling of loads

**Variables:**
Mass, vertical mass displacement, frequency of lifts

**Population covered:**
Free to choose (see Table B.1.1)

## Worksheet B.1a

**RISK ASSESSMENT METHOD 1 - SCREENING BY MEANS OF CRITICAL VALUES**

EN1005 Safety of machinery - Human physical performance -
Part 2: Manual handling of machinery and component parts of machinery

This method provides a quick screening procedure to identify whether the handling operation represents a risk to the operator(s). In Step 2, one of three critical operational situations (case 1-3) must be selected. The limiting condition is that all assumptions for handling operations are fulfilled.

***STEP 1 ▪ CONSIDER THE REFERENCE MASS***

1. identify the intended user population
2. select the reference mass ($M_{ref}$) according to the intended user population (table B.1.1)

***STEP 2 ▪ CARRY OUT THE RISK ASSESSMENT***

Please tick the following criteria for the handling operation, if met:

- ❑ two-handed operation only
- ❑ unrestricted standing posture and movements
- ❑ handling by one person only
- ❑ smooth lifting
- ❑ good coupling between the hands and the objects handled
- ❑ good coupling between the feet and floor
- ❑ manual handling activities, other than lifting, are minimal
- ❑ the objects to be lifted are not cold, hot or contaminated
- ❑ moderate ambient thermal environment

➔ If one or more of these criteria are not met refer to Method 2. If all criteria are met, then select one of the following critical variables. These apply to a work shift of 8 hours or less.

**Case 1**
**critical mass**

- ❑ the load handled does not exceed 70% of the reference mass selected from table B.1.1
- ❑ vertical displacement of the load is equal to or less than 25 cm between hip and shoulder height
- ❑ the trunk is upright and not rotated
- ❑ the load is kept close to the body
- ❑ the frequency of lifts is equal to or less than 0.00333 Hz (1 lift every 5 min)

**Case 2**
**critical vertical mass displacement**

- ❑ the load handled does not exceed 60% of the reference mass selected from table B.1.1
- ❑ vertical displacement of the load is not above shoulder height or below knee height
- ❑ the trunk is upright and not rotated
- ❑ the load is kept close to the body
- ❑ the frequency of lifts is equal to or less than 0.00333 Hz (1 lift every 5 min)

**Case 3**
**critical frequency**

- ❑ the load handled does not exceed 30% of the reference mass selected from table B.1.1
- ❑ vertical displacement of the load is equal to or less than 25 cm between hip and shoulder height
- ❑ the frequency of lifts is equal to or less than 0.08 Hz (5 lifts every min)
- ❑ the trunk is upright and not rotated
- ❑ the load is kept close to the body

or

- ❑ the load handled does not exceed 50% of the reference mass selected from table B.1.1
- ❑ vertical displacement of the load is equal to or less than 25 cm between hip and shoulder height
- ❑ the frequency of lifts is equal to or less than 0.04 Hz (2.5 lifts every min)
- ❑ the trunk is upright and not rotated
- ❑ the load is kept close to the body

***STEP 3 ▪ SELECT THE ACTION REQUIRED***

If the design fits one of the operational situations (cases 1-3) described above, the risk assessment has been carried out successfully.

If none of the operational situations are satisfied, or any of the criteria specified in Step 2 are not met, either:

➔ consider modifying or redesigning the machinery; or

➔ use a more detailed risk assessment procedure to identify critical risk factors (Method 2).

Source: prEN 1005-2, ANNEX C, 2000.

## Worksheet B.1b

**RISK ASSESSMENT METHOD 1 – SCREENING BY MEANS OF CRITICAL VALUES**

EN1005 Safety of machinery - Human physical performance -
Part 2: Manual handling of machinery and component parts of machinery

TABLE B.1.1 **Reference mass ($M_{ref}$) taking into consideration the intended user population**

| | $M_{ref}$ [kg] | Percentage of F&M | F | M | Population group | |
|---|---|---|---|---|---|---|
| **Field of application** | | | | | | |
| Domestic use[1] | 5 | Data not available | | | Children and the elderly | Total population |
| | 10 | 99 | 99 | 99 | General domestic population | |
| Professional use (general)[2] | 15 | 95 | 90 | 99 | General working population, including the young and old | General working population |
| | 25 | 85 | 70 | 90 | Adult working population | |
| Professional use (exceptional)[2] | 30 | Data not available | | | Special working population | Special working population |
| | 35 | | | | | |
| | 40 | | | | | |

*F: Female / M: Male*
*Notes:*
*1. Domestic use*
*When designing a machine for domestic use, 10 kg should be used as a general reference mass in the risk assessment. If children and elderly are included in the intended user population, the reference mass should be lowered to 5 kg.*
*2. Professional use*
- *General: When designing a machine for professional use, a reference mass of 25 kg should not be exceeded in general.*
- *Exceptional: While every effort should be made to avoid manual handling activities or reduce the risks to the lowest possible level, there may be exceptional circumstances where the reference mass might exceed 25 kg (e.g. where technological developments or interventions are not sufficiently advanced). Under these special conditions other measures have to be taken to control the risk according to EN 614 (e.g. technical aids, instructions and/or special training for the intended operator group).*

Source: prEN 1005-2, ANNEX C, 2000.

## Method B.2
## Risk estimation by tables

▪ **Variables:**
mass, vertical mass displacement, vertical location, horizontal location, angle of asymmetry, quality of grip, frequency of lifts in relation to work duration

▪ **Population covered:**
Free to choose (see Table B.2.1)

# Worksheet B.2a

**RISK ASSESSMENT: METHOD 2 - ESTIMATION BY TABLES**

EN1005 Safety of machinery – Human physical performance -
Part 2: Manual handling of machinery and component parts of machinery

***STEP 1 ▪ CONSIDER THE REFERENCE MASS***

1. Identify the intended user population
2. select the reference mass ($M_{ref}$) according to the intended user population (table B.2.1)

***STEP 2 ▪ CARRY OUT THE RISK ASSESSMENT***

Please indicate (tick), whether the handling operation meets the following criteria:

- ❑ two-handed operation only
- ❑ unrestricted standing posture and movements
- ❑ handling by one person only
- ❑ smooth lifting
- ❑ good coupling between the feet and floor
- ❑ manual handling activities, other than lifting, are minimal
- ❑ the objects to be handled are not cold, hot or contaminated
- ❑ moderate ambient thermal environment

➔ If one or more of these criteria are not met, refer to Method 3. If all criteria are met, then determine the level of risk by:
1. calculating the recommended mass limit ($R_{ML2}$) using the multipliers provided in table B.2.2
2. calculating the risk index ($R_I$) as follows:

$$\text{risk index } (R_I) = \frac{\text{actual mass}}{(R_{MLI})} = \frac{\_\_ \text{ [kg]}}{\text{[kg]}}$$

***STEP 3 ▪ SELECT THE ACTION REQUIRED***

| | |
|---|---|
| ❑ $R_I \leq 0.85$ | the risk may be regarded as tolerable. |
| ❑ $0.85 < R_I < 1.0$ | significant risk exists. It is recommended that:<br>➔ Method 3 is applied in order to identify how the risk may be reduced; or<br>➔ the machinery be either redesigned; or<br>➔ ensure, that the risk is tolerable. |
| ❑ $R_I \geq 1.0$ | redesign is necessary. The design can be improved by changing the situations that lead to low multipliers. |

TABLE B.2.1 **Reference mass ($M_{ref}$) taking into consideration the intended user population**

| | $M_{ref}$ [kg] | Percentage of F&M | F | M | Population group | |
|---|---|---|---|---|---|---|
| **Field of application** | | | | | | |
| Domestic use | 5 | Data not available | | | Children and the elderly | Total population |
| | 10 | 99 | 99 | 99 | General domestic population | |
| Professional use (general) | 15 | 95 | 90 | 99 | General working population, including the young and old | General working population |
| | 25 | 85 | 70 | 90 | Adult working population | |
| Professional use (exceptional) | 30 | Data not available | | | Special working population | Special working population |
| | 35 | | | | | |
| | 40 | | | | | |

*F: Female / M: Male*
*Note: Special circumstances (refer to table B.1.1 in Worksheet B.1b).*

Source: prEN 1005-2, ANNEX C, 2000.

## Worksheet B.2b

**RISK ASSESSMENT: METHOD 2 – ESTIMATION BY TABLES**

EN1005 Safety of machinery – Human physical performance -
Part 2: Manual handling of machinery and component parts of machinery

TABLE B.2.2 **Calculation of the recommended mass limit ($R_{ML2}$)**

| | | | | | | | | $R_{ML2}$ |
|---|---|---|---|---|---|---|---|---|
| **Reference mass ($M_{ref}$)** | | | | | | | | = |
| Reference mass [kg] (see table B.2.1) | | | | | | | | $M_{ref}$ |
| **Vertical multiplier ($V_M$)** | | | | | | | | x |
| Vertical location [cm] | 0 | 25 | 50 | 75 | 100 | 130 | >175 | $V_M$ |
| Factor | 0.78 | 0.85 | 0.93 | 1.00 | 0.93 | 0.84 | 0.00 | …….. |
| **Distance multiplier ($D_M$)** | | | | | | | | x |
| Vertical displacement [cm] | 25 | 30 | 40 | 50 | 70 | 100 | >175 | $D_M$ |
| Factor | 1.00 | 0.97 | 0.93 | 0.91 | 0.88 | 0.87 | 0.00 | …….. |
| **Horizontal multiplier ($H_M$)** | | | | | | | | x |
| Horizontal location [cm] | 25 | 30 | 40 | 50 | 55 | 60 | >63 | $H_M$ |
| Factor | 1.00 | 0.83 | 0.63 | 0.50 | 0.45 | 0.42 | 0.00 | …….. |
| **Asymmetric multiplier ($A_M$)** | | | | | | | | x |
| Angle of asymmetry [°] | 0 | 30 | 60 | 90 | 120 | 135 | >135 | $A_M$ |
| Factor | 1.00 | 0.90 | 0.81 | 0.71 | 0.62 | 0.57 | 0.00 | …….. |

| **Coupling multiplier ($C_M$)** | | | | x |
|---|---|---|---|---|
| Quality of grip | GOOD | FAIR | POOR | $C_M$ |
| Description | load length ≤ 40 cm; load height ≤ 30 cm; good handles or hand-hold cut-outs. Easy to handle loose parts and objects with wrap around grasp and without excessive wrist deviation. | load length ≤ 40 cm; load height ≤ 30 cm; and poor handles or hand hold cut -outs or 90° finger flexion. Easy to handle loose parts and objects with 90° finger flexion and without excessive wrist deviation. | load length > 40 cm or; load height > 30 cm; or difficult to handle parts or sagging objects or asymmetric centre of mass or unstable contents or hard to grasp object or use of gloves. | |
| Factor | 1.00 | 0.95 | 0.90 | …….. |

| **Frequency multiplier ($F_M$) dependent on work duration (d)** | | | | | | | | | x |
|---|---|---|---|---|---|---|---|---|---|
| | | FREQUENCY | | | | | | | $F_M$ |
| [Hz] | | 0.0033 | 0.0166 | 0.0666 | 0.1000 | 0.1500 | 0.2000 | > 0.2500 | |
| [lifts/min] | | 0.2 | 1 | 4 | 6 | 9 | 12 | >15 | |
| Work | d ≤ 1 h | 1.00 | 0.94 | 0.84 | 0.75 | 0.52 | 0.37 | 0.00 | |
| Duration (d) | 1 h < d ≤ 2 h | 0.95 | 0.88 | 0.72 | 0.50 | 0.30 | 0.00 | 0.00 | |
| | 2 h< d ≤ 8 h | 0.85 | 0.75 | 0.45 | 0.27 | 0.00 | 0.00 | 0.00 | …….. |
| | | | | | | | | | = |
| | | $R_{ML2} = M_{ref} \times V_M \times D_M \times H_M \times A_M \times C_M \times F_M =$ | | | | | | | …….. [kg] |

Source: prEN 1005-2, ANNEX C, 2000.

## Method B.3
## Risk estimation by formula calculations

**Variables:**
Reference mass, vertical mass displacement, vertical location, horizontal location, angle of asymmetry, quality of grip, frequency of lifts in relation to work duration, number of persons handling the load, additional physically demanding tasks

**Population covered:**
Free to choose (see Table B.3.1)

Source: prEN 1005-2, ANNEX C, 2000.

# Worksheet B.3a

**RISK ASSESSMENT: METHOD 3 – CALCULATION BY FORMULA**

EN1005 Safety of machinery – Human physical performance -
Part 2: Manual handling of machinery and component parts of machinery

***STEP 1 ▪ CONSIDER THE REFERENCE MASS***

1. identify the intended user population
2. select the reference mass ($M_{ref}$) according to the intended user population (table B.3.1)

***STEP 2 ▪ CARRY OUT THE RISK ASSESSMENT***

Please identify (tick), whether the handling operation meets the following criteria:

- ❑ unrestricted standing posture and movements
- ❑ smooth lifting
- ❑ good coupling between the feet and floor
- ❑ the objects to be handled are not cold, hot or contaminated
- ❑ moderate ambient thermal environment

➔ If one or more of the criteria are not met, consider ways of meeting each of the criteria, refer to chapter 4 of this standard. If all criteria are met, calculate the recommended mass limit ($R_{ML}$).

**Case 1**

❑ If the recommended mass limit ($R_{ML2}$) is already known (calculated during Method 2) then calculate the recommended mass limit ($R_{ML}$) as follows:
$\boldsymbol{R_{ML} = R_{ML2} \times O_M \times P_M \times A_T}$ **[kg]**

where:

| | | |
|---|---|---|
| $O_M$ one handed operation | ➔ if true $O_M = 0.6$ | ➔ otherwise $O_M = 1.0$ |
| $P_M$ two person operation | ➔ if true $P_M = 0.85$ | ➔ otherwise $P_M = 1.0$ |
| $A_T$ additional physically demanding tasks | ➔ if true $A_T = 0.8$ | ➔ otherwise $A_T = 1.0$ |

**Case 2**

❑ If the recommended mass limit ($R_{ML}$) has not been calculated then calculate the recommended mass limit ($R_{ML}$) as follows:
$\boldsymbol{R_{ML} = M_{ref} \times V_M \times D_M \times H_M \times A_M \times C_M \times F_M \times O_M \times P_M \times A_T}$

the following definitions apply:

| | | |
|---|---|---|
| $V_M = 1 - 0.003\,\lvert V - 75\rvert$ | ➔ if V < 0 cm, $V_M = 0.78$ | ➔ if V > 175 cm, $V_M = 0$ |
| $D_M = 0.82 + 4.5/D$ | ➔ if D < 25 cm, $D_M = 1$ | ➔ if D > 175 cm, $D_M = 0$ |
| $A_M = 1 - (0.0032A)$ | | ➔ if A > 135°, $A_M = 0$ |
| $H_M = 25/H$ | ➔ if H < 25 cm, $H_M = 1$ | ➔ if H > 63 cm, $H_M = 0$ |

$M_{ref}$ the reference mass from table B.3.1, in kg
***V*** vertical location of the load, in cm
***D*** vertical displacement of the load, in cm
***H*** horizontal location of the load, in cm
***A*** angle of asymmetry, in degree
$C_M$ coupling multiplier from table B.3.2
$F_M$ frequency multiplier from table B.3.3

| | | |
|---|---|---|
| $O_M$ one handed operation | ➔ if true $O_M = 0.6$ | ➔ otherwise $O_M = 1.0$ |
| $P_M$ two person operation | ➔ if true $P_M = 0.85$ | ➔ otherwise $P_M = 1.0$ |
| $A_T$ additional physically demanding tasks | ➔ if true $A_T = 0.8$ | ➔ otherwise $A_T = 1.0$ |

calculate the risk index ($R_I$) as follows: risk index ($R_I$) = $\frac{\text{actual mass}}{(R_{MLI})} = \_\_\_$ $\frac{[kg]}{[kg]}$

***STEP 3: SELECT THE ACTION REQUIRED***

| | |
|---|---|
| ❑ $\boldsymbol{R_I \le 0.85}$ | the risk may be regarded as tolerable. |
| ❑ $\boldsymbol{0.85 < R_I < 1.0}$ | significant risk exists. It is recommended to: ➔ redesign the machinery; or ➔ ensure that the risk is tolerable. |
| ❑ $\boldsymbol{R_I \ge 1.0}$ | redesign is necessary. The design can be improved by changing the situations that lead to low multipliers. |

## Worksheet B.3b

**RISK ASSESSMENT: METHOD 3 - CALCULATION BY FORMULA**

EN1005 Safety of machinery - Human physical performance -
Part 2: Manual handling of machinery and component parts of machinery

TABLE B.3.1 **Reference mass ($M_{ref}$) taking into consideration the intended user population**

| | $M_{ref}$ [kg] | Percentage of F&M | F | M | Population group | |
|---|---|---|---|---|---|---|
| **Field of application** | | | | | | |
| Domestic use | 5 | Data not available | | | Children and the elderly | Total population |
| | 10 | 99 | 99 | 99 | General domestic population | |
| Professional use (general) | 15 | 95 | 90 | 99 | General working population, including the young and old | General working population |
| | 25 | 85 | 70 | 90 | Adult working population | |
| Professional use (exceptional) | 30 | Data not available | | | Special working population | Special working population |
| | 35 | | | | | |
| | 40 | | | | | |

*F: Female/M: Male – Note: Special circumstances (refer to table B.1.1 in Worksheet B.1b)*

TABLE B.3.2 **Coupling multiplier ($C_M$)**

| | Good | Fair | Poor |
|---|---|---|---|
| **Quality of grip** | | | |
| Description | load length ≤ 40 cm; load height ≤ 30 cm; good handles or hand-hold cut-outs. Easy to handle loose parts and objects with wrap around grasp and without excessive wrist deviation. | load length ≤ 40 cm; load height ≤ 30 cm; **and** poor handles **or** hand-hold cut-outs or 90° finger flexion. Easy to handle loose parts and objects with 90° finger flexion and without excessive wrist deviation. | load length >40 cm **or**; load height > 30 cm; **or** difficult to handle parts **or** sagging objects **or** asymmetric centre of mass **or** unstable contents **or** hard to grasp object **or** use of gloves. |
| Factor | 1.00 | 0.95 | 0.90 |

TABLE B.3.3 **Frequency multiplier ($F_M$)**

| Frequency | | Work duration *(d)* 2 h < d ≤ 8 h | | 1 h < d ≤ 2 h | | d ≤ 1 h | |
|---|---|---|---|---|---|---|---|
| [Hz] | [Lifts/minute] | V < 75 cm | V ≥ 75 cm | V < 75 cm | V ≥ 75 cm | V < 75 cm | V ≥ 75 cm |
| ≤ 0.00333 | ≤ 0.2 | 0.85 | 0.85 | 0.95 | 0.95 | 1.00 | 1.00 |
| 0.00833 | 0.5 | 0.81 | 0.81 | 0.92 | 0.92 | 0.97 | 0.97 |
| 0.01666 | 1 | 0.75 | 0.75 | 0.88 | 0.88 | 0.94 | 0.94 |
| 0.03333 | 2 | 0.65 | 0.65 | 0.84 | 0.84 | 0.91 | 0.91 |
| 0.05000 | 3 | 0.55 | 0.55 | 0.79 | 0.79 | 0.88 | 0.88 |
| 0.06666 | 4 | 0.45 | 0.45 | 0.72 | 0.72 | 0.84 | 0.84 |
| 0.08333 | 5 | 0.35 | 0.35 | 0.60 | 0.60 | 0.80 | 0.80 |
| 0.10000 | 6 | 0.27 | 0.27 | 0.50 | 0.50 | 0.75 | 0.75 |
| 0.11666 | 7 | 0.22 | 0.22 | 0.42 | 0.42 | 0.70 | 0.70 |
| 0.13333 | 8 | 0.18 | 0.18 | 0.35 | 0.35 | 0.60 | 0.60 |
| 0.15000 | 9 | 0.00 | 0.15 | 0.30 | 0.30 | 0.52 | 0.52 |
| 0.16666 | 10 | 0.00 | 0.13 | 0.26 | 0.26 | 0.45 | 0.45 |
| 0.18333 | 11 | 0.00 | 0.00 | 0.00 | 0.23 | 0.41 | 0.41 |
| 0.20000 | 12 | 0.00 | 0.00 | 0.00 | 0.21 | 0.37 | 0.37 |
| 0.21666 | 13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 |
| 0.23333 | 14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 |
| 0.25000 | 15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 |
| >0.2500 | >15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

*V is the vertical location*

Source: prEN 1005-2, ANNEX C, 2000.

## Method B.4
## Assessment of lifting work

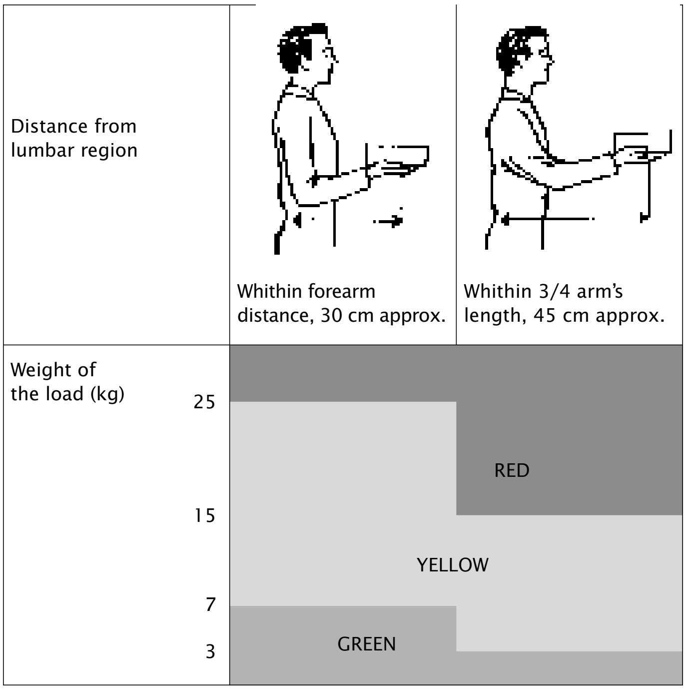
**Variables:**
Weight of the load,
distance from the body

**Population covered:**
The model is valid for both sexes

Source: AFS 1998: Swedish Regulation on MSD Prevention.

The following model for the assessment of lifting work concentrates on two main factors: the weight of the load, and the distance of its centre of gravity from front of the body. As a result, key factors like lifting frequency, duration of lifting work, lifting heights, and ease with which the load can be grasped are not included.

FIGURE B.4.1 **Model for assessment of lifting work**



## C. Risk estimation for force exertion

For this hazard, the external force (the actual amount of hand force exerted) values must be measured (in Newtons) for every machine-related pulling and pushing activity involving the operator's hands or legs. Force can be also estimated indirectly by the weight of the object manipulated in kilograms, taking account of hand posture and population strength data. Methods **C.1 - C.5** present relevant estimation models.

For force exertion like pushing and pulling with the whole body, or pushing a button or a pedal, *Table C.1.1* taken from EN 1005-3[50] shows a tabular way of carrying out risk estimation with values for isometric force capacity under optimal conditions. Both capacity data for the 15$^{th}$ percentile of professional users and the 1$^{st}$ percentile of domestic users are given. This figure also includes pushing and pulling with the whole body. Bear in mind that these data do not include a safety margin or constitute a risk index.

A simple model for assessment of pushing and pulling work from Swedish Regulations is presented in *Table C.2.1.*

Acceptable weights and forces from Snook and Ciriello, 1991 are given in *Table C.3.1.*

*Table C.4.1* gives recommended distance- and frequency-related forces (A. Mital *et al.*). If the actual value is higher than in these tables, the risk is not acceptable. The design must be changed or a further risk evaluation carried out. *Table C.5.1* shows a table for force multipliers for different female and male population from French standard NF X 35-106. *Table C.5.2* and *Figure C.5.1* from the same standard recommend force values for different postures and frequencies.

Experts can also use the prEN 1005-3 formula to calculate the risk index for different user groups and different force exertions.

50. EN 1005-3: Safety of machinery- Human physical performance - Part 3: Recommended force limits for machinery operation, CEN, 2002.

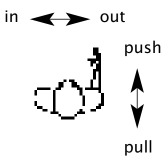
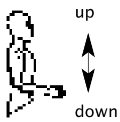
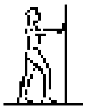
## Method C.1
## Force capacity limits for actions for professional and domestic use

**Variables:**
Hand force, activities

**Population covered:**
These limits represent the general European working population in the given age and gender mix. It is recommended that force limits for professional users should correspond to the 15th percentile of the whole adult population, i.e., males and females between 20 and 65 years of age. Force limits for machines intended for domestic use should correspond to the 1st percentile of the same adult population.

Source: EN 1005-3, 2002.

TABLE C.1.1 **Basic force capacity $F_B$. Pre-calculated isometric force capacity limits for some common actions for professional and domestic use**
The values apply to optimal working conditions

| Activity | | Professional use (N) | Domestic use (N) |
|---|---|---|---|
|  | Hand work (one hand) power grip | 250 | 184 |
|  | Arm work (sitting posture, one arm): | | |
| | ▪ upwards | 50 | 31 |
| | ▪ downwards | 75 | 44 |
| | ▪ outwards | 55 | 31 |
| | ▪ inwards | 75 | 49 |
| | ▪ pushing | | |
| | - with trunk support | 275 | 186 |
|  | - without trunk support | 62 | 30 |
| | ▪ pulling | | |
| | - with trunk support | 225 | 169 |
| | - without trunk support | 55 | 28 |
|  | Whole body work (standing posture): | | |
| | ▪ pushing | 200 | 119 |
| | ▪ pulling | 145 | 96 |
|  | Pedal work (sitting posture, with trunk support): | | |
| | ▪ ankle action | 250 | 154 |
| | ▪ leg action | 475 | 308 |

## Method C.2
## Assessment of pushing and pulling work

**Variables:**
Hand force starting, Hand force continuous

**Population covered:**
The limits apply to both sexes

Source: AFS 1998:1 Swedish Regulations on MSD Prevention.

TABLE C.2.1 **Model for assessment of pushing and pulling work**

| Force (N) | Red | Yellow | Green |
|---|---|---|---|
| Starting | >300 | 300-150 | <150 |
| Continuous | >200 | 200-100 | <100 |

This model refers to good ergonomic conditions, i.e., a symmetrical two-handed grip, properly designed handles positioned at a suitable height and good ambient conditions. If, for example, the object is to be moved over a long distance, the operation is repeated frequently or for a long time, or the grasping height deviates considerably from about elbow height, then the values in this model should be reduced accordingly. The same applies where the work is done using one hand only.

## Method C.3
## Acceptable weights and forces for manual handling tasks

**Variables:**
Kind of hand force: initial and sustained, frequency, vertical distance from floor to hands

**Population covered:**
90% male, 90% female

Source : Snook, S.H. and Ciriello, V.M., The design of manual handling tasks: revised tables of maximum acceptable weights and forces. *Ergonomics* 34 (9), 1991: 1197-1213.

TABLE C.3.1 **The design of manual handling tasks: revised tables of maximum acceptable weights and forces**

| | **2.1 m push / one push every** | | | | | **15.2 m push / one push every** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 min | 2 min | 5 min | 30 min | 8 h | 1 min | 2 min | 5 min | 30 min | 8 h |
| **Height** | | | | | | | | | | |
| | **Male P90** | | | | | | | | | |
| 144 | Initial forces | | | | | | | | | |
| | 25 | 25 | 26 | 26 | 31 | 19 | 19 | 20 | 21 | 25 |
| 144 | Sustained forces | | | | | | | | | |
| | 15 | 16 | 18 | 18 | 22 | 11 | 12 | 13 | 14 | 16 |
| | **Female P90** | | | | | | | | | |
| 135 | Initial forces | | | | | | | | | |
| | 17 | 18 | 20 | 21 | 22 | 14 | 14 | 15 | 16 | 17 |
| 135 | Sustained forces | | | | | | | | | |
| | 10 | 10 | 11 | 12 | 14 | 6 | 6 | 7 | 7 | 9 |

*Height: vertical distance from floor to hands (cm).*

## Method C.4
## Limit values for pushing and pulling with the whole body

**Variables:**
Distance, frequency, pull or push, kind of whole body force: initial and sustained

**Population covered:**
75% female, 90% male

Source: Delleman, N.J., van der Grinten, M.P. and Vuga, V.H. Den Haag, *Hildebrandt. Handmatig duwen/trekken en gezondheidseffecten*, 1995.

A Dutch study on whole-body pushing and pulling gives the following limit values (kg) (based on Mital, A., Nicholson, A.S. and Ayoub, M.M., *A guide to manual materials handling*, Taylor and Francis, London, 1993).

TABLE C.4.1 **Hildebrandt. Health impacts of manual push/pull movements**

| | **Frequency** | | | | |
|---|---|---|---|---|---|
| | **10/min** | **5/min** | **1/min** | **12/hour** | **1/8 hour** |
| **Distance** | | | | | |
| 2 m | 16-8 | 18-10 | 20-14 | D:24-16<br>T: 20-16 | D: 30-20<br>T:20-20 |
| 8 m | | 14-6 | 20-10 | 20-14 | D: 26-16<br>T: 20-18 |
| 15 m | | | 18-8 | 20-12 | 20-14 |
| 30 m | | | 16-6 | 18-10 | 20-12 |
| 60 m | | | | 16-6 | 20-10 |

*D: push / T: pull*
*The first figure is the limit value for initial pushing or pulling.*
*The second figure is the limit value for sustained pushing or pulling.*

## Method C.5
## Recommended force limits

**Variables:**
Frequency, direction of force, working postures

**Population:**
Free to choose

Source: NF X 35-106, Norme française, Ergonomie, *Limites d'efforts recommandées pour le travail et la manutention au poste de travail,* AFNOR, France, 1985.

French standard NF X 35-106 gives a method for calculating acceptable forces, frequencies and postures for different groups, along with a simple estimation method for local force exertion. While the forces are different for the various groups, the table below gives multipliers for the percentages of male or female population to be protected for MSD by the limit values. Table C.5.2 identifies and codifies -by letters- different actions and postures when exerting force. Figure C.5.1 recommends forces for the different situations and various frequencies.

TABLE C.5.1 **Ergonomics, Recommended force limits for work and handling operations at work stations**

| | % female | % male |
|---|---|---|
| **Multiplier** | | |
| 0.6 | 95 | 100 |
| 1.0 | 80 | 95 |
| 1.4 | 50 | 85 |
| 1.7 | 30 | 80 |
| 2.3 | 5 | 50 |

FIGURE C.5.1 **Basic nomogram (recommended force)**

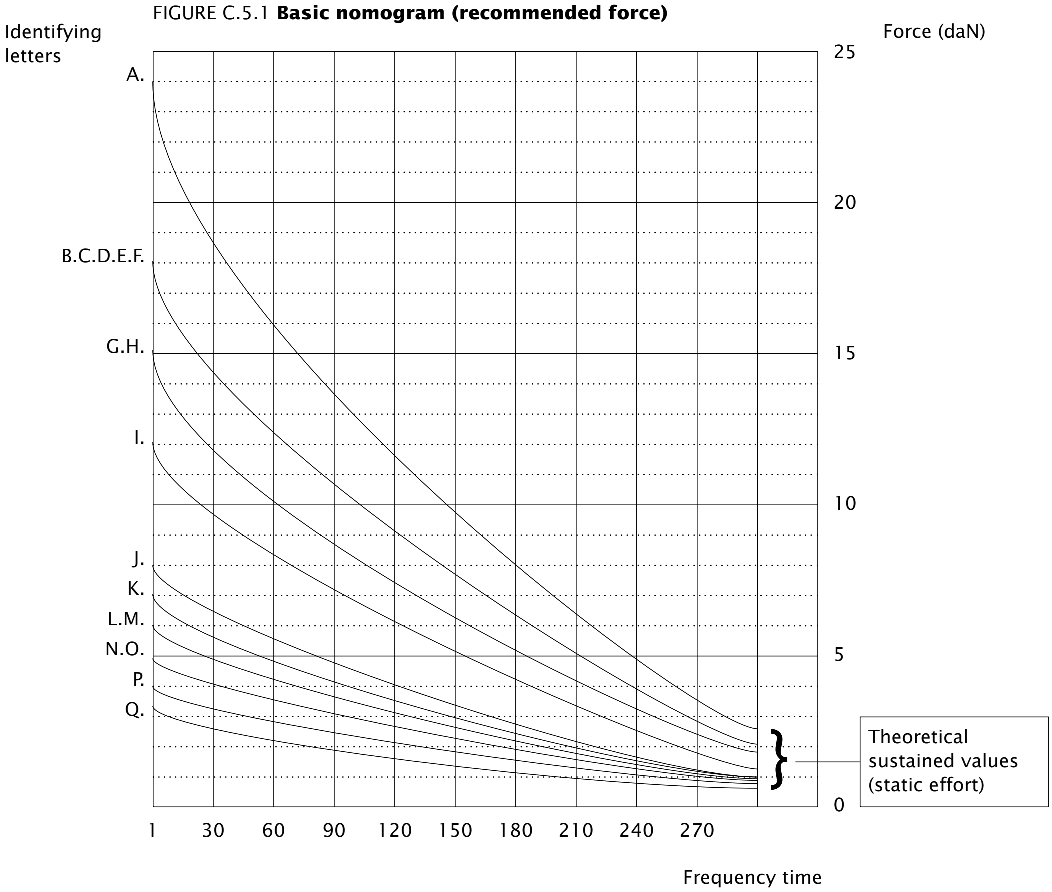
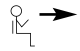
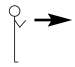
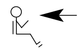
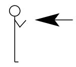
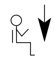
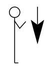
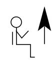
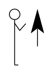
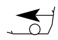
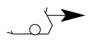
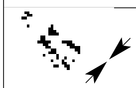
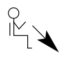
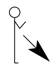


TABLE C.5.2 **A nomogram methodology for effort identification**

| Type of activity | Posture | Direction of effort | Identifying letters |
|---|---|---|---|
| PUSHING with one hand | SITTING<br>- back support |  | B |
| | STANDING |  | J |
| PULLING with one hand | SITTING<br>- foot support |  | G |
| | STANDING |  | L |
| LOWERING with one hand | SITTING |  | N* |
| | STANDING |  | K* |
| LIFTING with one hand | SITTING |  | Q* |
| | STANDING |  | M* |
| ADDUCTION | SITTING<br>or<br>STANDING |  | O* |
| ABDUCTION | |  | P* |
| GRIPPING | |  | C |
| TURNING with both hands<br>(steering wheel) | SITTING |  ⊢ | I* |
| | | ⊤ | D* |
| | STANDING |  ⊢ | H* |
| | | ⊤ | E* |
| PUSHING DOWN<br>with foot on pedal | SITTING<br>- back support |  | A |
| | STANDING |  | F |

Correction rules: For the identifying letters marked with an asterisk, halve the nomogram value if these efforts are exerted in an "acceptable" rather than "good" work volume.

## D. Risk estimation for repetitive movements

For this hazard, the work cycle and frequency of movements are also calculated in relation to other MSD risk factors like extreme and constrained postures and force exertion.

**Methods D.1-D.3** present tables, figures and worksheets for risk estimation. *Table D.1.1* gives a quick scan estimation of repetitive movements. *Table D.2.1* gives a recent limit value for the **Hand Activity Level (HAL)** published by the American Conference of Governmental Industrial Hygienists (2000). Worksheet D.3 presents a specific checklist (OCRA Checklist) recently developed and widely applied by the authors of the OCRA method (see Section 4) to give a quick estimation of the risk connected to repetitive movements of the upper limbs in different tasks in large manufacturing plants.

In Section 4, three methods that can be used to perform a more comprehensive integrated risk Assessment for the upper limbs are presented respectively in sections *4.1: "RULA" , 4.2:"OCRA" and 4.3: "Upper limb expert tool".*

### Method D.1
### Assessment of repetitive, monotonous work

**Variables:**
Frequency of working cycle, working postures and movement, freedom of action, work content and learning

**Population covered:**
Applicable to both sexes

Source: Hedén, K., Andersen, V., Kemmlert, K., Samdahl-Høiden, L., Seppänen, H. and Wickström, G. (1993), "Model for assessment of repetitive, monotonous work – RMW". In: Marras, W.S., Karwowski, W., Smith, J.L. and Pacholski, L. (1993), *The Ergonomics of Manual Work*, Taylor and Francis, London, pp. 315-317.

The table assumes a full shift (4-8 hours work per 24 hours). If work fits into one of the red cells during a greater part of the shift, changes must be made. If the work fits into all the green cells, it is no longer regarded as repetitive monotonous work.

TABLE D.1.1 **Model for assessment of repetitive, monotonous work - RMW**

| | Red | Yellow | Green |
|---|---|---|---|
| Working cycle | Repeated several times per minute | Repeated several times per hour | Repeated some times per hour |
| Working postures and movements | Fixed/uncomfortable postures and movements | Limited positions to alter working postures and movements | Work place with good physical lay-out. Good opportunities for varying work postures and movements |
| Freedom of action | Work is completely governed by something or someone else | Work is to some extent governed by something or someone else. Limited opportunities for influencing work performance | Good opportunities for fitting the work to one's own ability. Influence on planning and organizing of the work. |
| Work content learning | Employee performs one isolated task in a production process. Short training time. | Employee performs several tasks in a production process. Job rotation may be present. Training for different work areas. | Employee takes part in several tasks or in the whole production process including planning and control. Competence develops continuously. |

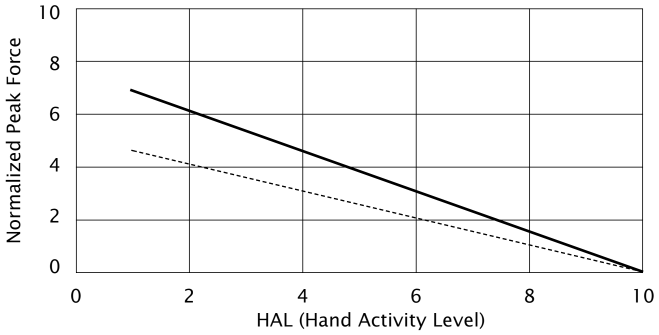
## Method D.2
## Hand activity level

**Variables:**
Normalized peak hand force, hand activity level (frequency, pauses)

**Population:**
Free to choose

The American Conference of Governmental Industrial Hygienists has published a **TLV for Hand Activity Level** (HAL, ACGIH, 2000). It is based on epidemiological, psychophysical and biomechanical studies and is intended for “mono-task” jobs performed for four hours or more per day. It specifically considers average hand activity level and peak hand force. The HAL rating scale covers idle hand to rapid steady motion, difficult to maintain while performing a task. The peak hand force is normalised on a scale of 0-10 that corresponds to 0%-100% of the applicable population strength. The peak force can be determined by trained observers, ratings by workers, or by using special instrumentation.

FIGURE D.2.1 **The TLV for reduction of work-related MSD based on “hand activity” or “HAL” and normalized peak hand force**




*The top line depicts the TLV. The bottom line is an action limit for which general controls are recommended.*

Source: *Hand Activity Level (HAL)*, Figure 1, 2000. From American Conference of Governmental Industrial Hygienists (ACGIH®), TLV®, Hand Activity Level Draft Documentation. Copyright 2001. Reprinted with permission.

TABLE D.2.1 **Hand activity level (0-10) is related to exertion frequency and duty cycle (% of work cycle where force is greater than 5% of maximum)**

| | | **Duty Cycle (%)** | | | | |
|---|---|---|---|---|---|---|
| **Frequency (exertion/s)** | **Period (s/exertion)** | **0-20** | **20-40** | **40-60** | **60-80** | **80-100** |
| 0.125 | 8.0 | 1 | 1 | – | – | – |
| 0.25 | 4.0 | 2 | 2 | 3 | – | – |
| 0.5 | 2.0 | 3 | 4 | 5 | 5 | 6 |
| 1.0 | 1.0 | 4 | 5 | 5 | 6 | 7 |
| 2.0 | 0.5 | – | 5 | 6 | 7 | 8 |

Source: *Hand Activity Level (HAL)*, Table 2, 2000.

FIGURE D.2.2

| **0** | **2** | **4** | **6** | **8** | **10** |
|---|---|---|---|---|---|
| Handle idle most of the time; no regular exertions | Consistent conspicuous long pauses; or very slow motions | Slow, steady motion/ exertions; frequent, brief pauses | Steady motion/ exertion; infrequent pauses | Rapid, steady motion/ exertions; no regular pauses | Rapid, steady motion/ difficulty keeping up or continuous exertion |

Source: *Hand Activity Level (HAL)*, Figure 2, 2000.

## Method D.3 OCRA Checklist

**Variables:**
Frequency of upper limb actions, posture and movements, use of force, recovery periods, additional risk factors

**Population:**
Adult working population, both sexes

This check-list describes a work-place and estimates the intrinsic risk, as if the work-place was used for the whole of the shift by one worker. This procedure makes it possible to identify which work-places in the company are at risk because of their intrinsic structural characteristics, the risk being classified as "absent" (green), "light" (yellow/red), "medium" (red).

In other words, in the first stage, the check-list supplies an initial estimate of the intrinsic risk of each work-place, but not the exposure indexes for the operators, because that part of the assessment must be completed later.

The analysis system suggested with the check-list begins with the establishment of pre-assigned scores (rising with the risk), for each of the 4 main risk factors considered (recovery periods, frequency, force, posture), and for the additional factors.

The final score is obtained by adding up the partial scores obtained for each of the risk factors: recovery, frequency, force, posture and additional. Since the numerical values indicated in the check-list have been "calibrated" to the multiplier factors supplied for calculation in the more exhaustive OCRA exposure index, the final check-list value can be interpreted in terms of its correspondence to the OCRA values.

Checklist values up to 3 correspond to OCRA values up to 1 (green area); values from 3 - 6 correspond to OCRA values between 1 - 2 (green/Yellow); values between 6 - 12 correspond to OCRA values between 2 - 4 (yellow red); values equal to or above 12 correspond to OCRA values equal to or above 4 and indicate high risk (red).

If the repetitive task lasts less than 6 hours within a single shift (part-time work) the value obtained can be corrected according to actual duration. If the repetitive part-time work only lasts 2 hours, the final value obtained with the check-list must be multiplied by 0.5 ; if it lasts 3 to 5 hours, then the final result must be multiplied by 0.75.

If an initial, indicative exposure index must be estimated for the workers, the following procedure must be adopted:

- if the operator/s works exclusively at the work-place described in the analysis, then the check-list score given to the work-place is the same as that given to the operators;
- if the operators works in multiple work-places, implying repetitive tasks, then the formula below should be used to obtain the specific exposure index of that operator:

  (score A x % PA) + (score B x % PB) + etc.

  where "score A" and "score B" are the scores obtained with the check-list for the various work-places in which the same operator works, and %PA and %PB represent the percentage duration of the repetitive tasks within the shift.

## Worksheet D.3 **The OCRA checklist**

*A Shortened Procedure for the Identification of Upper Limb overload In Repetitive Tasks*

Compiled by:

Date :

Name and short description of work-place:

........................................................................................................................................

........................................................................................................................................

........................................................................................................................................

........................................................................................................................................

........................................................................................................................................

........................................................................................................................................

No. of work-place:

***TYPE OF WORK INTERRUPTION***
(with pauses or other visual control tasks)

Max. score allowed = 10.
Choose one answer.
You can choose intermediate values.

**Recovery** [ ]

- [0] There is an interruption of at least 5 minutes every hour in the repetitive work (also count the lunch break)
- [1] There are 2 interruptions in the morning and 2 in the afternoon (plus the lunch break), lasting at least 7-10 minutes in the 7-8 hour shift, or at least 4 interruptions per shift (plus the lunch break), or four 7-10 minute interruptions in the 6-hour shift
- [3] There are 2 pauses, lasting at least 7-10 minutes each in the 6-hour shift (without lunch break); or, 3 pauses, plus the lunch break, in a 7-8-hour shift
- [4] There are 2 pauses, plus the lunch break, lasting at least 7—10 minutes each over a 7-8 hour shift (or 3 pauses without the lunch break), or 1 pause of at least 7-10 minutes over a 6-hour shift
- [6] There is a single pause, lasting at least 10 minutes, in a 7-hour shift without lunch break; or, in an 8-hour shift there is only a lunch break (the lunch break is not counted in the working hours)
- [10] There are no real pauses except for a few minutes (less than 5) in a 7 to 8-hour shift

*N.B.: it is helpful to attach to the check-list a map of the department on which the position and the number of the work-place examined can be marked.*

Notes:

..........................................................................................................

..........................................................................................................

..........................................................................................................

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..........................................................................................................

***ARM ACTIVITY AND WORKING FREQUENCY WITH WHICH THE CYCLES ARE PERFORMED***

If necessary, intermediate scores can be chosen. Max. score possible = 10.

Choose one answer (state whether left or right arm is involved the most).

- [0] Arm movements are slow, and frequent short interruptions are possible (20 actions per minute)
- [1] Arm movements are not too fast, but constant and regular. Short interruptions are possible (30 actions per minute)
- [3] Arm movements are quite fast and regular (about 40), but short interruptions are possible
- [4] Arm movements are quite fast and regular, only occasional and irregular short pauses are possible (about 40 actions per minute)
- [6] Arm movements are fast. Only occasional and irregular short pauses are possible (about 50 actions per minute)
- [8] Arm movements are very fast. The lack of interruptions makes it difficult to keep up the pace, which is about 60 actions per minute
- [10] Very high frequencies, 70 actions per minute, or more. Absolutely no interruptions are possible

**Frequency** [ ]

***PRESENCE OF WORKING ACTIVITIES INVOLVING THE REPEATED USE OF HAND-ARM FORCE***

At least once every few cycles during all the task analysed.

More than one answer can be ticked: add up the partial scores obtained.

If necessary, choose intermediate scores, and then add them together (describe the limb which is most involved, the same one for which the posture will have to be described).

❑ Yes ❑ No

➔ If yes:

This working task implies:

- ❑ The handling of objects weighing over 3 kg
- ❑ Gripping between forefinger and thumb, and lifting, objects weighing over 1 kg (in pinch)
- ❑ Using the weight of the body to obtain the necessary force to carry out a working action
- ❑ The hands are used as tools to hit or strike something

→

- [1] Once every few cycles
- [2] Once every cycle
- [4] About half of the cycle
- [8] For over half of the cycle

The working activity requires the use of intense force for:

- ❑ Pulling or pushing levers
- ❑ Pushing buttons
- ❑ Closing or opening
- ❑ Pressing or handling components
- ❑ Using tools
- ❑ .............................

→

- [4] 1/3 of the time
- [6] About half of the time
- [8] Over half of the time (*)
- [16] Nearly all the time (*)

*(*) N.B.: The two conditions evidenced are absolutely unacceptable.*

The working activity requires the use of moderate force for:

- ❑ Pulling or pushing levers
- ❑ Pushing buttons
- ❑ Closing or opening
- ❑ Pressing or handling components
- ❑ Using tools
- ❑ .............................

→

- [2] 1/3 of the time
- [4] About half of the time
- [6] Over half of the time
- [8] Nearly all the time

**Force** [ ]

| | | |
|---|---|---|
| ***ARMS IN AWKWARD POSITIONS DURING THE REPETITIVE TASK*** | ❑ RIGHT ❑ LEFT ❑ BOTH (mark the limb most involved) | |
| Highest possible score = 11 | [1] The arm/arms are not leaning on the workbench but are slightly uplifted for a little over half the time<br>[2] The arms have nothing to lean on and are kept nearly at shoulder height for about 1/3 of the time<br>[4] The arms are kept at about shoulder height, unsupported, for over half the time<br>[8] The arms are kept at about shoulder height, unsupported, all the time | ......... **A** |
| | [2] The wrist must bend in an extreme position, or must maintain awkward postures (such as wide flexions or extensions, or wide lateral deviations) for at least 1/3 of the time<br>[4] The wrist must bend in an extreme position, or must maintain awkward postures (such as wide flexions or extensions, or wide lateral deviations) for over half of the time<br>[8] The wrist must bend in an extreme position, all the time | ......... **B** |
| | [2] The elbow executes sudden movements (jerking movements, striking movements) for about 1/3 of the time<br>[4] The elbow executes sudden movements (jerking movements, striking movements) for over half the time<br>[8] The elbow executes sudden movements (jerking movements, striking movements) nearly all the time | ......... **C** |
| *N.B.: use the highest value obtained among the four groups of questions (A,B,C,D) only once, and if possible add to that of the last question* **E** | Grip objects, parts or tools with fingertips :<br>❑ With constricted fingers (pinch)<br>❑ With the hand nearly open (palmar grip)<br>❑ Keeping fingers hooked<br>→ [2] For about 1/3 of the time<br>[4] For over half the time<br>[8] All the time | ......... **D** |
| **Posture** ☐ | Presence of identical movements of shoulder and/or elbow, and/or wrist, and/or hands, repeated for at least 2/3 of the time (please also cross 3 if the cycle is shorter than 15 seconds)<br>[3] | ......... **E** |
| ***PRESENCE OF ADDITIONAL RISK FACTORS***<br>Choose only one answer per group of questions.<br>**Additional** ☐ | [2] Gloves unsuited to the task are used for over half the time (uncomfortable, too thick, wrong size, etc.)<br>[2] Vibrating tools are used for over half the time<br>[2] The tools employed cause compressions of the skin (reddening, callouses, blisters, etc.)<br>[2] Precision tasks are carried out for over half the time (tasks over areas smaller than 2 or 3 mm)<br>[2] More than one additional factor is present at the same time i.e.: ........................ and, taken together, they occupy over half the time<br>[3] One or more additional factors are present, and they occupy the whole of the time i.e.: ...........................<br>[1] Working pace set by the machine, but there are "breathing spaces" in which the working rhythm can either be slowed down or speeded up<br>[2] Working pace completely determined by the machine | |
| ***PRESENCE OF WORKING ACTIVITIES WITH TASKS ORGANISED IN CYCLES***<br>(Cycle = group of actions with upper limb movements, continuously repeated every few seconds or minutes.)<br>You can choose more than one answer. | ❑ For at least 2-3 hours in the work shift<br>❑ For at least 4-5 hours in the shift<br>❑ For 6-8 hours in total in the shift<br>❑ Work by incentives<br>❑ Usual work over hours | |

## *CALCULATING THE EXPOSURE INDEX FOR REPETITIVE TASKS*

To calculate the task index, add the values in the 5 boxes (Recovery + Frequency + Force + Posture + Additional). If there is more than one repetitive task carried out during the shift, use the following equation to obtain the overall score for repetitive work during the shift (% PA = percentage of time for task A during the shift).

**(score A x % PA) + (score B x % PB) + etc.**

Tasks carried out during the shift, and/or name of the workplace :

| Name of workplace | Duration (min) | Prevalence of shift | (P) |
|---|---|---|---|
| A | | | (PA) |
| B | | | (PB) |
| C | | | (PC) |
| D | | | (PD) |

N.B.: For part-time jobs lasting only 2 hours in the repetitive work shift, multiply the final value of the check-list by 0.50. For part-time jobs lasting 3-5 hours in the repetitive work shift, multiply the final check-list value by 0.75.

**Exposure index**

### *CORRESPONDENCE OF SCORES BETWEEN OCRA AND CHECK-LIST SCORES*

| Check list | OCRA | |
|---|---|---|
| < 3 | 1 | green |
| from 3 to 6 | 1 – 2 | green/yellow |
| 6 – 12 | 2 – 4 | yellow/red |
| > 12 | > 4 | red |

Sources: Colombini, D., Occhipinti, E. and Baracco, A. (2000). "A new checklist model, set with the OCRA index to evaluate exposure to repetitive movements of the upper limbs". In: *Proceedings of the IEA 2000/HFES 2000 Congress* (S. Diego, U.S.), vol. 5, pp. 716-719.

Colombini, D., Occhipinti, E., Cairoli, S. and Baracco, A. (2000). "Proposal and preliminary validation of a checklist for the assessment of occupational exposure to repetitive movements of the upper limbs". In: *La Medicina del Lavoro*, 91, 5, pp. 470-485.

## E. Risk estimation for hand-arm vibration

The measurement unit for this hazard is the frequency weighted root mean square (r.m.s.) acceleration in $m/s^2$. This value is relative to the duration of exposure. A basic question for estimating the risk is given, together with references to relevant standards. *Figure E,* from ISO 5349-1-2001 gives an overview of health effects of different exposures to vibration based on epidemiological data. If the answer to the following question is "yes", a relevant risk for MSD exists. Further risk evaluation or redesign is necessary.

**Does the machine produce hand-arm vibrations on the operator of more than 1.0 $m/s^2$?**

In the risk evaluation, contributory factors should also be considered (e.g.: whether the machine is likely to be operated in a cold environment, and any bad postures the operator may be likely to work in). The Machinery Directive requires manufacturers to inform users that the machine does not exceed 2.5 $m/s^2$ for hand-arm vibration. If this value is exceeded, the actual vibration value must be stated. Manufacturers must also inform the user about the residual risks.

More about risk evaluation methods can be found in the following relevant standards. Because operators may be potentially exposed to greater vibration than the emission values declared by the manufacturer, measurements of actual exposure are needed in addition to bench tests.
- EN 1033:1995: "Hand-arm vibration - Laboratory measurement of vibration at the grip surface of hand guided machinery- General".
- EN 28662-1:1993: "Hand portable power tools - Measurement of vibrations at the handle- Part 1: General".
- ISO 5349-1-2001: "Mechanical vibration - Measurement and evaluation of human exposure to hand transmitted vibration".

There is also a series of hand–arm vibration test standards for special groups of hand-held machinery. But there is still a lack of test standards for hand-operated and stationary machines which introduce vibrations into the hand-arm system via the work piece (e.g. vibratory plates)[51].

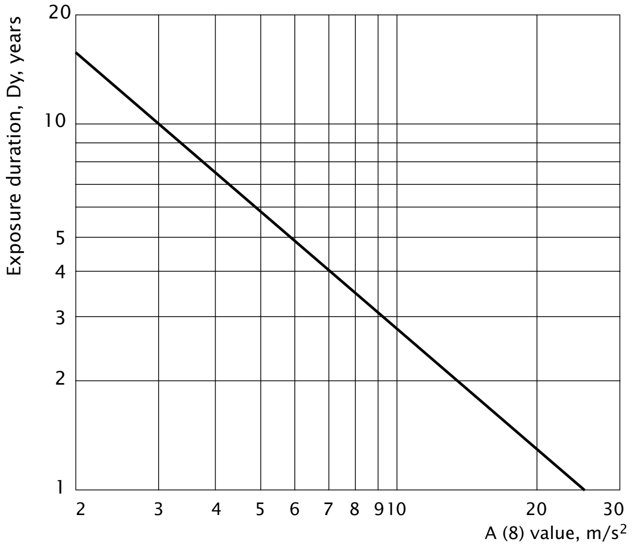
51. *Ermittlung des Normungsbedarfs zur Festlegung von Kennwerten für Vibrationen*, Kommission Arbeitsschutz und Normung - KAN, 1996.

**Method E**
**Relationship between hand-arm vibration exposure and effects on health**

**Variables:**
8 hours energy-equivalent hand-arm vibration total value, exposure duration in years

Source: ISO 5349-1-2001, Figure C.1.
These terms and definitions taken from ISO 5349-1 Figure C1 are reproduced with the permission of the International Organization for Standardization, ISO. This standard can be obtained from any ISO member and from the website of the ISO Central Secretariat at the followin URL: http://www.iso.org.


FIGURE E.1 **Vibration exposure for predicted 10% prevalence of vibration-induced white finger in a group of exposed persons**



## F. Risk estimation for whole-body vibration

The measurement unit for this hazard is the frequency weighted root mean square (r.m.s.) acceleration in $m/s^2$.

**Does the machine produce whole-body vibrations on the operator above 0.5 $m/s^2$?**

If the answer is "yes", a relevant risk for MSD exists. Further risk evaluation or redesign is needed.

The Machinery Directive requires manufacturers to inform users that the machine does not exceed 0.5 m/s2 for whole-body vibration. If this value is exceeded, the actual vibration value must be stated. Manufacturers must also inform the user about the residual risks.

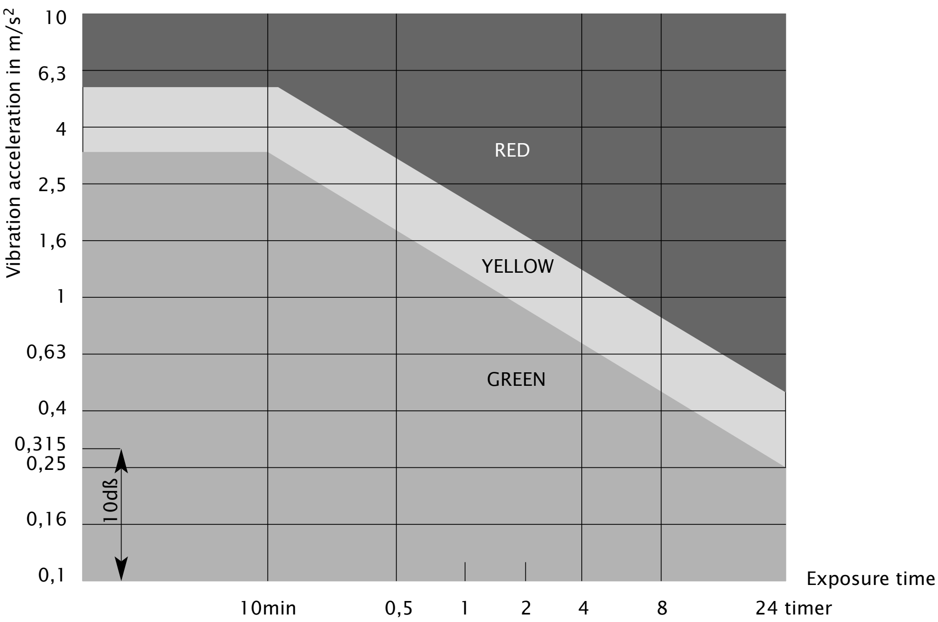
- EN 1032:1996: "Mechanical vibration - Testing of mobile machinery in order to measure the whole-body vibration emission value- General".
- ISO 2631-1:1997: "Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration – Part 1: General requirements".

### Method F
### Evaluation of exposure to whole-body vibration

**Variables:**
whole-body vibration acceleration, duration of exposure

Danish Regulations use a simplified ISO 2631-1: 1997 Figure B.1 scheme to evaluate exposure in whole-body vibration. In the scheme, the red zone is unacceptable, yellow is conditionally acceptable and green acceptable.

FIGURE F.1 **Evaluation of exposure to whole-body vibration**




Source: *Danish Regulations: At-meddelelse*, Nr. 4.06.5, Helkropsvibrationer, 1998.

## G. Risk estimation for energetic load

For this hazard, the operator's energy consumption for each activity related to the machine must be calculated (in KJ/min or kcal, 1 kcal = 4.186 KJ). In Method G, risk estimation criteria for energy consumption are presented in Table G.1. Selected examples of energy consumption for different postures, movements and types of work are given in Tables G.2, G.3 and G.4.

### Method G
### Acceptable energy consumption

**Variables:**
Energy consumption, duration

**Population covered:**
80% female, 95% male

The energy consumption guidance given in the table allow designers to make an overall estimation in three levels: green, yellow and red.

TABLE G.1 **Estimation of energetic workload in physical workload**

| Energy consumption | Endurance load | | Peak load | |
|---|---|---|---|---|
| **kJ/min** | **8 hours** | **1 hour** | **10 min** | **< 10 min** |
| < 8 | green | | | |
| 8-10 | green | green | | |
| 10-13 | green | green | | |
| 13-17 | yellow | green | green | |
| 17-21 | red | green | green | |
| 21-25 | red | green | green | |
| 25-31 | | yellow | green | green |
| 31-38 | | red | yellow | green |
| 38-46 | | red | red | yellow |
| 46-54 | | | red | red |
| 54-63 | | | | red |

TABLE G.2 **Energy consumption for different postures**

| Postures | Energy consumption kJ/min |
|---|---|
| Sitting | 1 |
| Kneeling | 2 |
| Squatting | 2 |
| Standing | 2.5 |
| Bent forward | 3.5 |

TABLE G.3 **Energy consumption for different movements**

| Movements | Energy consumption kJ/min |
|---|---|
| Walking, 2-5 km/hour | 6.5-17 |
| Climbing a hill, 2-5 km/hour: | |
| ▪ slope 5 degrees | 13-32 |
| ▪ slope 10 degrees | 22-55 |
| Walking down the hill, 5 km/hour: | |
| ▪ slope 5 degrees | 9 |
| ▪ slope 10 degrees | 7.5 |
| Walking with a backload, 4 km/hour: | |
| ▪ 10 kg | 15.5 |
| ▪ 30 kg | 22.5 |
| ▪ 50 kg | 35 |
| Climbing stairs and ladders: | |
| ▪ upwards 60-140 stairs/min | 34.5-80 |
| ▪ downwards 60-140 stairs/min | 9.5-22.5 |
| Climbing a vertical ladder, 12-24 m/min: | |
| ▪ without load | 45-89.5 |
| ▪ with 10 kg | 51.5-103 |

TABLE G.4. **Energy consumption for different types of labour**

| Type of work | average kJ/min |
|---|---|
| Working with the hands: | |
| ▪ light | 1.5 |
| ▪ moderate | 3 |
| ▪ heavy | 4.5 |
| Working with one arm: | |
| ▪ light | 4 |
| ▪ moderate | 6 |
| ▪ heavy | 8.5 |
| Working with two arms: | |
| ▪ light | 7 |
| ▪ moderate | 9.5 |
| ▪ heavy | 12 |
| Working with the whole body: | |
| ▪ light | 14 |
| ▪ moderate | 21 |
| ▪ heavy | 30 |
| ▪ very heavy | 43 |

Source Tables G.1-G.4: SPITZER, H., HETTINGER, T. and KAMINSKY, G., *Tables for estimation of energetic workload in physical workload. REFA 6*, Berlin, 1982.

## 3.4 What next?

The risk estimation for the different factors should lead to one of three alternatives:

a. the risk is estimated to be *acceptable*: continue the design process to build a mock-up for evaluating the machine in practice, then repeat the risk estimation.

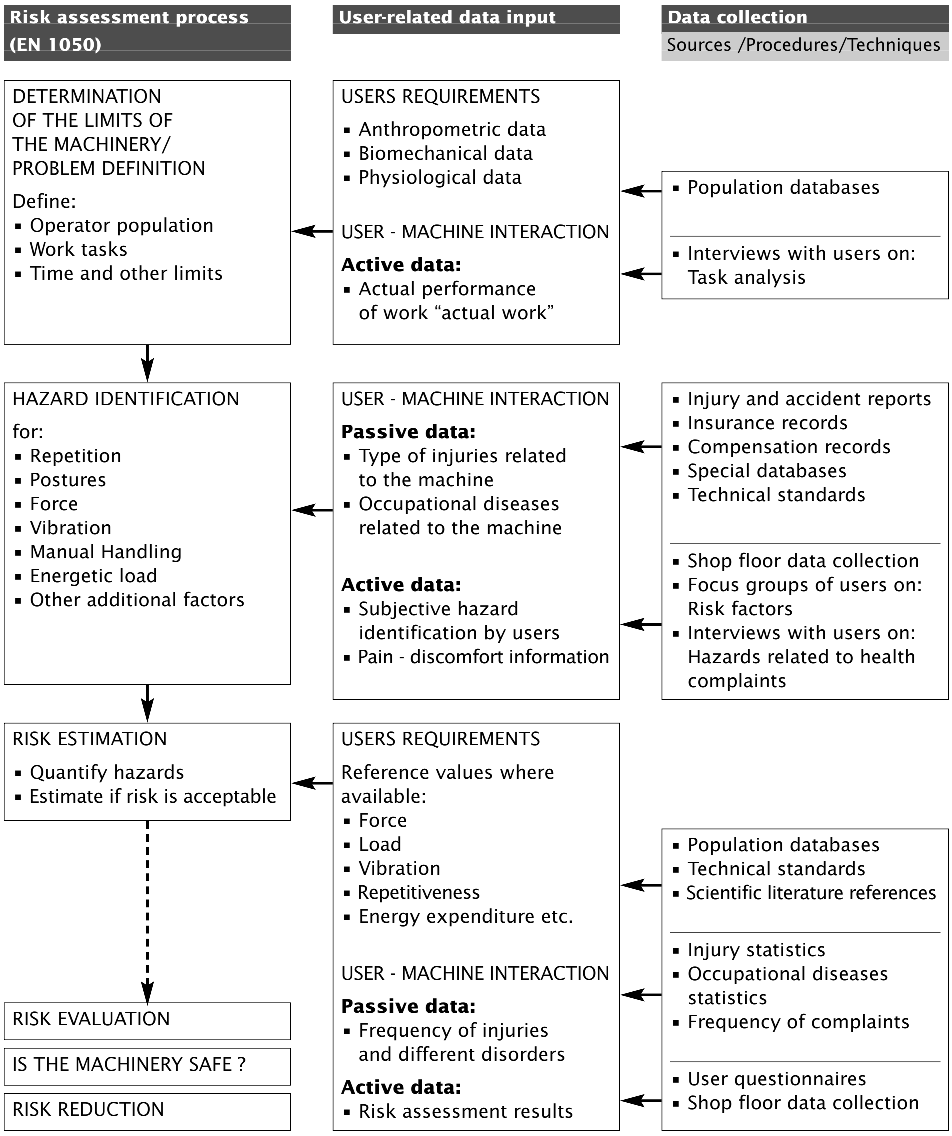
b. *conditionally acceptable:*
   - change the design and repeat the risk estimation; or
   - continue the risk analysis with a more detailed risk evaluation.

c. *not acceptable:* change the design or look again at the limits of the machinery.

For upper limb risks, go to Section 4, where three recent methods proposing a more integrated approach for risk assessment are set out in detail.

A diagram illustrating the risk estimation process for MSD risk factors on machinery design and relevant user input for each phase follows.

DIAGRAM: **Risk estimation process for MSD risk factors on machinery design - users' input**



# Section 4
# **Integrated Risk Estimation Procedures**

Although quite complex, the following recently-developed integrated procedures take into account combinations of risk factors, and so are briefly described to complete the mix of current approaches to MSD risk estimation.

Until recently, many work task development and research methods have focused on analyzing energy consumption and overall work postures or different work tasks during a work shift. More recently, integrated approaches to the investigation of various risk factors for work-related upper limb disorders have been put forward. Table 2 lists and briefly describes some of the available methods in chronological order[52].

TABLE 2 **Assessment methods for physical strain**

| Methods | Characteristics | Field of application |
|---|---|---|
| OWAS, Karhu, O. *et al.*, 1977 | Analyses overall work postures, force and frequency during a work shift, *Quantitative* | Whole body |
| RULA, Mc Atamney and Corlett, 1993 | Provides risk index and action levels after postural analysis of coded static and dynamic postures, takes into account physical factors like muscular performance, repetition, forces, *Quantitative* | Upper limbs |
| A. Kilbom, 1994 | Recommendations for risk assessment in repetitive work for different body regions, type of work and frequency, *Semiquantitative* | Upper limbs |
| REBA, Mc Atamney and Hignett, 1995 | Provides action levels after postural analysis of coded body segments, estimates load/force and coupling, *Quantitative* | Whole body |
| PLIBEL, Kemmlert, 1995 | Identifies risk factors via a checklist for different body regions, deals with awkward postures, work movements, poor equipment design and other organizational factors, *Qualitative* | Whole body |
| Malchaire and Indesteege, 1997 | Three-step risk analysis method, *Qualitative* | Upper limbs |
| OCRA, E. Occhipinti, D. Colombini, 1998 | Provides a risk index taking into account working postures, repetition, frequency, force, duration of work, recovery periods, and additional factors, *Quantitative* | Upper limbs |
| QEC, P. Buckle, 1998 | Estimates exposure levels for body postures, repetition, force/load, task duration, with a hypothesised score table for their interaction, *Quantitative* | Whole body |
| Upper limb expert tool, R. Ketola, R. Toivonen, E. Viinkari-Juntura, FIOH, 2001 | Assesses work load taking into account repetition, force, awkward postures, duration of exposure and some additional factors, *Semiquantitative* | Upper limbs |

52. Li, G. and Buckle, P., 1999, Current techniques for assessing physical exposure to work related musculoskeletal risks, with emphasis on posture-based methods, *Ergonomics*, 42, 5, pp. 674-695.

Three of the above methods - RULA, OCRA and the Upper Limb expert tool – will now be described in detail for the following reasons. The RULA (Rapid Upper Limb Assessment) method investigates the exposure of individual workers to risk factors associated with work-related upper limb disorders. The validation study for RULA found a statistically significant association between the posture scores for neck, upper and lower arm, and discomfort and pain. It is a well-validated method applied for several years by many experts in Europe and the US. In 1998, Occhipinti and Colombini presented a new procedure for an "exposure index" – the OCRA index. This method was accepted by the International Ergonomics Association in a consensus document for upper limb disorders[53]. A preliminary validation study on the OCRA method found a high level of concordance between the OCRA index and the overall occurrence of work-related upper limb MSD. Finally, the Upper Limb expert tool is a very recently developed method based on an older Finnish tool for ergonomic task analysis.

These methods can be used by experts as risk assessment tools for MSD:

- **RULA**
  This method follows a five-step approach. Steps One, Two and Three look at a range of postures; record them and calculate their scores. Step Four brings other physical factors into the assessment. In Step Five, the body part scores are included in a Global Risk Index referable to an action level classified as "green", "yellow" or "red".

- **OCRA**
  The OCRA "risk index" results from the ratio of number of technical actions actually performed during the shift, to the number of recommended technical actions. The authors advise adopting a prudential classification system, since further validation is necessary.

| | | |
|---|---|---|
| OCRA INDEX < 1 | green area | acceptable |
| OCRA INDEX between 1 and 2 | green- yellow area | conditionally acceptable |
| OCRA INDEX between 2 and 4 | yellow-red area | conditionally acceptable |
| OCRA INDEX > 4 | red area | not acceptable |

  The calculation model uses multiplier factors for force, posture, complementary factors and lack of recovery.

- **Upper Limb expert tool**
  This method, recently developed by researchers from the Finish Institute for Occupational Health (FIOH), is based on a dichotomous scale (presence/absence of risk) of hazards like repetitive use of hand, hand force and awkward postures. The higher the total of "yes" answers to the presence of hazards, the greater the risk.

53. Colombini D., Occhipinti E., Delleman N., Fallentin N., Kilbom A. and Grieco A., *Exposure assessment of upper limb repetitive movements: A consensus document*, IEA, 1999.

## Method 4.1 RULA

### *STEP 1 – OBSERVING AND SELECTING THE POSTURE(S) TO ASSESS*

A RULA assessment represents a moment in the work cycle (a "snapshot" of a posture). Thus the first step is to observe the whole work cycle, noting the changing postures being adopted to perform the work and selecting those which will be assessed. Depending upon the task and situation, either the longest held posture or what appears to be the worst significant posture(s) adopted should be analysed. Separate RULA scores are usually calculated for right and left sides of the body, since tasks may not be performed symmetrically with both arms.

### *STEP 2 – SCORING AND RECORDING THE POSTURE*

For each posture chosen, scores are entered on the score sheet in Diagram 4.1.1. Firstly we need to score the posture of each body part in turn, using the guides given for the upper limb in Diagram 4.1.2 and the neck, trunk and legs in Diagram 4.1.3. Record each score in the appropriate box found on the left side of the score sheet in Diagram 4.1.1. If assessment of the right and left upper limbs is required, the diagonal line dividing the necessary boxes means that the same recording sheet can be used. However, scores should be evaluated separately. It is often sufficient to assess one side of the body only. This will be true when the posture is symmetrical or when the work is largely being undertaken using only one side of the body.

Start with scoring the posture of body parts in group A. Begin with the position of the upper arm. Look at its position from the side and decide which of the "stick men" in Diagram 4.1.2 most closely corresponds. The score will be the number over the head of the appropriate stick man. Then look at the text to the side of the figures. This allows for the score to be modified if the shoulder is raised, upper arm abducted (held away from the side of the body) or the weight of the arm is supported. You should now have a score for the upper arm, which should be entered into the "upper arm box" on the score sheet (Diagram 4.1.1).

Follow exactly the same process for the lower arms, wrist and wrist twist, entering the scores in the appropriate boxes on the recording sheet. An explanation is needed for wrist twist. When a person is working at a horizontal work surface, if the hands are in a handshake position this would be considered to be "mainly in the mid-range of twist" and score 1. If the hand is in a palm upwards or palm downwards position, it would be 'at or near the end of twisting range' and score 2.

You should then go on to score the posture of the body parts in group B (the neck, trunk and legs). Use the body figures in Diagram 4.1.3 and follow the same process as described for group A (the upper limb). Again you should enter your scores into the relevant boxes on the score sheet.

### *STEP 3 – CALCULATING POSTURE SCORES*

You should now have the column of scores in the boxes on the left side of the score sheet completed for each of the body parts in groups A and B. Do not add these scores together to calculate score A or posture score B. Instead, use Tables A and B, respectively, in Diagram 4.1.4.

First of all, refer to Table A. Follow the appropriate upper arm score and then lower arm score across the table to identify which row you require. Then follow the appropriate wrist posture score and then wrist twist score down the table to identify which column you require. Where the column and row intersect is posture score A. Enter it into posture score A box on the score sheet (Diagram 4.1.1).

Follow the same process using Table B. This time the neck score will identify the row and the trunk score and legs score the column. Enter the score found where the column and row intersect into the box for posture score B.

### *STEP 4 – SCORING AND RECORDING MUSCLE USE AND FORCE SCORES*

It is now necessary to determine the muscle use and force scores for group A using the definitions in Diagram 4.1.4. Firstly, decide if there is any muscle use of the upper limb either to maintain a static posture or to perform repetitive work. If neither of these situations applies then the score is 0. If one or the other is true, the score is 1. In some circumstances both will apply (for example when holding the arm outstretched and repetitively operating a hand tool). In this case the score will be 2. Enter the score in the muscle use score box on the recording form in Diagram 4.1.1.

Secondly, identify whether any external loads or forces are being applied with the upper limb. The definitions given in the box in Diagram 4.1.4 should be self-explanatory and will determine the force score to record.

Now consider muscle use and external loads or forces for group B (neck, trunk and legs). Calculate the two scores for these body parts in exactly the same way as described above. Just remember when it comes to the force score that we are interested only in external loads or forces (for example, operating a foot pedal). The load on the feet due to a standing worker supporting his or her own body weight should not be included.

### *STEP 5 – CALCULATING THE GRAND SCORE AND ACTION LEVEL*

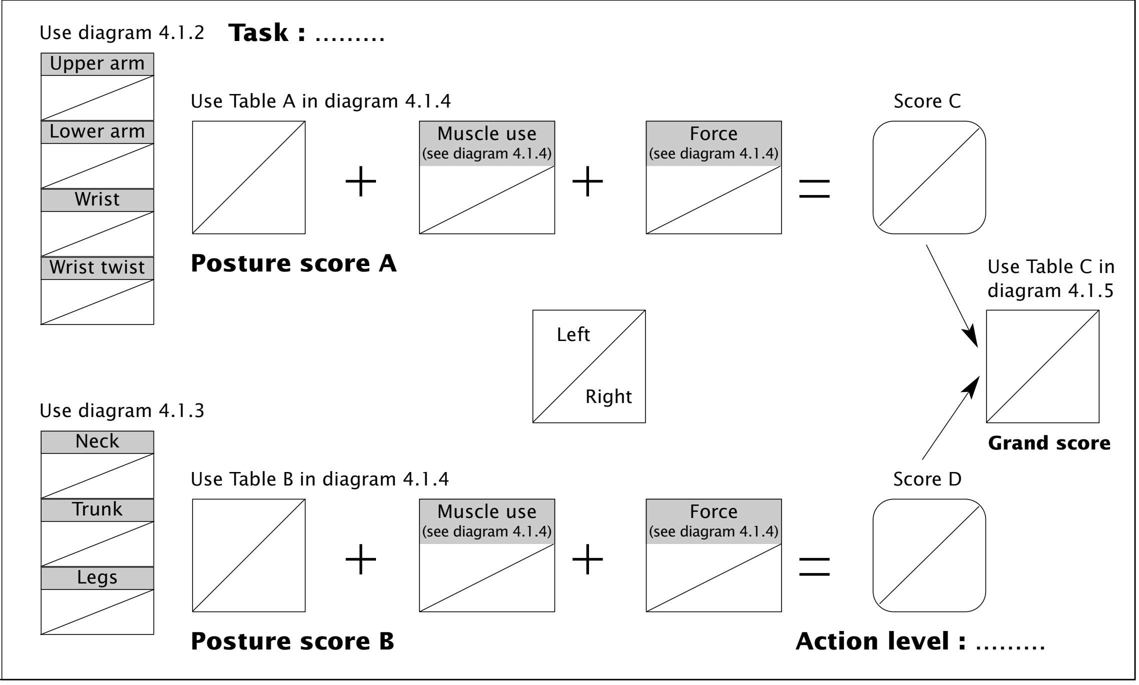
The posture score in Diagram 4.1.1, muscle use score and force score are then added together to produce score C for the upper limb. Similarly, add posture score B to its muscle use and force score for score D for the rest of the body. A grand score is then found using Table C in Diagram 4.1.5. Again you should follow the relevant column and row and the point at which they intersect is the grand score.

The need for intervention and modifications to the work or workplace can be assessed by comparing the Grand Score to the criteria for Action Levels shown beside Table C. Since the human body is a complex and adaptive system, they provide a guide only, which can be used as an aid in effective control of any risks identified. In most cases the action leads to a more detailed investigation and specification of the modifications required.

Another way of utilising grand scores would be to record and compare them before and after any changes are made to the workplace, thus assessing whether the modifications have achieved the desired purpose.

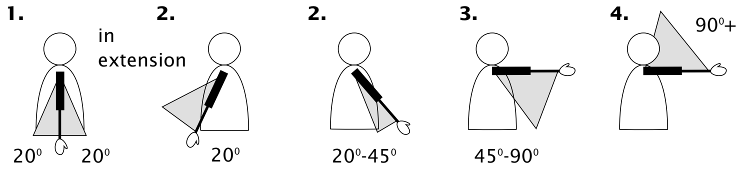
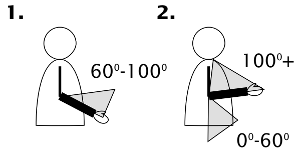
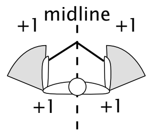
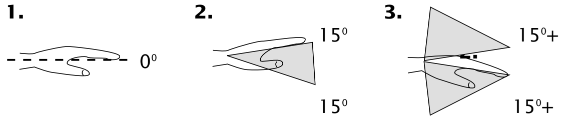
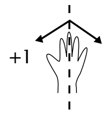
## Diagram 4.1.1

**Rula score sheet**



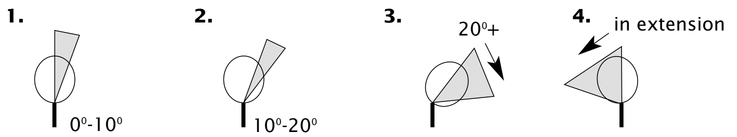
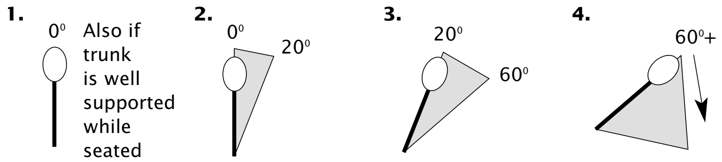
## Diagram 4.1.2

**Rula Group A body parts**

| | |
|---|---|
| **UPPER ARMS**<br>▪ Add 1 if shoulder is raised<br>▪ Add 1 if upper arm is abducted<br>▪ Subtract 1 if leaning or supporting the weight of the arm |   |
| **LOWER ARMS** |  <br>▪ Add 1 if working across the midline of the body or out to the side   |
| **WRIST** |    <br>▪ Add 1 if wrist is bent away from the midline |
| **WRIST TWIST** | **1.** Mainly in mid-range of twist<br>**2.** At or near the end of twisting range |

## Diagram 4.1.3

**Rula Group B body parts**

| | |
|---|---|
| **NECK**<br>▪ Add 1 if the neck is twisting<br>▪ Add 1 if the neck is side-bending |   |
| **TRUNK**<br>▪ Add 1 if the trunk is twisting<br>▪ Add 1 if the trunk is side-bending |   |
| **LEGS** | **1.** If legs and feet are well supported and in an evenly balanced posture<br>**2.** If not |

## Diagram 4.1.4

**Calculating posture, muscle use and forces scores**

TABLE A **Upper Limb Posture Score**

| Upper arm | Lower arm | Wrist posture score 1 |  | 2 |  | 3 |  | 4 |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Twist |  | Twist |  | Twist |  | Twist |  |
|  |  | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 |
|  | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
|  | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 4 |
| 2 | 1 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 |
|  | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 |
|  | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 |
| 3 | 1 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 |
|  | 2 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 |
|  | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
| 4 | 1 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
|  | 2 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
|  | 3 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6 |
| 5 | 1 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 7 |
|  | 2 | 5 | 6 | 6 | 6 | 6 | 6 | 7 | 7 |
|  | 3 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 8 |
| 6 | 1 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 9 |
|  | 2 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 9 |
|  | 3 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |

***MUSCLE USE SCORE***

Give a score of 1 if the posture is :

- Mainly static, e.g. held for longer than 1 minute
- Repeated more than 4 times/minute

TABLE B **Neck, Trunk, Legs Posture Score**

| Neck Posture Score | Trunk posture score 1 |  | 2 |  | 3 |  | 4 |  | 5 |  | 6 |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Legs |  | Legs |  | Legs |  | Legs |  | Legs |  | Legs |  |
|  | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 1 | 1 | 3 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 6 | 7 | 7 |
| 2 | 2 | 3 | 2 | 3 | 4 | 5 | 5 | 5 | 6 | 7 | 7 | 7 |
| 3 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 7 | 7 |
| 4 | 5 | 5 | 5 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 8 | 8 |
| 5 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| 6 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 9 |

***FORCES OR LOAD SCORE***

**0.**
- No resistance or less than 2 kg intermittent load or force

**1.**
- 2-10 kg intermittent load or force

**2.**
- 2-10 kg static load
- 2-10 kg repeated load or force
- 10 kg or more intermittent load or force

**3.**
- 10 kg or more static load
- 10 kg or more repeated load or force
- Shock or force with a rapid build-up

## Diagram 4.1.5

TABLE C **Grand score table with corresponding action levels**

Score D (Neck, trunk, legs)

| Score C (Upper limb) | 1 | 2 | 3 | 4 | 5 | 6 | 7+ |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 |
| 2 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 3 | 3 | 3 | 3 | 4 | 4 | 5 | 6 |
| 4 | 3 | 3 | 3 | 4 | 5 | 6 | 6 |
| 5 | 4 | 4 | 4 | 5 | 6 | 7 | 7 |
| 6 | 4 | 4 | 5 | 6 | 6 | 7 | 7 |
| 7 | 5 | 5 | 6 | 6 | 7 | 7 | 7 |
| 8 | 5 | 5 | 6 | 7 | 7 | 7 | 7 |

**Action level 1**

A score of one or two indicates that posture is acceptable if it is not maintained or repeated for long periods.

**Action level 2**

A score of three or four indicates further investigation is needed and changes may be required.

**Action level 3**

A score of five or six indicates investigation is needed and changes are required soon.

**Action level 4**

A score of seven or more indicates investigation and changes are required immediately.

Source : ATAMNEY L. Mc and CORLETT E.N., 1993, RULA : A survey method for the investigation of work-related upper limb disorders, *Applied Ergonomics*, 24, pp. 91-97.

**Method 4.2**
**OCRA**

This method follows a three-step approach. Step One considers a range of postures. Step Two takes other physical factors into the assessment. In Step Three, the body part scores are included in a Global Risk Index referable to an action level classified as “green”, “yellow” or “red”.

**References**


- Colombini, D., An observational method for classifying exposure to repetitive movements of the upper limbs, *Ergonomics*, vol. 41, No. 9, 1261:1289, September 1998.
- Occhipinti, E., OCRA: a concise index for the assessment of exposure to repetitive movements of the upper limbs, *Ergonomics*, vol. 41, No. 9, 1290:1311, September 1998.
- Colombini, D., Occhipinti, E., Delleman, N., Fallentin, N., Kilbom, A., Grieco, A., "Exposure assessment of upper limb repetitive movements: a consensus document". In: *International Encyclopedia of Ergonomics and Human Factors*, ed. W. Karwowski, Taylor and Francis, vol. 1, pp. 52-66, 2001.
- Colombini, D., Occhipinti, E., Grieco, A., *La valutazione e la gestione del rischio da movimenti e sforzi ripetuti degli arti superiori*, Franco Angeli ed., Milano, 2000.
- Occhipinti, E., Colombini, D., *The Ocra risk index for assessment of WMSDs risk with repetitive movements of the upper limbs: further validation data.* Proceedings of the IEA 2000/HFES 2000 Congress (S. Diego, U.S.), vol. 5, pp. 712-715, 2000.


**Definition and scope**

OCRA is designed to analyse repetitive upper limb movements and the different physical hazards for upper limb WMSDs (work-related musculoskeletal disorders).

The inputs are the different physical hazards. The output is a synthetic index which estimates the risks of WMSDs and leads to different actions based on a three zone model (green/yellow/red).

**Limitations**

The OCRA method is not particularly easy to apply; it involves only observation procedures; the main organisational variables (rhythms; breaks) are included, but not psychosocial variables.

***METHODOLOGY***

Every task involving repetitive movements is analysed for each job performed by a worker or group of workers. Step One is to analyse (describe) work organisation (sequence of tasks, duration, breaks). Step Two is to analyse (describe) for each relevant task (there may only be one): repetitiveness, force, posture and additional factors. Recovery periods for the entire work-shift are also taken into account. Step Three combines all the data collected to calculate the OCRA index.

**General consideration: risk factor considered**

Risk estimation needs to consider, in relation to their duration, those hazards:
a) repetitiveness (frequency)
b) force
c) awkward postures and movements
d) recovery time
e) complementary hazards

***STEP 1 – WORK ORGANISATION ANALYSIS***

- Identify distribution of work and pauses during the work-shift.
- Identify tasks, especially those involving a repeated identical cycle for at least 1 hr/work day.
- Measure the duration of repetitive tasks and single cycles.
- Identify the sequence of technical actions in each cycle.

*See Data Sheet 4.2.1 for work organisation description.*
*See definitions for organisation analysis and risk factor descriptions in Table 4.2.1.*

TABLE 4.2.1 **Main definitions of recurring terminology in exposure assessment**

| |
|---|
| ▪ **Organised work**: the organised grouping of work activities that are carried out within a single working shift; it may be composed of one or more tasks.<br>▪ **Task**: specific working activity intended to attain a specific operational result. The following are identified:<br>- Repetitive tasks: characterised by repeated cycles with mechanical actions.<br>- Non-repetitive tasks: characterised by the presence of non-cyclical mechanical actions.<br>▪ **Cycle**: a continuously repeated sequence of technical mainly mechanical, actions of relatively short duration.<br>▪ **Technical action** (mechanical): an action that involves a mechanical activity; not necessarily identified with single joint movement, but rather with the complex movements of one or more body regions that enable the completion of an elementary operation. |
| MAIN RISK FACTORS :<br>▪ **Recovery**: period of time within the work shift or within a cycle during which no repetitive mechanical actions are carried out. It implies relatively long pauses after a period of mechanical actions during which the metabolic and mechanical recovery of the muscle can take place. Lack of recovery is the relational risk factor.<br>▪ **Repetitiveness**: the occurrence of a time-bound continually-repeated sequence of identical events (cycles).<br>▪ **Frequency**: number of technical (mechanical) actions per given time unit (no. of actions per minute).<br>▪ **Force**: the physical effort required by the worker for the execution of the technical actions.<br>▪ **Posture**: the set of postures and movements used by each of the main joints of the upper limbs in order to execute the sequence of technical actions that characterise a cycle.<br>Awkward posture: risky postures for the main joints of the upper limbs. |
| ADDITIONAL RISK FACTORS:<br>these additional risk factors may be present in repetitive tasks but are not necessarily or always present. Their type, intensity and duration leads to an increased level of overall exposure. |

***STEP 2 – RELEVANT HAZARDS IDENTIFICATION /DESCRIPTION***

Describe and quantify hazards and exposure in a cycle for each relevant task (1 or more).

**2.1 Repetitiveness – Frequency**

Count, in detail, number of technical actions (mechanical) in the cycle and, considering cycle duration, calculate the number of technical actions per minute.
*Observing the videotaped task, describe the technical actions in the cycle performed by the upper limbs (left and right). Then calculate the total number of technical action per cycle, per task and per work shift.*

**2.2 Force**

Describe the muscular effort subjectively perceived as arising from the upper limbs (Borg, 1982) for each action (or group of actions) in the cycle.
*Collect data, using data sheet 4.2.2; each score has to be related to % of duration of the effort during the cycle. Then calculate the mean weighted effort of the cycle.*

**2.3 Posture and movements**

Describe the frequency and duration of postures or movements of the four main body segments (shoulder, elbow, wrist, hand) during a typical cycle of each repetitive task examined.

Describe, for each segment:
- the fraction of cycle time (1/3, 2/3, 3/3) in which a joint has reached an extreme level (e.g.: more than 45° of shoulder abduction, more than 80° of shoulder flexion, more than 20° of shoulder extension). Risk is present where nearly 1/3 of the cycle time is spent in an extreme position. The risk is higher for 2/3, and extreme for 3/3, of cycle time.
- whether each segment has performed the same technical action or the same body movement for more than 50% of cycle time (2/3 of cycle time for safety's sake). This is another risk condition.

If the two risk conditions are found together, "postural involvement" is extreme for that segment.
*You can use Data Sheet 4.2.3 to collect and codify the information.*

**2.4 Additional hazards**

Consider the presence of additional risk factors (mechanical or environmental). Use of vibrating tools, extreme precision requirements, localised compression, low temperatures, use of inadequate gloves, slippery surfaces, rapid or sudden wrenching movements required, return shock. **Psychosocial hazards are not considered.**

**2.5 Recovery time distribution and duration**

*If work is done with rapid movements:*

Describe the task sequences which involve upper limb overload, those with light (non-repetitive) involvement and then pause. Finally, describe the frequency of workday recovery periods and the ratio of repetitive task/recovery period durations.

Break the task and pause sequences down by shift duration. Observe whether a 10-minute recovery time follows 50 minutes of repetitive work. Identify the time spent each hour in adequate recovery or in fatigue.

A simpler method is to observe whether there is repetitive work and adequate recovery periods in each hour worked.

For each working hour:
- If work time/recovery time ratio is between 5:1 and 6:1, hazard exposure will be 0.
- If the ratio is between 7:1 and 11:1, hazard exposure will be 0,5.
- For higher ratios hazard exposure is 1.

*If work mainly involves static efforts:*

Extract the shortest recovery times needed for muscle fatigue from Table 4.2.2 for each contraction force and for different contraction durations.

TABLE 4.2.2 **Calculation of recovery periods (in seconds) for operations requiring isometric contractions (equal to or longer than 20 seconds) for applied times and forces**

| | Maintenance time | Recovery period | |
|---|---|---|---|
| **Force (Borg scale)** | | | |
| up to 2 | 20 | 2 | 10% |
| (20% MVC*) | 30 | 3 | 10% |
| | 45 | 7 | 15% |
| | 120 | 60 | 50% |
| | 180 | 180 | 100% |
| | 240 | 480 | 200% |
| | 300 | 1200 | 400% |
| | 450 | 2700 | 600% |
| about 3 | 20 | 10 | 50% |
| (30% MVC) | 40 | 40 | 100% |
| | 60 | 120 | 200% |
| | 90 | 360 | 400% |
| | 120 | 720 | 600% |
| | 150 | 1200 | 800% |
| about 4 | 20 | 20 | 100% |
| (40% MVC) | 30 | 60 | 200% |
| | 50 | 200 | 400% |
| | 70 | 420 | 600% |
| circa 5 | 20 | 40 | 50% |
| (50% MVC) | 30 | 120 | 400% |
| | 40 | 240 | 600% |
| | 90 | 720 | 800% |

* Maximum Voluntary Contraction (muscle activity required to support a maximum load).

***STEP 3 – INTEGRATED AND SYNTHETIC RISK EVALUATION (OCRA INDEX)***

The OCRA risk index for repetitive movements is:

$$\text{OCRA} = \frac{\text{N. Techn. Actions actually performed during the shift}}{\text{N. Techn. Actions recommended for the same shift}}$$

*To calculate the number of recommended technical actions per shift, work from a "reference" technical action frequency of 30 actions/min, reducing the reference frequency (if necessary) by applying the results of the Step 2 analysis. Consider the force – posture – additional hazards at this point.*
*This gives you the adjusted frequency per minute for each task; multiply each adjusted frequency for the effective duration (in minute) of each task and sum the results.*

*For the whole shift we need to consider the factor Recovery Periods and the Total Duration as additional adjusting factors for estimating the n. of technical actions recommended for the whole shift.*
*Use Data Sheet 4.2.4 (a and b) to help in working out the OCRA index.*

At last, from the calculated value of OCRA we can estimate risk as acceptable, conditionally acceptable or not acceptable:

- IE < 1 green area acceptable
- IE between 1 and 2 green-yellow area conditionally acceptable
- IE between 2 and 4 yellow-red area conditionally acceptable
- IE > 4 red area not acceptable

**Association between OCRA, WMSDs occurrence and predictive models**

The relationship between OCRA and WMSDs can be summarised in the following simple linear regression equation:

$$Y = 4.2\,X \qquad \text{Where: } Y = \frac{\text{No. WMSDs} \times 100}{\text{No. exposed individuals}} \qquad X = \text{OCRA index}$$

This regression equation is calculated without the constant (e.g., if OCRA is 0, then there are no WMSDs), and starting from the data examined until this point, it has an $R^2$ of 0.89, and extremely high statistical significance ($p < 0.00001$).

The term *WMSDs / No. exposed individuals* stands for the prevalence of single upper limb occupational pathologies calculated on the number of exposed individuals. This datum is obviously different from the alternative one used: the prevalence of individuals affected by WMSDs (one or more).

When considering the above regression equation as a predictive model (OCRA index is a forecast index of collective risk for a given exposed population to contract WMSDs) the confidence limits (95%) within which the forecast may oscillate should be considered for a better forecast. On the basis of the data available, these limits will in turn make the OCRA multiplier factor (4.2) oscillate between 3.2 (minimum value) and 5.2 (maximum value). Therefore, the equation which expresses the forecast model (95% confidence) can be expressed as follows:

Prevalence (%) WMSDs = (4.2 + 1) OCRA

By adopting this type of model, once the OCRA index has been calculated, it is possible to estimate the prevalence of WMSDs that can be expected over a general ten-year span for the group of exposed individuals.

Table 4.2.3 shows examples of forecasts, with specific OCRA index values.

TABLE 4.2.3 **Prediction of WMSDs prevalence in a group of exposed individuals (10-year basis), given specific OCRA index values**

| | Forecast of WMSDs ( % ) | | |
|---|---|---|---|
| **OCRA value** | **min.** | **central** | **max** |
| 1 | 3.2 | **4.2** | 5.2 |
| 2 | 6.4 | **8.4** | 10.4 |
| 4 | 12.8 | **16.8** | 20.8 |
| 8 | 21.6 | **33.6** | 41.6 |

## Data Sheet 4.2.1 **Description and assessment of jobs featuring repetitive tasks**

Company name: . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Department/Area: . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Station: . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

***BRIEF JOB OUTLINE:***

Cutting disks from mother-of-pearl seashells for the manufacture of buttons.
The worker operates a lever with the right hand and uses the left hand to cut the disks.
The worker is seated.

***DESCRIPTION OF TASK(S) CHARACTERIZING THE SHIFT***

| Task name | Cycles present | Cycle duration (sec.) | N°. of cycles in task | Task duration in minutes (Total = 450 min) |
|---|---|---|---|---|
| A. Cutting of large shells | yes | 30 | | 180 |
| B. Cutting of small shells | yes | 30 | | 190 |
| C. | yes | | | |
| D. | yes | | | |

| Task name | | Duration - Hourly frequency | |
|---|---|---|---|
| X. Maintenance | no | 15 min. : 11.45/12.00<br>15 min. : 15.45/16.00 | 30 |
| Y. | no | | |
| Z. | no | | |
| | | | |

| Shift | Break | Duration | Timetable | Official breaks |
|---|---|---|---|---|
| one | meal | 60 min. | 12.00 - 1.00 pm | |
| | | | | |
| | | | | |
| | | | | |

***NON-OFFICIAL BUT IDENTIFIABLE AND RECURRENT BREAKS***

| Break | Duration | Timetable | N.b. |
|---|---|---|---|
| P1 - Morning | 10 min. | 9.50/10.00 am | |
| P2 - A-Noon | 10 min. | 2.00/2.10 pm | |
| | | | |

***SEQUENCE OF TASK(S) AND BREAKS DURING THE SHIFT***

<table>
<tr><th>8.00-9.00</th><th colspan="2">9.00-10.00</th><th>10.00-11.00</th><th colspan="2">11.00-12.00</th><th>12.00-1.00</th><th>1.00-2.00</th><th colspan="2">2.00-3.00</th><th colspan="2">3.00-4.00</th><th>–</th></tr>
<tr><td>A</td><td>B</td><td>P1</td><td>A</td><td>B</td><td>X</td><td>Meal br.</td><td>A</td><td>P2</td><td>B</td><td>B</td><td>X</td><td></td></tr>
<tr><td>1 hour</td><td colspan="2">10 min</td><td></td><td colspan="2">15 min</td><td></td><td></td><td colspan="2">10 min</td><td colspan="2">15 min</td><td></td></tr>
</table>

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |

## Data Sheet 4.2.2 **Force assessment**
## Subjective assessment of perceived exertion with Borg's scale

Line: ..........................................................................................

Operator: ......................................................................................

Shift: .........................................................................................

Which actions require you to use force with your arms or hands in a representative cycle?
Can you explain the reason for this?

| List of actions requiring force | Rating | Duration in time in % | Reason for the use of force |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| Remaining time | | | |
| Weighted effort by time | | | |

Rate each action you described according to the following scale:

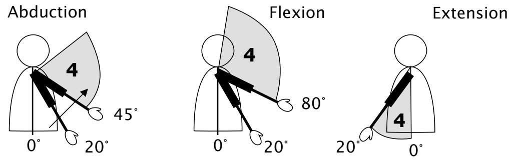
| | | | |
|---|---|---|---|
| **0** | totally absent | **5** | strong (heavy) |
| **0.5** | extremely weak (just noticeable) | **6** | |
| **1** | very weak | **7** | very strong |
| **2** | weak (light) | **8** | |
| **3** | moderate | **9** | |
| **4** | somewhat strong | **10** | extremely strong (almost maximum) |

## Data Sheet 4.2.3 **Analysis of upper limb postures as a function of time**

Task: .......................................................................................... ❑ Right ❑ Left

### HUMERO-SCAPULAR POSITION AND MOVEMENTS

**RISK SCORE IN CYCLE**




**[A1]** Movements in risk areas: Occupy: [4] 1/3, [8] 2/3, [12] 3/3 of cycle time

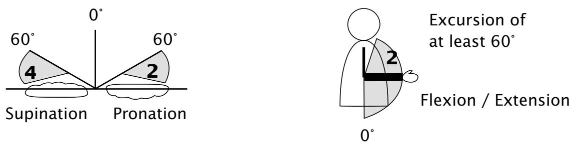
**[A2]** Lack of variation (stereotypy): carries out working gestures of same type, involving the shoulder, for at least 50% of cycle time: [4]

**[A3]** Keeps arms uplifted (not supported) in risk areas: [4] 1/3, [8] 2/3, [12] 3/3 of cycle time

**[A4]** Keeps arms uplifted (not supported) by over 20°, or in extension for at least 50% of cycle time: [4]

|__|__| **SHOULDER**

### MOVEMENTS OF THE ELBOW

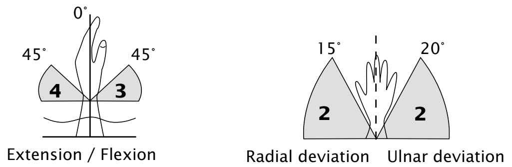



**[B1]** Movements in risk areas :
They occupy : [4] 1/3, [8] 2/3, [12] 3/3 supination
[2] 1/3, [4] 2/3, [6] 3/3 pronation
[2] 1/3, [4] 2/3, [6] 3/3 flexion
} of cycle time

**[B2]** Lack of variations : carries out the same type of gestures and movements involving the elbow for at least 50% of cycle time: [4]

|__|__| **ELBOW**

### POSITIONS AND MOVEMENTS OF THE WRIST




**[C1]** Movements in risk areas (or maintenance)
Takes up: [2] 1/3, [4] 2/3, [6] 3/3 R/U deviation
[4] 1/3, [8] 2/3, [12] 3/3 extension
[3] 1/3, [6] 2/3, [9] 3/3 flexion
} of cycle time

**[C2]** Lack of variation : carries out working gestures of same type, involving the wrists for at least 50% of cycle time: [4]

|__|__| **WRIST**

### TYPE OF GRIP AND FINGER MOVEMENTS

**[D1]** Grip time and finger position

| | | | | | |
|---|---|---|---|---|---|
| [ ] | Grip (3-4 cm) | [1] 1/3, | [2] 2/3, | [3] 3/3 | of cycle time |
| [ ] | Tight grip (1,5 cm) | [2] 1/3, | [4] 2/3, | [6] 3/3 | |
| [ ] | Pinch | [3] 1/3, | [6] 2/3, | [9] 3/3 | |
| [ ] | Palmar grip | [4] 1/3, | [8] 2/3, | [12] 3/3 | |
| [ ] | Hook grip | [4] 1/3, | [8] 2/3, | [12] 3/3 | |
| [ ] | Digitation | [4] 1/3, | [8] 2/3, | [12] 3/3 | |
| [ ] | ........... | [ ] 1/3, | [ ] 2/3, | [ ] 3/3 | |
| [ ] | ........... | [ ] 1/3, | [ ] 2/3, | [ ] 3/3 | |
| [ ] | ........... | [ ] 1/3, | [ ] 2/3, | [ ] 3/3 | |

Lack of variation :

**[D2]** carries out working gestures of same type, involving the same finger for at least 50% of cycle time: [4]

**[D3]** keep an object continually for at least 50% of cycle time: [4]

|__|__| **GRIP/HAND**

## Data Sheet 4.2.4a **Summary of data for calculating index of exposure to repetitive movements of the upper limbs**

Department or line: . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Station or task: . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Shift: . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

***CHARACTERIZATION OF REPETITIVE TASKS PERFORMED DURING SHIFT***

| | A | B | C | D |
|---|---|---|---|---|
| ▪ duration of task in shift (min) | | | | |
| ▪ mean cycle duration (sec) | | | | |
| ▪ action frequency (no. of actions/min) | | | | |
| ▪ total actions in task | | | | |

**Total actions in shift (sum of A, B, C, D)** [ ] Ae

***CHARACTERIZATION OF NON-REPETITIVE TASKS PERFORMED DURING SHIFT***

| | X | Y | Z |
|---|---|---|---|
| ▪ duration (min) | | | |
| ▪ comparable to recovery | | | |
| ▪ not comparable to recovery min | | | |

**Total time (minutes) spent in non-repetitive tasks (considered as recovery periods)** [ ]

***CHARACTERIZATION OF BREAKS DURING SHIFT***

▪ duration of break per lunch (min) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

▪ other breaks . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

▪ total duration of other breaks (min) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

***TIME-WISE DISTRIBUTION OF TASKS AND BREAKS IN SHIFT***

(describe exact sequence of tasks and breaks, and their relative duration in minutes)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

1 hour n. hours

***NO. OF HOURS IN SHIFT FEATURING LACK OF RECOVERY TIMES***

N. = ........................

## Data Sheet 4.2.4b **Calculation of OCRA risk index**

***ACTION FREQUENCY CONSTANT (NO. OF ACTIONS/MIN.)***

| RIGHT ARM | | | | LEFT ARM | | | | |
|---|---|---|---|---|---|---|---|---|
| A | B | C | D | A | B | C | D | Task/s |
| 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | **C.F.** |

×

***FORCE FACTOR (PERCEIVED EFFORT)***

| Borg | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Factor | 1 | 0.85 | 0.75 | 0.65 | 0.55 | 0.45 | 0.35 | 0.2 | 0.1 | 0.01 |

| A | B | C | D | A | B | C | D | Task/s |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **Ff** |

***POSTURAL FACTOR***

| Value | 0-3 | 4-7 | 8-11 | 12-15 | 16 |
|---|---|---|---|---|---|
| Factor | 1 | 0.70 | 0.60 | 0.50 | 0.33 |

| | A | B | C | D | A | B | C | D | Task/s |
|---|---|---|---|---|---|---|---|---|---|
| Shoulder | | | | | | | | | |
| Elbow | | | | | | | | | |
| Wrist | | | | | | | | | |
| Hand | | | | | | | | | **Fp** |
| (*) | | | | | | | | | |

(*) select lowest factor between elbow, wrist and hand

×

***ADDITIONAL FACTORS***

| Value | 0 | 4 | 8 | 12 |
|---|---|---|---|---|
| Factor | 1 | 0.95 | 0.90 | 0.80 |

| A | B | C | D | A | B | C | D | Task/s |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **Fc** |

×

***DURATION OF REPETITIVE TASK***

| A | B | C | D | A | B | C | D | Task/s |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

=

Nº. recommended actions
for repetitive task, and in total
(partial result, without recovery factor)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| α | β | γ | δ | α | β | γ | δ |

| Right π | Left π |
|---|---|
| | |
| (α+β+γ+δ) | (α+β+γ+δ) |

***FACTOR REFERRING TO THE LACK OF RECOVERY PERIODS***
(no. of hours without adequate recovery)

| Hours | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Factor | 1 | 0.00 | 0.80 | 0.70 | 0.60 | 0.45 | 0.25 | 0.10 | 0 |

| **Fr** |
|---|
| |

***FACTOR REFERRING TO OVERALL DURATION OF REPETITIVE TASKS***

| Minutes | < 120 | 120 – 239 | 240 – 480 | > 480 |
|---|---|---|---|---|
| Factor | 2 | 1.5 | 1 | 0.5 |

| **Fd** |
|---|
| |

| Right =Arp = π x Fr x Fd | Left Arp = π x Fr x Fd |
|---|---|
| | |
| (α+β+γ+δ) | (α+β+γ+δ) |

**I.E. = Total no. of actions observed in repetitive tasks Ae / No. recommended actions Arp =**

| Right | Left |
|---|---|
| | |
| | |

| Right | Left |
|---|---|
| | |

**Method 4.3 Upper Limb expert tool**

## Worksheet 4.3. **Physical load assessment for upper extremities**

**1. Name of worker** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Dominant hand : ❑ Right ❑ Left

**2. Job title** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Temperature: ...... ºC

| **3. Work cycle** Break down into cycles. Measure the duration of each cycle (in seconds). Find out how many times each cycle is repeated per day (repetition/day). Calculate the total duration of the cycles per day. | | | | **4. Repetitive use of hand** ▪ Cycle duration is < or = 30s and involves repetitive movement of hand, wrist or fingers ▪ Cycle time involves similar hand or wrist motion patterns over 50% of the cycle time | | | | **5. Use of hand force** ▪ Worker lifts, carries, pushes or pulls objects heavier than 4.5 kg for over 1/3 of cycle time or ▪ Uses a tool or a part heavier than 2.5 kg over 1/3 of cycle time | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work cycle** | **Duration (s)** | **Repetitions/ day** | **Duration/ day (minutes)** | **Right** | | **Left** | | **Right** | | **Left** | |
| 1. | | | | No | Yes | No | Yes | No | Yes | No | Yes |
| 2. | | | | | | | | | | | |
| 3. | | | | | | | | | | | |
| 4. | | | | | | | | | | | |

| **6. Pinch grip** Worker holds an object between the thumb and fingertips (distance between thumb and fingertips < or = 5cm) for over 1/3 of the cycle | | | | **7. Non-neutral wrist posture** Flexion extension/ radial ulnar deviation angle of the wrist < or = for over 1/3 of cycle time. The posture can be a combination of the above. | | | | **8. Elevation of upper arm** The angle between the body and upper arm is > or = 90 for over 1/3 of cycle time. Observe the posture from both front and side view. | | | | Add up the ticks (√) on the grey columns of each work cycle and circle the result in the scale below. The higher the total, the more strenuous the work for the upper extremities. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Right** | | **Left** | | **Right** | | **Left** | | **Right** | | **Left** | | **Right** | | | | | | **Left** | | | | | |
| No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | 0 | 1 | 2 | 3 | 4 | 5 | 0 | 1 | 2 | 3 | 4 | 5 |
| | | | | | | | | | | | | 0 | 1 | 2 | 3 | 4 | 5 | 0 | 1 | 2 | 3 | 4 | 5 |
| | | | | | | | | | | | | 0 | 1 | 2 | 3 | 4 | 5 | 0 | 1 | 2 | 3 | 4 | 5 |
| | | | | | | | | | | | | 0 | 1 | 2 | 3 | 4 | 5 | 0 | 1 | 2 | 3 | 4 | 5 |

| | **No** | **Yes** |
|---|---|---|
| ▪ Do hard objects or parts of tools cause localised pressure on the fingers, palm, forearm or elbow? | | |
| ▪ Does the worker use vibrating tools? | | |
| ▪ Does cold exhaust air blow on the hand or wrist? | | |
| ▪ Do gloves hinder gripping? | | |

Go back to the duration/day column. The longer the duration of the cycle including load factors, the greater the effect on the upper extremity. Ergonomic improvements should be considered, especially for work consisting of strenuous tasks lasting over 60 min.

Source: Ritva Ketola, Risto Toivonen and Eira Viikari-Juntura, Interobserver repeatability and validity of an observation method to assess physical loads imposed on the upper extremities, *Ergonomics*, Vol. 44, No 2, Appendix, 2001.

Section 5
# Conclusion

More information is needed about risks for MSD and the real incidence of complaints, pain symptoms and MSD occurrences. This can add to the current knowledge on “dose-effect” relations for MSD and improve the methodology for risk assessment. Researchers and different experts in the field of occupational safety and health and machinery design should work on this. Standardisation has an important role to play.

It is also important to have comprehensive documentation available to take the risk assessment into the following phase. It is not always possible to go on to the next step of risk assessment - risk evaluation - and determine whether the machine is safe. If the risk is estimated as unacceptable, the designer should go straight on to the measures which must be taken.

It is essential to provide designers with practical ways of improving situations scored as “conditionally acceptable” or “unacceptable” in the risk estimation. So, better education and implementation of knowledge about MSD and ways of achieving improvements are crucial. This means integrating ergonomics and MSD prevention more closely into the process of innovation and technological progress in machinery design.

The TUTB hopes that the checklists and summaries of methods outlined in this guide will help to inform future improvements in work equipment design.

# Annex

In this Annex, we present a questionnaire for sampling users' experienced strain and estimation of load. The questionnaire[54] can be rated on the basis of personal workplace experiences, or more specifically during work with particular machinery. It makes no direct line with machinery design as such, but establishes the association that awkward postures have with physical strain and discomfort. It can be used by designers to evaluate existing machinery so as to identify and avoid in the re-design postures that can cause discomfort and strain.

54. Schaub and Landau, IAD Darmstadt University of Technology, 1998.

## IAD questionnaire to determine physical strain

Division: ............................... Position: .......................................................................

Company: ............................... Analyst: ............................. Date: ........... Time: ..............

**Type of strain** *(please select)* Activity:

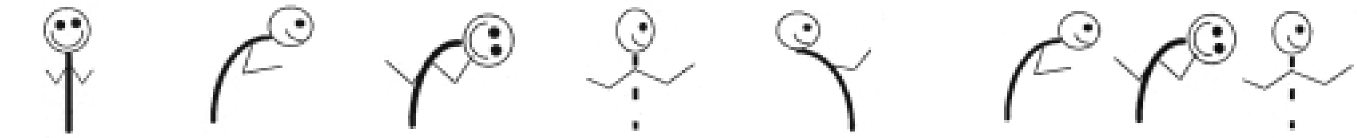
| ❑ **Handling of loads** | | ❑ **Forces or** ❑ **Moments** | | ❑ **Little or no external loads/forces/moments** | |
|---|---|---|---|---|---|
| Load weight and lifting type | | Amount of strain per arm | | | |
| Maximum: ...... [kg] | ❑ one arm | Maximum l: ...... | r: ...... [N, Nm] | ❑ static posture | ❑ low-freq. movement |
| Average: ...... [kg] | ❑ two arms | Average l: ...... | r: ...... [N, Nm] | ❑ high-freq. movement | |

**Frequency and duration of strain** | **Type of strain** *(in essence)*

| Shift length | Number of cycles per shift: | or total | | |
|---|---|---|---|---|
| ...... [min] | Length of cycle: ...... [sec] or [min] | Time under load: ...... [min] | ❑ Short-cycle | ❑ Cumulative |
| | Load length/cycle: ...... [sec] or [min] | Distance carried if applic.: ...... [m] | ❑ Long-cycle | ❑ Acyclical |

**Body pose/posture and direction/point(s) of application of a force**

**Trunk position** *(please check)* **and direction of force** *(please draw as arrow in front and side view)*



❑ trunk erect ❑ trunk bent forward ❑ trunk bent sideways ❑ trunk turned ❑ trunk bent backwards ❑ trunk bent sideways and forward or turned and bent forward or sideways

**Leg position** *(more than one answer possible)*

❑ sitting - normal ❑ sitting - legs and seat at same height

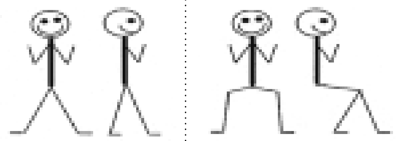
❑ standing on 2 legs, legs straight ❑ standing on 1 leg, leg straight

❑ standing on 2 legs, legs bent ❑ standing on 1 leg, leg bent

❑ standing on toes ❑ crawling or climbing ❑ walking

❑ squatting ❑ kneeling ❑ lying

**Support** *(if any; sitting/standing)*

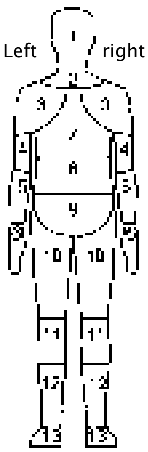


please mark with arrows in both views

**Arm position** *(multiple answers possible, check weight arm(s))* **and force point of application** *(if arm forces)*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ❑ **Left:** | ❑ near<br>❑ front | ❑ med. far<br>❑ diagonal | ❑ far<br>❑ side | **Elevation of hand:** | ❑ < foot<br>❑ pelvis | ❑ foot<br>❑ waist | ❑ lower leg<br>❑ chest | ❑ knee<br>❑ shoulder | ❑ thigh<br>❑ head | ❑ > head |
| ❑ **Right:** | ❑ near<br>❑ front | ❑ med. far<br>❑ diagonal | ❑ far<br>❑ side | **Elevation of hand:** | ❑ < foot<br>❑ pelvis | ❑ foot<br>❑ waist | ❑ lower leg<br>❑ chest | ❑ knee<br>❑ shoulder | ❑ thigh<br>❑ head | ❑ > head |

**Description of particularly strained regions of body**




In describing the joint system, if the region does not include the joint then the numbers refer to the joint lying towards the middle of the body. Thus, number 10 corresponds to the hip joint, 5 the elbow joint, 13 the ankle joint and 6 the wrist. Areas without joints are shaded.

| **Body region** | | 1 | 2 | 3l | 3r | 4l | 4r | 5l | 5r | 6l | 6r | 7 | 8 | 9 | 10l | 10r | 11l | 11r | 12l | 12r | 13l | 13r |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Muscle strain | static | | | | | | | | | | | | | | | | | | | | | |
| | dynamic | | | | | | | | | | | | | | | | | | | | | |
| | jerky | | | | | | | | | | | | | | | | | | | | | |
| Joint strain | static | | | | | | | | | | | | | | | | | | | | | |
| | dynamic | | | | | | | | | | | | | | | | | | | | | |
| | jerky | | | | | | | | | | | | | | | | | | | | | |
| Posture movement | static | | | | | | | | | | | | | | | | | | | | | |
| | low-freq. | | | | | | | | | | | | | | | | | | | | | |
| | high-freq. | | | | | | | | | | | | | | | | | | | | | |
| Joint angle relative to maximum | small | | | | | | | | | | | | | | | | | | | | | |
| | med. | | | | | | | | | | | | | | | | | | | | | |
| | large | | | | | | | | | | | | | | | | | | | | | |

l = left / r = right

**External factors** *(e.g. room temperature, technical work aids, freedom of movement) (if applicable, also personal data (age, gender, etc.))*

# References


- ACGIH, *Hand Activity Level* (HAL), 2000.
- ANSI (USA)-Draft ANSI Z-365, *Control of Cumulative Trauma Disorders,* 1997.
- Atamney L. Mc and Corlett E. N., 1993, RULA: A survey method for the investigation of work-related upper limb disorders, *Applied Ergonomics*, 24, pp. 91-97.
- Borg G., Psychophysical scaling with applications in physical work and the perception of exertion, *Scan. J. of Work and Environmental Health*, 1990, 16, pp. 55-58.
- Buckle Peter and Devereux J., 1999, *Work-related neck and upper limb musculoskeletal disorders*, European Agency for Safety and Health at Work.
- Caplan Stanley, 1990, Using focus group methodology for ergonomic design, *Ergonomics*, Vol. 33, No 5, pp. 527-533.
- Colombini D., Occhipinti E., Delleman N., Fallentin N., Kilbom A. and Grieco A., 1999, *Exposure assessment of upper limb repetitive movements: A consensus document*, Technical Committee on Musculoskeletal Disorders of International Ergonomics Association (IEA).
- Daniellou F., 1999, *Une contribution au nécessaire recensement des "Repères pour s'affronter aux TMS"*, Actes du séminaire sur les TMS, Lyon, ANACT.
- Fallentin N., Kristensen B., Mikkelsen S., Andersen J., Bonde J., Frost P. and Endahl L., 2001, Physical exposure assessment in monotonous repetitive work-the PRIM study, *Scandinavian Journal of Environmental Health,* 27, pp. 21-29.
- Garrigou A., Daniellou F., Garballeda G., Ruaud S., 1995, Activity analysis in participatory design and analysis of participatory design activity, *International Journal of Industrial Ergonomics* 15, pp. 311-327.
- Hagberg Mats, Silverstein Barbara *et al.*, Scientific editors Ilkka Kuorinka and Lina Forcier, 1995, *Work Related Musculoskeletal Disorders. A reference book for prevention*, Taylor and Francis.
- Haines Helen M. and Professor Wilson John R., 1998, *Development of a framework for participatory ergonomics,* Institute for Occupational Ergonomics, HSE.
- Hignett S. and L. Mc Atamney, 2000, REBA- Rapid entire body assessment, *Applied Ergonomics*, 31, pp. 201-205.
- *International Journal of Industrial Ergonomics*, Volume 15, No. 5, 1995, Special issue: "Participatory Ergonomics", eds M. Nagamachi and A. S. Imada, Elsevier Science.
- Karthu O., P. Kansi and I. Kuorinka, 1977, Correcting working postures in industry: a practical method for analysis, *Applied Ergonomics*, 8, pp. 199-201.
- Karthu O., *et al.*, 1981, OWAS: Ovako Working Posture Analysis System, Observing working postures in industry: examples of OWAS application, *Applied Ergonomics*, 12, pp. 13-17.
- Karwowski W. and Marras W. S. 1998, *The occupational ergonomics handbook*, CRC Press.
- Kemmlert K., 1995, A method assigned for the identification of ergonomic hazards- PLIBEL, *Applied Ergonomics*, Vol 36, No 3 pp. 199-211.
- Ketola Ritva, Toivonen Risto and Juntura Eira Viikari, 2001, Interobserver repeatability and validity of an observation method to assess physical loads imposed on the upper extremities, *Ergonomics*, Vol 44, No 2, pp. 119-131.
- Keyserling W. M., Stetson D. S., Silverstein B. A. and Brouwer M. L., 1993, A checklist for evaluating ergonomic risk factors associated with upper extremity cumulative trauma disorders, *Ergonomics*, Vol 36, No 7, pp. 807-831.
- Kilbom A., 1994, Repetitive work of the upper extremity: Part I- Guidelines for the practitioner, *International Journal of Industrial Ergonomics* 14, pp. 51-57.
- Koukoulaki Th., 2000, Social partner perspectives on preventing work-related musculoskeletal disorders: The emloyees' viewpoint, *Magazine of the European Agency for Safety and Health at Work*, 3.
- Kuorinka I., 1994, Repetitive work in prespective, Proceedings of the 12$^{th}$ Triennial Congress of the IEA, Volume 1, *International perspectives on Ergonomics.*

- Kuorinka I., Jonsson B., Kilbom A., Vinterberg H., Biering-Sorensen F., Andersson G. and Jorgensen K., 1987, Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms, *Applied Ergonomics*, 18.3, pp. 233-237.
- Li G. and Buckle P., 1998, *The development of a practical method for the exposure assessment of risks to work-related musculoskeletal disorders.* General report to the HSE, Robens Centre for Health Ergonomics, European Institute of Health and Medical sciences, University of Surrey.
- Li G. and Buckle P., 1999, Current techniques for assessing physical exposure to work related musculoskeletal risks, with emphasis on posture-based methods, *Ergonomics*, 42, 5, pp. 674-695.
- Luximon A. and Goonetilleke Ravindra S., 2001, Simplified subjective workload assessment technique, *Ergonomics*, Vol 44, No. 3, pp. 229-243.
- Macin P., 1995, *Ergonomic essential safety requirements in the Machinery Directive*, BTS 2 and BTS 4 Seminar on Ergonomics, Brussels.
- Malchaire J. and Indesteege B., *Troubles musculosquelettiques-Analyse du risque*, INRCT, Brussels, 1997.
- Merllié D. and Paoli P., 2000, *Third European survey in working conditions*, Report by European Foundation for improvement of living and working conditions.
- National Research Council, Institute of medicine, 2001, *Musculoskeletal Disorders and the workplace, Low back and Upper Extremities*, National Academy Press, Washington DC.
- NIOSH, 1997, *Musculoskeletal Disorders and Workplace Factors, A critical review of Epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back*, CDC, Cincinnati, USA.
- NIOSH, 1994, *Applications manual for the revised NIOSH Lifting Equation,* CDC, Cincinnati, OH 45226, USA.
- O'Neill R., 1999, *Europe under strain, A report on trade union initiatives to combat workplace musculoskeletal disorders,* European Trade Union Technical Bureau for Health and safety.
- PREMUS-ISEOH'98, 1999, Epidemiology meets work-related musculoskeletal disorders, Keynote presentations of the joint scientific meeting, *Scandinavian Journal of Work, Environment & Health.*
- Punnet L. and Van de Beek Allard J., 2000, *American Journal of Industrial Medicine* 37, A comparison of approaches to modeling the relationship between Ergonomic exposures and Upper Extremity Disorders, pp. 645-655.
- Sapir M., 1995, *A user's perspective,* TUTB, BTS 2 and BTS 4 Seminar on Ergonomics, Brussels, CEN.
- Sapir M. and Koukoulaki Th., 2001, *Europe under strain: a European Trade Union campaign on prevention of Musculoskeletal Disorders at workplaces,* Yearbook 2000, Edited by E. Gabaglio & Reiner Hoffmann, European Trade Union Institute, Brussels.
- Salvendy G., 1997, *Handbook of Human Factors and ergonomics,* John Wiley & Sons.
- Takala P. and Freund J., 2000, *OWAS Revised: Biomechanical calculations and time aspects of loading,* Esa- Finish Institute of Occupational Health, Proceedings of the IEA 2000/ HFES 2000 Congress.
- Tozzi A., 1999, MSD in Europe: Unions show a lead, *TUTB Newsletter* No. 11-12.
- Valenduc G., 2000, La société de l'information et l'intensification de travail, *Cahiers Marxistes*, pp. 27- 44, December - January 2000.
- Violante F., Armstrong T. and Kilbom A., *Work related musculoskeletal disorders of the upper limb and back,* 2000, Taylor & Francis.
- Wilson John R. and Corlett E. N., 1995, *Evaluation of human work, A practical ergonomics methodology.*

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