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# Ergonomics — Manual handling —

# Part 3: Handling of low loads at high frequency

*Ergonomie — Manutention manuelle —*

*Partie 3: Manipulation de charges faibles à fréquence de répétition élevée*



Reference number
ISO 11228-3:2007(E)

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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11228-3 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 3, *Anthropometry and biomechanics*.

ISO 11228 consists of the following parts, under the general title *Ergonomics — Manual handling*:

— *Part 1: Lifting and carrying*

— *Part 2: Pushing and pulling*

— *Part 3: Handling of low loads at high frequency*

## Introduction

Handling of low loads at high frequency (repetitive work) can cause pain and fatigue, which could lead to musculoskeletal disorders, reduced productivity, and deteriorated posture and movement co-ordination. The latter can increase the risk of errors and may result in reduced quality and hazardous situations. Good ergonomic design and proper organization of work are basic requirements for the avoidance of the adverse effects mentioned.

Risk factors in repetitive work include the frequency of actions, exposure duration, postures and movement of body segments, forces associated with the work, work organization, job control, demands on work output (e.g. quality, task precision) and level of training/skill. Additional factors can include environmental factors, such as climate, noise, vibration and illumination.

The recommendations provided by this part of ISO 11228 are based on available scientific evidence concerning the physiology and epidemiology of manual work. The knowledge is, however, limited, and the suggested guidelines are subject to change according to future research.

# Ergonomics — Manual handling —

# Part 3:
# Handling of low loads at high frequency

## 1 Scope

This part of ISO 11228 establishes ergonomic recommendations for repetitive work tasks involving the manual handling of low loads at high frequency. It provides guidance on the identification and assessment of risk factors commonly associated with handling low loads at high frequency, thereby allowing evaluation of the related health risks to the working population. The recommendations apply to the adult working population and are intended to give reasonable protection for nearly all healthy adults. Those recommendations concerning health risks and control measures are mainly based on experimental studies regarding musculoskeletal loading, discomfort/pain and endurance/fatigue related to methods of working. For the evaluation of working postures, refer to ISO 11226.

This part of ISO 11228 is intended to provide information for all those involved in the design or redesign of work, jobs and products.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6385, *Ergonomic principles in the design of work systems*

ISO 11226, *Ergonomics — Evaluation of static working postures*

ISO 11228-1, *Ergonomics — Manual handling — Part 1: Lifting and carrying*

ISO 11228-2, *Ergonomics — Manual handling — Part 2: Pushing and pulling*

ISO 14738, *Safety of machinery — Anthropometric requirements for the design of workstations at machinery*

ISO 15534 (all parts), *Ergonomic design for the safety of machinery*

## 3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the terms and definitions given in ISO 6385, ISO 11228-1, ISO 11228-2, ISO 11226 and the following terms, definitions, symbols and abbreviated terms apply.

NOTE In the definitions involving frequency, a unit of time is mentioned because more than one method is involved, each using a different unit, e.g. seconds in HAL (see Annex D), minutes in the OCRA Index (see Annex C) and Strain Index (see Annex D).

### 3.1 Terms and definitions

**3.1.1**
**repetitive task**
task characterized by repeated work cycles

**3.1.2**
**work cycle**
sequence of (technical) actions that are repeated always the same way

**3.1.3**
**cycle time**
$t_C$
time, in seconds, elapsing from the moment when one operator begins a work cycle to the moment that the same work cycle is repeated

**3.1.4**
**technical action**
elementary manual actions required to complete the operations within the cycle

EXAMPLE Holding, turning, pushing or cutting.

**3.1.5**
**repetitiveness**
characteristic of a task when a person is continuously repeating the same work cycle, technical actions and movements

**3.1.6**
**frequency of actions**
number of technical actions per unit of time

**3.1.7**
**force**
$F$
physical effort of the operator required to execute the task

**3.1.8**
**postures and movements**
positions and movements of body segment(s) or joint(s) required to execute the task

**3.1.9**
**recovery time**
period of rest following a period of activity which allows restoration of musculoskeletal function (in minutes)

**3.1.10**
**additional risk factor**
object and environmental factors for which there is evidence of causal or aggravating relationship with work-related musculoskeletal disorders of the upper limb

EXAMPLE Vibration, local pressure, cold environment or cold surfaces.

**3.1.11**
**move**
transport of an object to a given destination using the upper limbs and without walking

**3.1.12**
**reach**
shift the hand towards a prefixed destination

**3.1.13**
**carry**
transport of an object to a given destination by walking

## 3.2 Symbols and abbreviated terms

| | |
|---|---|
| $A_M$ | additional multiplier |
| ATA | actual technical action |
| $f$ | frequency of actions per minute |
| $F$ | force (N) |
| $F_B$ | basic force limit |
| $F_L$ | force limit |
| $F_M$ | force multiplier |
| $j$ | generic repetitive tasks |
| $k_f$ | constant of frequency of technical actions per minute |
| $L$ | actual load |
| MODA PTS | modular analysis predetermined time system |
| MSD | musculoskeletal disorders |
| MTA | motion time analysis |
| MTM | methods/time measurement |
| MVC | maximum voluntary contraction |
| $n_{ATA}$ | overall number of actual technical actions within a shift |
| $n_{ep}$ | number of exposed individuals |
| $n_{pa}$ | number of persons affected by one or more UL-WMSD |
| $n_{RPA}$ | partial reference number of technical actions within a shift |
| $n_{rt}$ | number of repetitive task(s) performed during a shift |
| $n_{RTA}$ | overall number of reference technical actions within a shift |

| | |
|---|---|
| $n_{TC}$ | number of technical actions in a cycle |
| OCRA | occupational repetitive action |
| PA | prevalence (%) of persons affected |
| $P_M$ | posture multiplier |
| PTS | predetermined time system |
| RTA | reference technical action |
| $R_{eM}$ | repetitiveness multiplier |
| $R_{cM}$ | recovery multiplier |
| SE | standard error |
| $t$ | net duration of each repetitive task, in minutes |
| $t_C$ | cycle time, in seconds |
| TA | technical action |
| $t_M$ | duration multiplier |
| UL-WMSD | upper limb work-related musculoskeletal disorders |
| WF | work factor |

## 4 Recommendations

### 4.1 Avoiding repetitive handling tasks

Hazardous manual handling tasks should be avoided wherever possible. This can be achieved through work enlargements, job rotation and/or mechanization/automation within the framework of a participative ergonomics approach. In the case of repetitive handling of low loads at high frequency, many tasks can be modified through the use of robotics or automated production systems.

NOTE A "participative ergonomics approach" signifies the practical involvement of workers, supported by suitable communication, in planning and managing a significant amount of their work activities, with sufficient knowledge and ability to influence both processes and outcomes in order to achieve desirable goals.

### 4.2 Risk assessment

#### 4.2.1 General

When repetitive handling is unavoidable, a four-step approach in accordance with ISO Guide 51 and ISO 14121, and involving both risk assessment and risk reduction, should be adopted. The four steps are hazard identification, risk estimation, risk evaluation and risk reduction.

The procedure shown in Figure 1 should be adopted when carrying out a risk assessment of jobs involving the manual handling of low loads at high frequency.

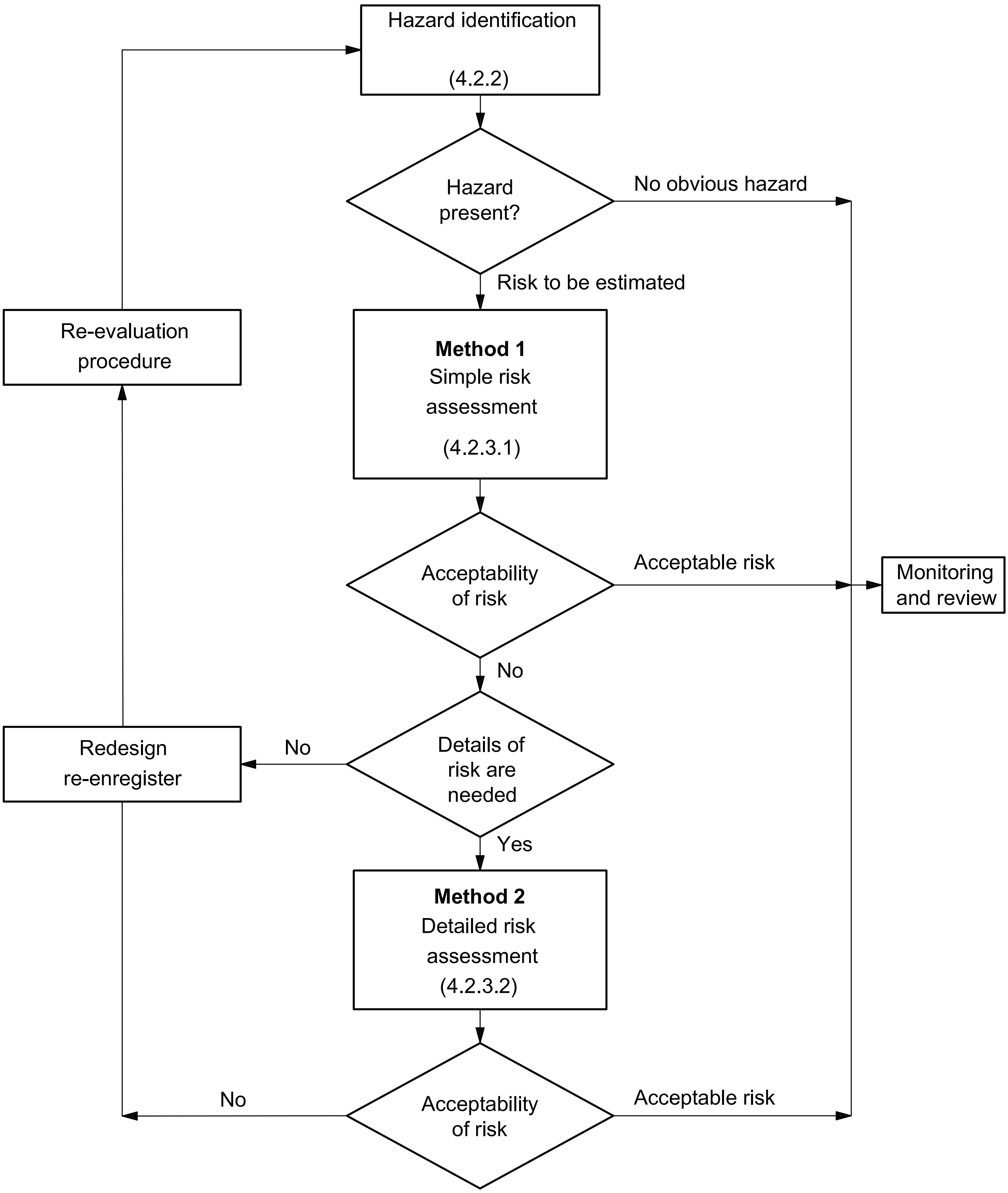



**Figure 1 — Risk assessment procedure**

### 4.2.2 Hazard identification

#### 4.2.2.1 General

The first step of the risk assessment is to identify whether hazards exist which may expose individuals to a risk of injury. If such hazards are present, then a more detailed risk assessment can be necessary. When determining if one or more of the following hazards is present, consideration should be given to the guidelines for avoiding them.

#### 4.2.2.2 Repetition

Frequent repetitive movements give rise to a risk of injury that can vary depending on the context of the movement pattern and the individual. As the movement cycle increases and/or the cycle time decreases, the risk of injury increases. Repetitive movements should be avoided within a task or job.

#### 4.2.2.3 Posture and movement

Sitting restricts overall movement of the body, particularly those of the lower leg and back. This may lead to increased and complex loading of the back and upper extremities. Standing for prolonged periods of time often results in pain/discomfort in the legs and lower back and can lead to venous pooling in the legs. Complex postures involving combined movements (e.g. flexed and twisted) can present greater risk (see ISO 11226). Whenever possible, workers should be given the option to vary between sitting and standing.

Work tasks and operations should provide variations to the working posture: both whole-body postures and movement of specific limbs. In the work tasks, extreme ranges of joint movement should be avoided; there is also need to avoid prolonged static postures.

#### 4.2.2.4 Force

Forceful exertions can be harmful. Tasks should involve smooth force exertions, with the avoidance of sudden or jerky movements. Handling precision (accurate picking and placement), and the type and nature of the grip can introduce additional muscular activation.

#### 4.2.2.5 Duration and insufficient recovery

Insufficient time for the body to recover between repetitive movements (i.e. lack of recovery time) increases the risk of injury. Duration can be broken down into different levels, i.e. work shift duration, job duration, task duration. The opportunity for recovery or rest may fall within each of these work periods.

#### 4.2.2.6 Object characteristics

Inappropriately designed objects could have characteristics that can cause harm (e.g. contact forces, shape, dimensions, coupling, object temperature). Inappropriately placed handholds may lead to awkward hand/arm postures. Non-cushioned handholds and objects constructed of a smooth material increase the difficulty of grasping the object and increase force requirements. The size and shape of the object being handled and the coupling between it and the operator’s hands will determine the grip type and the force that the operator must exert.

#### 4.2.2.7 Vibration and impact forces

Exposure to hand/arm vibration, shocks or impacts can lead to a desensitizing of the hand and increase the force necessary for gripping an object or tool. Prolonged exposure to these types of risk factors has also been linked to vascular and neurological disorders of the upper limbs.

#### 4.2.2.8 Environmental conditions (lighting, climate, noise, etc.)

Inappropriate lighting, hot and cold environments and high levels of noise can impose additional hazards. Wet or contaminated surfaces are likely to inhibit the ability to exert forces and increase the risk of injury. The designer of products shall consider environmental conditions only within the limits of the foreseeable use of the product.

#### 4.2.2.9 Work organization

Work organization (e.g. task duration, job duration, recovery time, shift patterns) has an important part to play in the exposure to musculoskeletal risk factors. This should be structured to facilitate rest periods and avoid the use of similar muscle groups over the duration of the work shift. Job rotation, job diversification and job enlargement are all methods of structuring the work to facilitate variation and recovery within the work period.

#### 4.2.2.10 Psychosocial factors (e.g. job complexity, job demands, job content)

Psychological response to work and workplace conditions has an important influence on general health and, in particular, musculoskeletal health. These factors include the design, organization and management of work, the specific impact of workplace risk factors, such as work content, and the overall social environment (i.e. the context of work). Many of the effects of these psychosocial factors occur via stress-related processes, which can have a direct effect on biochemical and physiological responses.

#### 4.2.2.11 Individuals

Individual skills, training, age, gender, health problems and pregnancy are personal characteristics that can influence performance and should be considered in the risk assessment. Skill and experience are likely to benefit the individual when performing the task and reduce the risk of injury. Training can increase the level of skill.

Important aspects of work design include the amount of control an individual has over his/her work, the level of work demands, the variety of tasks he/she is required to perform and the level of support provided by managers, supervisors and/or co-workers. Undesirable psychosocial aspects of a job contributing to a risk of musculoskeletal disorders include the following:

- workers have little or no control over their work and work methods or organization;
- tasks require high levels of attention and concentration;
- workers are unable to make full use of their skills;
- workers have little or no involvement in decision making;
- workers are expected to carry out repetitive, monotonous tasks exclusively;
- work is machine- or system-paced;
- work demands are perceived as excessive;
- payment systems encourage working too quickly or without breaks;
- work systems limit opportunities for social interaction;
- high levels of effort are not balanced by sufficient reward (resources, remuneration, self-esteem, status, etc.).

### 4.2.3 Risk estimation

#### 4.2.3.1 Method 1 — Simple risk assessment

Risk estimation is performed by a simple risk assessment of jobs composed by a single repetitive task (monotask jobs).

The procedure and checklist model presented in Annex B is preferred for the carrying out of the simple risk assessment. There are four parts to this assessment procedure:

- preliminary information describing the job task;
- hazard identification and risk estimation procedure and checklist;
- overall evaluation of the risk;
- remedial action to be taken.

NOTE As a second choice, other simple methods and checklists given in Annex A can be used, taking into consideration the specific characteristics of the repetitive task under examination.

Risk estimation using Method 1 should allow the classification of the risk by the three-zone approach (green, yellow and red) and determine the consequent action to be taken. The three risk zones are defined as follows.

a) **Green zone (acceptable risk)**

   The risk of disease or injury is negligible or is at an acceptably low level for the entire working population. No action is required.

b) **Yellow zone (conditionally acceptable risk)**

   There is a risk of disease or injury that cannot be neglected for the entire working population or part of it. The risk shall be further estimated (using the more detailed assessment of Method 2), analysed together with contributory risk factors and followed as soon as possible by redesign. Where redesign is not possible, other measures to control the risk shall be taken.

c) **Red zone (not acceptable)**

   There is a considerable risk of disease or injury that cannot be neglected for the operator population. Immediate action to reduce the risk (e.g. redesign, work organization, worker instruction and training) is necessary (see 4.3 and Annex E).

#### 4.2.3.2 Method 2 — Detailed risk assessment

##### 4.2.3.2.1 General criteria

If the risk estimated using Method 1 is considered to be YELLOW or RED, or if the job is composed of two or more repetitive tasks (multitask job), the performing of a more detailed risk assessment is recommended. This will also allow a better determination of the remedial measures to be taken.

For detailed risk assessment, OCRA (occupational repetitive action) is the preferred method (see 4.2.3.2.2). It is recommended for the specific purposes of this part of ISO 11228 because, given the knowledge at the time of publication, it considers all the relevant risk factors, is also applicable to “multitask jobs”, and provides criteria — based on extensive epidemiological data — for forecasting the occurrence of UL-WMSD (upper limb work-related musculoskeletal disorders) in exposed working populations.



Other detailed risk assessment methods are available which can be used for a detailed risk assessment, depending on the kind of risk factors identified by Method 1, the nature of the job and the experience of the analyst.

Annex D gives basic information about other detailed risk assessment methods useful for the purposes of this part of ISO 11228, together with some remarks about their applicative limits at the time of publication.

Whichever method is used for detailed risk assessment, it should allow the classification of the risk by the three-zone model and determine the consequences to be acted upon in accordance with Table 1.

**Table 1 — Method 2 — Final assessment criteria**

| Zone | Risk level | Consequences |
|---|---|---|
| Green | No risk | Acceptable: no consequences |
| Yellow | Very low risk | Improve structural risk factors (posture, force, technical actions, etc.) or take other organizational measures |
| Red | Risk | Redesign tasks and workplaces according to priorities |

#### 4.2.3.2.2 OCRA method for detailed risk assessment

The OCRA index is the ratio between the number of actual technical actions, ATA, carried out during a work shift and the number of reference technical actions, RTA, for each upper limb, specifically determined in the scenario under examination [11], [38].

The OCRA risk assessment procedure consists of three basic steps:

a) **Step 1**

Calculate the frequency of technical actions/min and the overall number of ATA carried out in the shift (by each upper limb).

b) **Step 2**

Calculate the overall number of RTA.

c) **Step 3**

Calculate the OCRA index and perform a risk evaluation.

Table 2 (ATA and RTA calculation in monotask jobs), Table 3 (ATA and RTA calculation in multitask jobs) and Table 4 (OCRA index calculation and risk evaluation) give an overview of the procedure detailed in Annex C.

**Table 2 — OCRA assessment procedure for monotask jobs — Steps 1 and 2**

| | | |
|---|---|---|
| **Step1** | **Calculate the overall number of actual technical actions, $n_{ATA}$, carried out in a shift by each upper limb.** | |
| ↓ | a) | Count the number of technical actions, $n_{TC}$, in a cycle. |
| | b) | Evaluate their frequency, $f$, per minute, considering the cycle time, $t_C$, in seconds: $$f = n_{TC} \times \frac{60}{t_C}$$ |
| | c) | Evaluate the net duration, $t$, of the repetitive task in the shift, in minutes. |
| | d) | Calculate the overall number of ATA carried out in the shift: $$n_{ATA} = f \times t$$ |
| **Step 2** | **Calculate the overall number of RTA within the shift:** $$n_{RTA} = k_f \times F_M \times P_M \times R_{eM} \times A_M \times t \times R_{cM} \times t_M$$ | |
| ↓ | 30 | Constant of frequency, $k_f$, of technical actions = 30/min |
| | × | |
| | $F_M$ | Force multiplier |
| | × | |
| | $P_M$ | Posture multiplier |
| | × | |
| | $R_{eM}$ | Repetitiveness multiplier |
| | × | |
| | $A_M$ | Additional multiplier |
| | × | |
| | $t$ | Duration of the repetitive task, in minutes |
| | = | |
| | $n_{RPA}$ | Partial reference number of technical actions in the shift |
| | × | |
| | $t_M$ | Duration multiplier |
| | × | |
| | $R_{cM}$ | Recovery multiplier |
| | = | |
| | $n_{RTA}$ | Overall number of RTA |
| NOTE | See 3.2. for the complete list of symbols and abbreviated terms used in this part of ISO 11228. | |

**Table 3 — OCRA assessment procedure for multitask jobs — Steps 1 and 2**

| | | | | | |
|---|---|---|---|---|---|
| **Step1** | **Calculate the overall number of actual technical actions, $n_{ATA}$, carried out in a shift by each upper limb, considering each repetitive task, $j$, in the shift.** | | | | |
| ↓ | a) | Count the number of technical actions in a cycle for each repetitive task ($n_{TCj}$): | | | |
| | | **Task A** | **Task B** | **Task C** | **Task $n$** |
| | | $n_{TC}$ | $n_{TC}$ | $n_{TC}$ | $n_{TC}$ |
| | b) | Evaluate the frequency of action per minute for each repetitive task, $f_j$, considering the cycle time for each repetitive task, $t_{Cj}$, in seconds: | | | |
| | | **Task A** | **Task B** | **Task C** | **Task $n$** |
| | | $f$ | $f$ | $f$ | $f$ |
| | c) | Evaluate the net duration ($t_j$) of each repetitive task in the shift, in minutes. | | | |
| | | **Task A** | **Task B** | **Task C** | **Task $n$** |
| | | $t$ | $t$ | $t$ | $t$ |
| | d) | Calculate the overall number of ATA carried out in each repetitive task and, by summing them, the overall number of ATA in the shift: $n_{ATA} = \sum \left( f_j \times t_j \right)$ | | | |
| | | **Task A** | **Task B** | **Task C** | **Task $n$** |
| | $n_{ATA}$ = | $t \times f$ | $t \times f$ | $t \times f$ | $t \times f$ |
| **Step 2** | **Calculate the overall number of RTA within the shift:** $n_{RTA} = \sum_{j=1}^{n} \left[ k_f \left( F_{Mj} \times P_{Mj} \times R_{eMj} \times A_{Mj} \right) \times t_j \right] \times \left( R_{cM} \times t_M \right)$ | | | | |
| ↓ | 30 | **Task A** | **Task B** | **Task C** | **Task $n$** |
| | | 30 | 30 | 30 | 30 |
| | × | × | × | × | × |
| | $F_{Mj}$ | $F_M$ | $F_M$ | $F_M$ | $F_M$ |
| | × | × | × | × | × |
| | $P_{Mj}$ | $P_M$ | $P_M$ | $P_M$ | $P_M$ |
| | × | × | × | × | × |
| | $R_{eMj}$ | $R_{eM}$ | $R_{eM}$ | $R_{eM}$ | $R_{eM}$ |
| | × | × | × | × | × |
| | $A_{Mj}$ | $A_M$ | $A_M$ | $A_M$ | $A_M$ |
| | × | × | × | × | × |
| | $t$ | $t$ | $t$ | $t$ | $t$ |
| | = | = | = | = | = |

**Table 3** (*continued*)

| | $n_{RPAj}$ | RPA Task A | RPA Task B | RPA Task C | RPA Task $n$ |
|---|---|---|---|---|---|
| ↓ | | | | | |
| | $n_{RPA,tot}$ | | Total of partial reference numbers of technical actions in shift $n_{RPA,tot}$ | | |
| | × | | × | | |
| | $t_M$ | | Duration multiplier $t_M$ | | |
| | × | | × | | |
| | $R_{cM}$ | | Recovery multiplier $R_{cM}$ | | |
| | = | | = | | |
| | $n_{RTA}$ | | $n_{RTA}$ | | |

NOTE See 3.2. for the complete list of symbols and abbreviated terms used in this part of ISO 11228.

**Table 4 — OCRA index calculation and risk evaluation — Step 3**

**Step3** — **Calculate the OCRA index and carry out the risk evaluation:**

OCRA Index = $\dfrac{n_{ATA}}{n_{RTA}} = \dfrac{\text{Number of actual technical actions in the shift}}{\text{Number of reference technical actions in the shift}}$

Risk evaluation

| Zone | OCRA Index value | Risk level |
|---|---|---|
| Green | $\leqslant$ 2,2 | No risk |
| Yellow | 2,3–3,5 | Very low risk |
| Red | $>$ 3,5 | Risk |

## 4.3 Risk reduction

A proper risk assessment is the basis for appropriate choices in risk reduction. Risk reduction can be achieved by combining, in different ways, improvements in different risk factors and should consider, among other things

— the avoidance and limitation of repetitive handling, especially for long daily durations without proper recovery periods or at high frequencies,

— proper design of the task, workplaces and work organization, also using existing International Standards and introducing adequate task variation,

— proper design of the objects, tools and materials handled,

— proper design of the work environment,

— individual workers' capacities and level of skill for the specific task.

See Annex E for more detailed information about risk reduction options.

# Annex A
(informative)

# Risk assessment — General framework and information on available methods

## A.1 General framework

The Consensus Document listed under Reference [10], which was prepared and published by the IEA[1)] Technical Committee, *Musculoskeletal Disorders*, with the endorsement of ICOH, defines in a general model the main risk factors to be considered and presents observational procedures that can be used in their description, classification and evaluation.

In its conclusions, the document underlines the need for an integrated evaluation by means of concise exposure indices.

The general model of description and assessment of tasks, concerning all exposed workers in a given situation, is aimed at analysing four main risk factors: repetitiveness, force, awkward postures and movements, and lack of proper recovery periods. Such factors should be assessed as functions of time (mainly considering their respective durations). In addition to these factors, others, grouped under the term “additional risk factors”, should be considered; these are mechanical factors (e.g. vibrations, localized mechanical compressions), environmental factors (e.g. exposure to cold) and organizational factors (e.g. pace determined by machinery), and for most of them there is evidence of association with UL-WMSD.

Each identified risk factor should be properly described and classified. This allows, on the one hand, identification of possible requirements and preliminary preventive interventions for each factor and, on the other hand, eventually, the consideration of all the factors contributing to the overall “exposure” within a general and mutually integrated framework. From this viewpoint “numerical” or “categorical” classifications of results may be useful to make management of results easier, even if it is important to avoid the feeling of an excessive objectiveness of methods whose classification criteria can still be empirical.

In adopting Reference [10], it should be emphasized that the OCRA method (and the OCRA index) [11], [38] represents an endeavour to organize the data obtained from the descriptive analysis of the various mechanical risk factors, as they are collected following indications contained in the Consensus Document itself.

The main advantages of the OCRA method are the following:

— it provides a detailed analysis of all the main mechanical and organizational risk factors for UL-WMSD;

— it uses a common language with respect to traditional methods of task analysis (predetermined time systems): this makes company technicians (production engineers, analysts) more familiar with the method and helps them to improve work procedures;

— it considers all the repetitive tasks involved in a complex (or rotating) job and estimates the overall worker’s risk level;

— in many epidemiological surveys it has shown itself to be well related with health effects (such as the occurrence of UL-WMSD); therefore, it is a good predictor (within definite limits) of the risk at a given OCRA level.

---

1) International ergonomics association



As for the OCRA method's disadvantages, it should be underlined that it can be time consuming, especially for complex tasks and multitask jobs, and does not consider all psychosocial factors related to the individual sphere.

These considerations were the basis for the choice of the OCRA method in Annex C as the reference method for detailed risk assessment.

However, other methods are proposed in the literature for a detailed risk assessment; in the following paragraphs the main of those methods will be briefly presented, also taking into account their potential limits in respect to the general model here considered.

## A.2 Review of other methods of risk assessment

Several other methods/procedures for the risk assessment of repetitive movements and efforts of the upper limbs which also provide synthetic exposure scores are already available in the literature.

A non-exhaustive list is given in Table A.1 (adapted from Reference [32]).

Most of them are simple (and often empiric) screening tools, not tailored for a detailed risk assessment: they could be used at an entry level (step 1) as an alternative to the recommended Method 1 presented in 4.2.3.1 and Annex B).

Other methods, such as OWAS and, in part, RULA, are primarily devoted to the study of working postures and give less consideration to the other main risk factors involved in repetitive handling at high frequency.

A special mention should be given to the tool OREGE [21], a movement identification and evaluation aid whose purpose is to quantify biomechanical stresses represented by forces, constraining postures and movement repetitiveness. Developed by France's *Institut National de Recherche et de Sécurité* (INRS), it has not been included in Table A.1 because, as proposed by INRS, it cannot stand alone and can be used only in the context of a more general and specified approach to UL-WMSD prevention. The application of the tool requires a specific ergonomic ability because it is mainly based on observation of the operator, his/her perception of constraints and on dialogue between the expert and the operator, and final assessment is based largely on expert knowledge and experience. OREGE uses other tools (i.e. visuoanalogic scales for the estimation of frequency and force, RULA for the estimation of postures) in a combined way. Notwithstanding this "mixed" approach, which makes it unsuitable for the specific scope of application of this part of ISO 11228, OREGE represents an interesting and participatory method for the prevention of UL-WMSD at the field level, justifying its mention in this short review.

Of the methods included in Table A.1, only a few allow for a detailed risk assessment in some way corresponding to the general model [10]. In addition to the OCRA index, these are, substantially, the Strain Index and the HAL/ACGIH TLV (for monotask handwork), which methods are also briefly presented in Annex D along with data presented in Reference [9].

**Table A.1 — Non-exhaustive list of main methods for risk assessment of repetitive movements/exertions at high frequency**

| Method | | Main characteristics | Kind of output | Body part assessment |
|---|---|---|---|---|
| **OWAS** | Ref. [26] | Analysis of postures of different body segments; it also considers their frequency during a work shift. | Quantitative | Whole body |
| **RULA** | Ref. [34] | Rapid coded analysis of static and dynamic postures; it also considers force and action frequency: the result is an exposure score that drives to the kind of preventive measures to be taken. | Quantitative | Upper limbs |
| **REBA** | Ref. [18] | Similar to RULA (checklist), it considers all body segments while also taking into account manual handling of loads. | Quantitative | Whole body |
| **PLIBEL** [a] | Ref. [27] | Checklist for the identification of different risk factors for different body segments; it considers awkward postures, movements, equipment and other organizational aspects. | Quantitative | Whole body |
| **Strain Index** | Ref. [35] | Detailed method (monotask) that considers the following risk factors: intensity of exertion, duration of exertion per cycle, efforts per minute, hand/wrist posture, speed of work, and duration of task per day. | Quantitative | Distal upper limbs |
| **QEC** [a] | Ref. [31] | Quick method for estimating the exposure level; it considers different postures, force, load handled, duration of task with hypothesized scores for their interaction. | Quantitative | Whole body |
| **OSHA checklist** [a] | Ref. [45] | Checklist proposed during the development of the OSHA standard (withdrawn); it considers repetitiveness, awkward postures, force, some additional factors and some organizational aspects. | Quantitative | Upper limbs |
| **HAL/TLV ACGIH** | Ref. [1] | Detailed method (for monotask handwork lasting almost 4 h per shift) mainly based on the analysis of frequency of actions (in relation to duty cycle) and of peak force; other main factors are generically considered. | Quantitative | Upper limbs |
| **Upper limb expert tool** [a] | Ref. [28] | Screening method evaluating the “work load”, it considers repetition, force, awkward postures, task duration and some additional factors. | Semi-quantitative | Upper limbs |
| **OCRA index** | Ref. [11], [38] | Detailed method that considers the following risk factors: frequency of technical actions, repetitiveness, awkward postures, force, additional factors, lack of recovery periods, duration of repetitive task. | Quantitative | Upper limbs |
| **OCRA checklist** [a] | Ref. [11], [41] | Semi-detailed method that considers, in a simplified way, the same risk factors as the OCRA index. Exposure level is classified in the three-zone system.<br>Applicable also to multitask repetitive jobs. | Quantitative | Upper limbs |

[a] Method/tool useful for the purposes of Method 1.

# Annex B
(informative)

# Method 1 — Simple risk assessment checklist

## B.1 General

This annex provides checklists and the evaluation model for the simple risk assessment of Method 1 (see 4.2.3.1). The structure and content of the checklist is as follows.

— **Preliminary information describing the job task**

B.2.1 consists of general information (job description, tasks to be evaluated, etc.). Initial consideration should also be given to the prevalence of work-related health complaints and/or work changes (planned or improvised) made to the work equipment or tools.

— **Hazard identification, risk estimation procedure and checklist**

B.2.2 presents a procedure that adopts a five-step approach, taking account of the four primary physical risk factors (repetition, high force, awkward posture and movements, insufficient recovery), as well as any other additional risk factors which may be present. When hazards are identified, steps should be taken to reduce or eliminate these hazards from the task/job (see Annex E).

The characteristics of the work cycle are the primary risk factors for a job. Step 1 of the assessment is therefore the base of the risk estimation. The other risk factors that are relevant for the risk assessment are awkward or uncomfortable postures (step 2), use of force by upper limbs (step 3), lack of recovery periods (step 4) and additional risk factors (step 5).

— **Overall evaluation of the risk**

B.2.3 describes the method for the overall risk assessment and the actions to be taken in consequence. If one of the risk factors is found to be in the red zone, then the overall risk is RED; if none of the risk levels are RED, but one or more is in the yellow zone then the overall risk is YELLOW; if all risk levels are in the green zone then the overall risk level is GREEN. For additional factors, the level of risk decreases as one moves towards the green zone. In making an overall assessment, additional factors should always be taken into consideration. See 4.2.3.1 for an explanation of the risk zones and consequential action.

— **Remedial action to be taken**

See B.2.4 for the remedial action that should be formulated and carried out.

## B.2 Checklist

### B.2.1 Preliminary information

Complete Table B.1.

**Table B.1**

| | |
|---|---|
| Job description:<br><br>Operations covered by this assessment (detailed description):<br><br>Locations:<br><br>Personnel involved:<br><br>Date of assessment: | Diagrams (other information): |

### B.2.2 Hazard identification and risk evaluation

This part of the checklist is used for a specific risk evaluation if the work is repetitive. The risk should always be further analysed if the work involves nearly identical movements that are frequently repeated for a significant period of the normal workday. If the duration of the repetitive work is for less than 1 h/day or 5 h/week, the risk caused by repetition is considered negligible. In that case, no further risk evaluation of the repetitiveness is needed.

Complete Table B.2.

**Table B.2**

| Questions to consider (possible risk factors) | Risk evaluation (zone) | | |
|---|---|---|---|
| | **GREEN**, if... | **YELLOW**, if... | **RED**, if... |
| **Step 1** — **Repetitive movements/duration** — Does the job involve...<br>**Yes** **No**<br>☐ ☐ A work cycle or a sequence of movements that is repeated more than twice per minute and for more than 50 % of the task duration?<br>☐ ☐ Repeating nearly identical movements of the fingers, hands or arms every few seconds?<br>☐ ☐ Intense use of the finger(s), hand(s) or wrist(s)?<br>☐ ☐ Repetitive shoulder/arm movement (regular movements with some pauses or almost continuous arm movement)?<br>If the reply to all questions is "No", the evaluation is GREEN and no further evaluation is needed.<br>If the answer to one or more questions is "Yes", the work is categorized as repetitive. Use the right-hand columns to evaluate acceptable duration if no other significant risk factors are present and proceed to a further evaluation of the combined risk factors by steps 2, 3 and 4. | Repetitive movements, but no other risk factors, for no more than 3 h total on a "normal" workday<br>AND<br>No more than 1 h without a break<br>If this statement is true, then the total evaluation is GREEN and no further evaluation is needed.<br>☐ | The conditions described in the red and green zone are not true.<br>☐ | Repetitive movements without any other risk factors for more than 4 h total on a "normal" workday<br>☐ |

**Table B.2** (*continued*)

| Questions to consider (possible risk factors) | Risk evaluation (zone) | | |
|---|---|---|---|
| | **GREEN**, if... | **YELLOW**, if... | **RED**, if... |
| **Step 2 — Repetitive movements/duration** — Does the job involve repetitive or frequent...<br>**Yes** **No** (See Annex C)<br>☐ ☐ Bending the wrist(s) up and/or down or to the side?<br>☐ ☐ Turning or twisting of the hands so that the palm is facing up or down?<br>☐ ☐ Forceful movements, i.e. gripping of the fingers while the wrist is bent or wide finger or hand span while gripping, holding or manipulating items?<br>☐ ☐ Movements of the upper arm to the front or side of the body?<br>☐ ☐ Side bending or rotating movements of the back or head? | Repetitive, small deviations of the neutral positions of the fingers, wrists, elbows, shoulders or neck for no more than 3 h total per workday<br>OR<br>Repetitive, moderate-to-large deviations for no more than 2 h total per workday<br>AND (both)<br>No more than 30 consecutive minutes without a break or task variation | The conditions described in the red and green zones are not true | Moderate to large deviations of the neutral joint positions of the fingers, wrists, elbows, shoulders or neck for more than 3 h total per workday<br>AND<br>Less if more than 30 min without a break<br>(*Moderate-to-large joint deviations* means > 50 % of the ROM. If maximum deviations near ROM a specific evaluation is needed.) |
| If the reply to all questions is “No”, then there are no awkward postures as a combined risk factor to the repetitive movements. Continue with step 3 to evaluated the force factor.<br>If the answer to one or more questions is “Yes”, use the right-hand columns to evaluate the risk and then proceed to step 3. | ☐ | ☐ | ☐ |

**Table B.2** (*continued*)

| Questions to consider (possible risk factors) | Risk evaluation (zone) | | |
|---|---|---|---|
| | **GREEN**, if... | **YELLOW**, if... | **RED**, if... |
| **Step 3** — **Force** — Does the job involve repetitive or frequent...<br>**Yes** **No**<br>a) Lifting or holding of tools, materials or objects weighing more than<br>☐ ☐ 0,2 kg per finger (lifting in pinch d)?<br>☐ ☐ 2 kg per hand?<br>b) Gripping, rotating, pushing or pulling of tools, materials<br>☐ ☐ by arm/hand work with a force exceeding 10 % of reference values, $F_b$, as given in EN 1005-3:2002 [53], step 1 (i.e. 25 N for grip force)?<br>c) Use of control actuators<br>☐ ☐ with a force/torque exceeding those recommended in ISO 9355-3 [67] (i.e. 20 N for contact grip by hand, 10 N for pinch grip)?<br>d) Pinch grips, i.e. holding or grasping objects between thumb and finger<br>☐ ☐ with a force of more than 10 N?<br>If the reply to all questions is “No”, then there are no forceful exertions as a combined risk factor to the repetitive movements. Continue with step 4 to evaluate the recovery factor.<br>If the reply to one or more questions is “Yes”, evaluate the risk using the right-hand column, then proceed to step 4. | Repetitive force exertion (without awkward postures) for no more than 2 h total per normal workday<br>OR<br>Repetitive force exertion combined with awkward postures for no more than 1 h per normal workday<br>AND (both)<br>No more than 30 consecutive minutes without a break or task variation<br>☐ | The conditions described in the red and green zones are not true.<br>☐ | Repetitive force exertion without awkward postures for more than 3 h per normal workday<br>OR<br>Repetitive force exertion combined with awkward postures for more than 2 h per normal workday<br>(shorter duration if more than 30 consecutive minutes without a break or task variation)<br>☐ |

**Table B.2** (*continued*)

| **Questions to consider (possible risk factors)** | **Risk evaluation (zone)** | | |
|---|---|---|---|
| | **GREEN**, if... | **YELLOW**, if... | **RED**, if... |
| **Step 4 — Recovery periods** — Does the job involve...<br>**Yes** **No**<br>☐ ☐ Lack of breaks?<br>☐ ☐ Poor variation of tasks?<br>☐ ☐ Lack of recovery periods<br>Use the right-hand columns to answer these questions and evaluate the risk of lack of recovery periods.<br>Then proceed to step 5 and evaluate additional risk factors. | At least 30 min lunch break and 10 min break in the morning and 10 min break in the afternoon<br>AND<br>No more than 1 hour's work without break or task variation<br>☐ | The conditions described in the red and green zones are not true.<br>☐ | Less than 30 min lunch break<br>OR<br>More than 1 hour's work without break or task variation<br>☐ |

**Table B.2** (*continued*)

| Questions to consider (possible risk factors) | | | | | |
|---|---|---|---|---|---|
| **Step 5 — Additional risk factors** | | | | | |
| **Physical** | | | **Psychosocial** | | |
| **Yes** | **No** | Does the repetitive job involve... | **Yes** | **No** | Does the repetitive job involve... |
| ☐ | ☐ | Use of vibrating tools? | ☐ | ☐ | High work pressure/too much work to finish within the working hours? |
| ☐ | ☐ | Localized compression of anatomical structures due to tools? | ☐ | ☐ | Lack of control of planning and arrangement of the work tasks? |
| ☐ | ☐ | Exposure to hot or cold? | ☐ | ☐ | Lack of support from colleagues or managers? |
| ☐ | ☐ | Personal protective equipment that restricts movements or inhibits performance? | ☐ | ☐ | A high mental load, high concentration or attention? |
| ☐ | ☐ | Risk of sudden, unexpected/uncontrolled movement (i.e. slippery floor, falling objects, bad grasp)? | ☐ | ☐ | An isolated task in a production process? |
| ☐ | ☐ | Quick acceleration/deceleration of movements? | ☐ | ☐ | Paced work, by a machine or persons? |
| ☐ | ☐ | Static force/load? For example... | ☐ | ☐ | Predefined work rates or bonus systems? |
| ☐ | ☐ | Raised shoulder arms (holding the arms/objects against gravity)? | | | |
| ☐ | ☐ | Continuous gripping onto tools (such as knives in slaughterhouse, fish industry)? | | | |
| ☐ | ☐ | Locked or fixed postures (bad design of tools or workplaces, lack of space)? | | | |
| ☐ | ☐ | Hammering, shock or forces with rapid build-up? | | | |
| ☐ | ☐ | High-precision work combined with force? | | | |

| Results | | | | | |
|---|---|---|---|---|---|
| **Zone** | **Step 1** | **Step 2** | **Step 3** | **Step 4** | **Step 5** |
| **Green** | | | | | |
| **Yellow** | | | | | |
| **Red** | | | | | |

**Table B.2** (*continued*)

| |
|---|
| This information can be gathered by observing the work situation or by using validated questionnaires. |
| If additional factors are present, these should be considered after the risk factors of steps 1–4 have been dealt with. |
| Evaluate static postures/duration according to ISO 11226. |
| Large range of movement: if very large deviations (near maximum ROM) are prevalent it is important to do a specific evaluation of possible acute risk or short-term risk. For a full evaluation of working postures, use other evaluation methods, see ISO 11226. For evaluation of environmental factors affecting postures, use ISO 14738 and ISO 15534 (planning of space, preferred working area and height). These International Standards can be very relevant for a further/specific risk evaluation of posture. |
| High force: if very forceful exertions (near MVC) are prevalent, it is important to do a specific evaluation of possible acute risk or short-term risk. For a full evaluation of force exertions, it might be relevant to use other evaluation methods: for lifting, ISO 11228-1, and for push/pull, ISO 11228-2. These International Standards may be very relevant for a further/specific force evaluation. |

## B.2.3 Assessment of overall risk level

### B.2.3.1 Red evaluation

If one of the risk levels examined in B.2.2 was found to be in the red zone, then the overall risk is RED. If the job falls within this zone, then the work is judged to be harmful. The severity of risk is increased if one or more of the additional risk factors also falls within the red zone. It is recommended that measures be taken to eliminate or reduce the risk factors or that a more detailed risk assessment be performed using Method 2 (see Annex C).

### B.2.3.2 Yellow evaluation

If none of the risk levels examined in B.2.2 was found to be RED, but one or more were YELLOW, then the job is judged to be within the yellow zone. If one severe or two additional factors (step 5) are present, the overall risk level shifts from YELLOW to RED. In case of a yellow evaluation, a more detailed risk assessment is needed, using Method 2 (see Annex C), or else remedial action should be taken to reduce the risk to the green level.

### B.2.3.3 Green evaluation

If all risks are GREEN then the overall risk level is acceptable. If the job falls within the green zone, the risk of developing work-related musculoskeletal disorders is most likely considered to be acceptable. However, if additional risk factors are present (step 5), it is recommended that an attempt be made to reduce or eliminate these risks.

## B.2.4 Remedial action to be taken

Complete Table B.3.

**Table B.3**

| **Remedial steps that should be taken** (in order of priority) | **Person who should take the action** | **Date by which action should be taken** | **Date and responsibility for follow-up initiatives** |
|---|---|---|---|
| 1<br>2<br>3<br>4<br>5 | | | |
| Date for reassessment:<br>Assessor's name:<br>Signature: | | | |

Take action and check that it has the desired effect by repeating Method 1.

# Annex C
(informative)

# Method 2 — OCRA method for detailed risk assessment

## C.1 General

This annex gives all the relevant information for applying the OCRA (occupational repetitive action) method in accordance with this part of ISO 11228.

C.2 to C.5 describe in detail, step by step, how the OCRA index is determined; C.6 provides the means for determining technical actions for step 1; C.7, C.8 and C.9 explain, respectively, how to determine force levels, analyse postures and movements and identify and evaluate the different factors and force multipliers applied in step 2; C.10 gives information about the criteria adopted for OCRA Index classification (step 3) as well as on forecast models of the expected percentage of persons affected (PA) by one or more UL-WMSD; while C.11 provides applicative examples of the use of the OCRA method for assessing repetitive tasks.

## C.2 OCRA Index

The OCRA Index is the ratio between the number of actual technical actions (ATA) carried out during a work shift and the number of reference technical actions (RTA), for each upper limb, specifically determined in the scenario under examination [11], [38]:

$$\text{OCRA Index} = \frac{n_{\text{ATA}}}{n_{\text{RTA}}} \qquad \text{(C.1)}$$

where

$n_{\text{ATA}}$ is the overall number of ATA in the shift;

$n_{\text{RTA}}$ is the number of RTA in the shift.

The three-step procedure for determining the index is detailed in C.3 to C.5 (see also 4.2.3.2.2).

## C.3 Step 1

Calculate the frequency of technical actions (TA) per minute and the overall number of ATA carried out in the shift by each upper limb (see also Table 2).

a) Count the number of technical actions ($n_{\text{TC}}$) in a representative cycle of each repetitive task in the job.

See C.6 for details on how to determine the technical actions.

b) Evaluate their frequency, $f$, per minute, considering the cycle time, $t_{\text{C}}$, in seconds:

$$f = n_{\text{TC}} \times \frac{60}{t_{\text{C}}} \qquad \text{(C.2)}$$

c) Evaluate the net duration, $t$, of the repetitive task in the shift, in minutes.

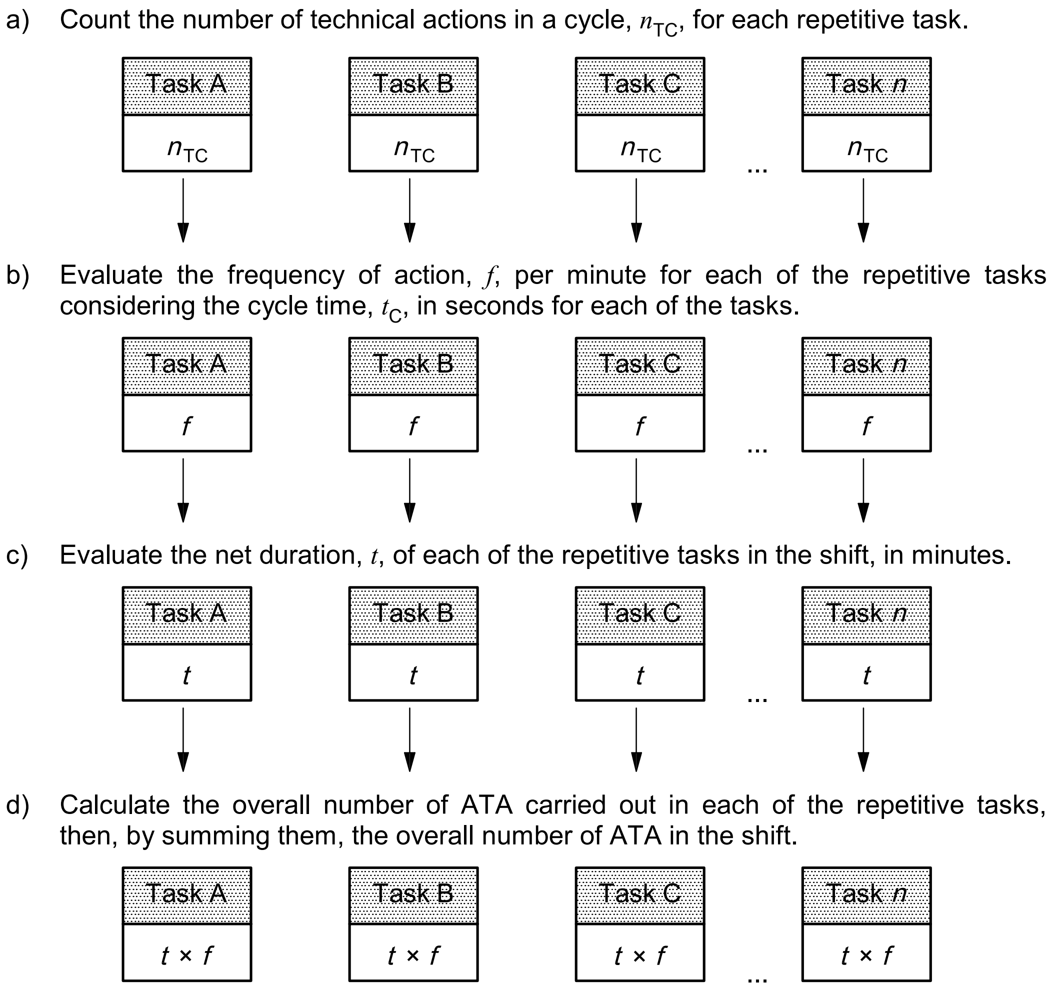


d) Calculate the overall number of ATA carried out in the shift:

$$n_{\text{ATA}} = f \times t \tag{C.3}$$

For a *multitask* analysis, follow the procedure shown in Figure C.1 (see also Table 3).




$$n_{\text{ATA}} = \sum \left( f_j \times t_j \right) \tag{C.4}$$

**Figure C.1**

## C.4 Step 2

### C.4.1 General formula

Use the following formula to calculate the overall number of RTA within a shift (the OCRA method considers a number of risk factors and corresponding multipliers):

$$n_{\text{RTA}} = \sum_{j=1}^{n} \left[ k_{\text{f}} \left( F_{\text{M}j} \times P_{\text{M}j} \times R_{\text{eM}j} \times A_{\text{M}j} \right) \times t_j \right] \times \left( R_{\text{cM}} \times t_{\text{M}} \right) \quad \text{(C.5)}$$

where

- $n$ is the number of repetitive tasks performed during a shift;
- $j$ is the generic repetitive task;
- $k_{\text{f}}$ is the constant of frequency of technical actions per minute (= 30);
- $F_{\text{M}}$ frequent or high force exertions (force multiplier) in each repetitive task, $j$;
- $P_{\text{M}}$ awkward or uncomfortable postures or movements (posture multiplier) in each repetitive task, $j$;
- $R_{\text{eM}}$ high repetition of the same movements (repetitiveness multiplier) in each repetitive task, $j$;
- $A_{\text{M}}$ presence of additional factors (additional multiplier) in each repetitive task, $j$;
- $t$ is the net duration, in minutes, of each repetitive task, $j$;
- $R_{\text{cM}}$ is the multiplier for the risk factor lack of recovery period (recovery multiplier);
- $t_{\text{M}}$ is the multiplier according to the overall duration of all repetitive tasks during a shift (duration multiplier).

The determination of these multipliers is given in C.4.2 to C.4.7.

### C.4.2 Determining RTA

In practice, use the following procedure to determine the overall number of reference technical actions, $n_{\text{RTA}}$, within a shift.

a) For each repetitive task, start from $k_{\text{f}}$ (30 actions/min).

b) For each task, weight the frequency constant, $k_{\text{f}}$, using the respective multipliers and considering the presence and degree of the risk factors force, $F_{\text{M}}$, posture, $P_{\text{M}}$, repetitiveness, $R_{\text{eM}}$, and additional, $A_{\text{M}}$.

c) Multiply the weighted frequency thus obtained, for each task, by the number of minutes of the real duration, $t$, of each repetitive task.

d) Sum up the values obtained for the different tasks.

e) Multiply the resulting value by the multiplier factor for recovery periods, $R_{\text{cM}}$.

f) Apply the last multiplier factor that considers the total time spent in repetitive tasks during the whole shift, $t_{\text{M}}$.

g) The value thus obtained represents the total number of RTA in the shift for the examined job (made up of one or more repetitive tasks), $n_{\text{RTA}}$.

### C.4.3 Determining force multiplier, $F_M$

Step 2 is considered here in more detail.

Determine the force multiplier, $F_M$, which will be equal to 1 if the following "optimal" conditions (see EN 1005-3) are met:

— the isometric force does not exceed 50 % of the values proposed for 15th force percentile for professional use in the healthy adult European population;

— actions do not imply fast movements;

— the frequency of force exertions is no more than 1 in 5 min and the action time is no more than 3 s;

— the duration of the repetitive task is no more than 1 h.

If these conditions are not met, use Table C.1 to determine an $F_M$ that applies to the average level of force as a function of time. The force level is given as a percentage of maximum voluntary contraction, MVC, or as a percentage of the basic force limit, $F_B$, as determined in EN 1005-3, Step A. If the percentage of MVC or the $F_B$ is difficult to assess, a value derived from the application of the CR-10 Borg scale [6], [7] can be used (second procedure). The corresponding $F_M$ can be derived from Table C.1. Use $F_M$ = 0,01 when the technical actions require "peaks" above 50 % of MVC or a score of 5 (or more) on the Borg scale for more than 10 % of the cycle time.

**Table C.1 — Multiplier relative to different uses of force**

| **Force level,** % of MVC, or $F_B$ | 5 | 10 | 20 | 30 | 40 | ⩾ 50 |
|---|---|---|---|---|---|---|
| **CR-10 Borg score** | 0,5<br>very, very weak | 1<br>very weak | 2<br>weak | 3<br>moderate | 4<br>somewhat strong | ⩾ 5<br>strong/very strong |
| **Force multiplier,** $F_M$ | 1 | 0,85 | 0,65 | 0,35 | 0,2 | 0,01 |
| These values can be interpolated if intermediate results are obtained. | | | | | | |

See C.7 for further explanation on how to determine force levels.

### C.4.4 Determining posture (and movements) multiplier, $P_M$

The multiplier $P_M$ is equal to 1 when one of the postures or movements, given in Table C.2 is present for less than 1/3 of the cycle time; otherwise use Table C.2 to obtain the specific $P_M$. Choose the lowest $P_M$ (corresponding to the worst condition) between the posture and movements analysed.

Also consider shoulder postures and movements by checking that the arms are not held or moved:

— at about shoulder level (flexion or abduction at about 80° or more) for more than 10 % of cycle time and/or for more than 2 actions/min [42];

— in mild abduction (between 45° and 80°) for more than 1/3 of cycle time and/or for more than 10 actions/min.

If one of those two conditions occurs, a risk of shoulder disorder exists and should be accurately considered. See C.8 for further explanation on how to analyse postures and movements of the upper limbs.

**Table C.2 — Multiplier factor for awkward postures**

| Awkward posture and/or movement [10] | | Portion of cycle time | | | |
|---|---|---|---|---|---|
| | | **Less than 1/3** from 1 % to 24 % | **1/3** from 25 % to 50 % | **2/3** from 51 % to 80 % | **3/3** more than 80 % |
| **Elbow** | supination (⩾ 60°) | 1 | 0,7 | 0,6 | 0,5 |
| **Wrist** | extension (⩾ 45°) or flexion (⩾ 45°) | | | | |
| **Hand** | hook grip or palmar grip (wide span) | | | | |
| **Elbow** | pronation (⩾ 60°) or flexion/extension (⩾ 60°) | | 1 | 0,7 | 0,6 |
| **Wrist** | radio/ulnar deviation (⩾ 20°) | | | | |
| **Hand** | pinch | | | | |

### C.4.5 Determining repetitiveness multiplier, $R_{eM}$

When the task requires the performance of the same technical actions for at least 50 % of the cycle time, or when the cycle time is shorter than 15 s, $R_{eM}$ = 0,7. Otherwise, $R_{eM}$ = 1.

### C.4.6 Determining additional multiplier, $A_M$

The main additional factors include the use of vibrating tools, gestures implying countershock (such as hammering), requirement for absolute accuracy, localized compression of anatomical structures, exposure to cold surfaces and environments, the use of gloves interfering with handling ability and high pace completely determined by the machinery.

If additional factors are absent for most of the task duration, $A_M$ = 1. Otherwise:

— if one or more additional factors are present at the same time for 1/3 (from 25 % to 50 %) of the cycle time, $A_M$ = 0,95;

— if one or more additional factors are present at the same time for 2/3 (from 51 % to 80 %) of the cycle time, $A_M$ = 0,90;

— if one or more additional factors are present at the same time for 3/3 (more than 80 %) of the cycle time, $A_M$ = 0,80.

C.9 further explains how to identify and evaluate the different additional factors.



### C.4.7 Determining partial reference number, $n_{\mathrm{RPA}}$

#### C.4.7.1 Monotask analysis

Multiply the adjusted $k_{\mathrm{f}}$, thus obtained for $t_j$, to obtain, for each task, $j$, a partial reference number of technical actions, $n_{\mathrm{RPA}}$:

$$n_{\mathrm{RPA}j} = k_{\mathrm{f}} \left( F_{\mathrm{M}j} \times P_{\mathrm{M}j} \times R_{\mathrm{eM}j} \times A_{\mathrm{M}j} \right) \times t_j \quad \text{(C.6)}$$

Figure C.2 shows the procedure for calculating $n_{\mathrm{RPA}j}$ in an monotask analysis.

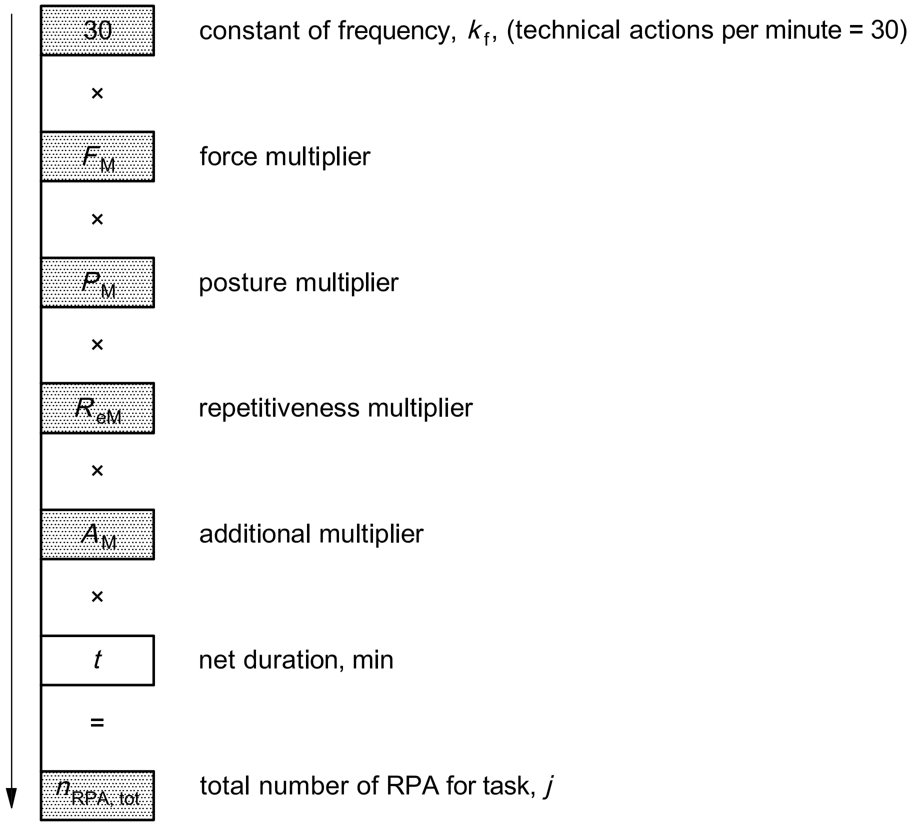



**Figure C.2**

#### C.4.7.2 Multitask analysis

For a multitask analysis, when more than one repetitive task is present, repeat the procedure given in C.4.3 to C.4.7 for each repetitive task, $j$, in the shift, then sum all $n_{\mathrm{RPA}j}$ as shown in Figure C.3.

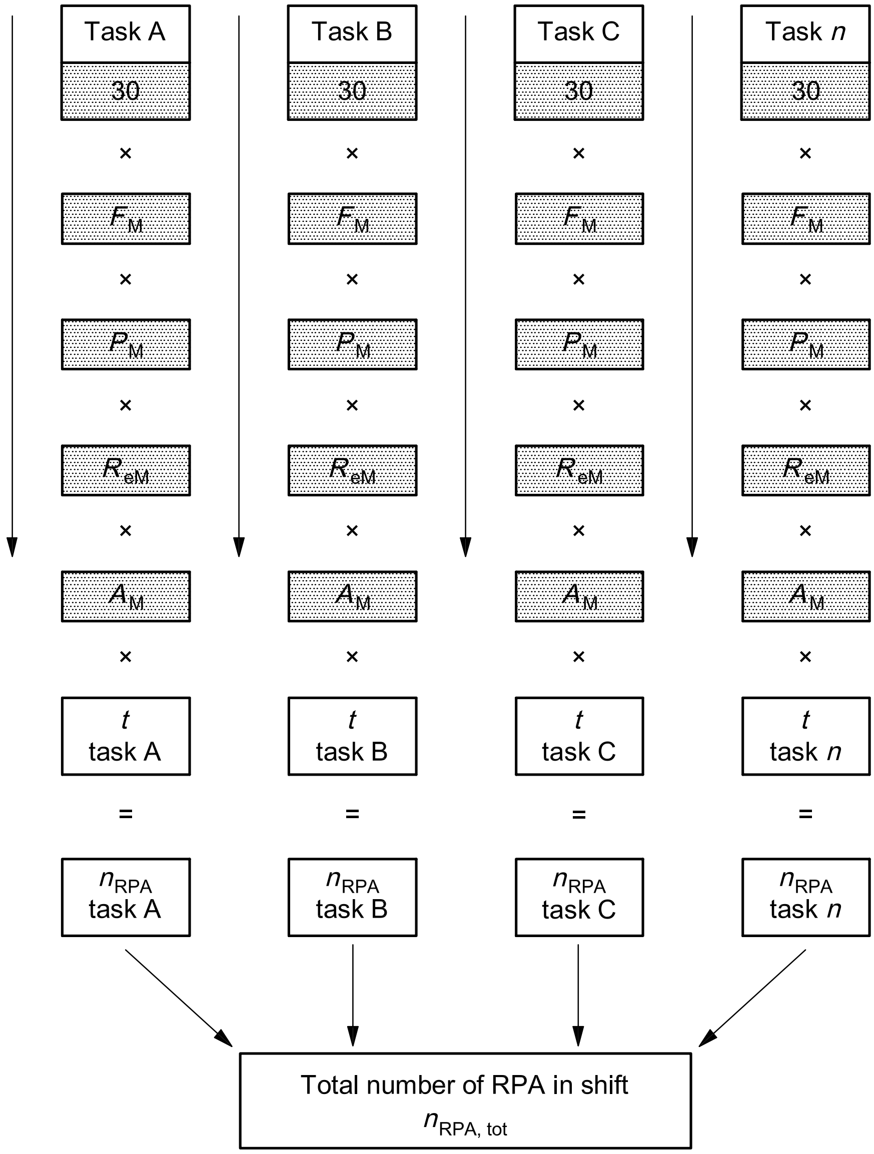



**Figure C.3**

### C.4.8 Determining recovery period multiplier, $R_{cM}$

Determine the recovery multiplier, $R_{cM}$, and adjust the total of partial numbers of reference technical actions, $n_{RPA,tot}$, in relation to the presence and distribution of recovery periods.

A recovery period is a period of rest which allows restoration of the musculoskeletal function in one or more muscle/tendon groups.

The following can be considered as recovery periods:

— breaks (official or non-official), including the lunch break;

— visual control tasks;

— periods within the cycle that leave muscle groups totally at rest consecutively for at least 10 s, almost every few minutes.

For repetitive tasks, the reference condition is represented by the presence, for each hour of repetitive task, of work breaks of at least ten consecutive minutes, or, for working periods lasting less than 1 h, in a ratio of 5:1 between work time and recovery time [1], [8], [48].

In relation to these reference criteria it is possible to consider how many hours of a work shift do not have an adequate recovery period. It requires the observation, one by one, of the single hours that make up a work shift: for each hour, check whether there are repetitive tasks and adequate recovery periods. For the hour preceding the lunch break (if it is present), and for the hour before the end of the shift, the recovery period is represented by these two events.

On the basis of the presence or absence of adequate recovery periods within every hour of repetitive work, count the number of hours with "no recovery". This done, adjust $n_{\mathrm{RPA,tot}}$ and determine $R_{\mathrm{cM}}$ in accordance with Table C.3.

**Table C.3 — Elements for determining $R_{\mathrm{cM}}$**

| **Without adequate recovery,** h | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| **Recovery multiplier,** $R_{\mathrm{cM}}$ | 1 | 0,90 | 0,80 | 0,70 | 0,60 | 0,45 | 0,25 | 0,10 | 0 |

### C.4.9 Determining duration multiplier, $t_{\mathrm{M}}$

Determine the duration multiplier, $t_{\mathrm{M}}$, and adjust $n_{\mathrm{RPA,tot}}$ in relation to the daily duration, in minutes, of all repetitive tasks.

Within a working shift, knowing the overall duration of manual repetitive tasks is important for determining the overall risk for upper limbs. When repetitive manual tasks last for a relevant part of the shift, $t_{\mathrm{M}} = 1$. In some contexts, however, there may be differences with respect to this more "typical" scenario (e.g. regularly working overtime, part-time work, repetitive manual tasks for only a part of a shift); the duration multiplier considers these changes with respect to usual exposure conditions. Table C.4 gives the values of $t_{\mathrm{M}}$ in relation to the overall duration of manual repetitive tasks.

**Table C.4 — Elements for determining $t_{\mathrm{M}}$**

| **Total time of repetitive tasks during shift,** h | < 120 | 120–239 | 240–480 | > 480 |
|---|---|---|---|---|
| **Duration multiplier,** $t_{\mathrm{M}}$ | 2 | 1,5 | 1 | 0,5 |

**Interpolated multipliers** [a]

| < 121 | 121–180 | 181–240 | 241–300 | 301–360 | 361–420 | 421–480 | > 480 |
|---|---|---|---|---|---|---|---|
| 2 | 1,7 | 1,5 | 1,3 | 1,2 | 1,1 | 1 | 0,5 |

[a] The values may be interpolated if more precise multipliers are needed.

Once $R_{\mathrm{cM}}$ and $t_{\mathrm{M}}$ have been identified, the overall number of reference technical actions, $n_{\mathrm{RTA}}$, within a shift, can be calculated using Equation (C.7):

$$n_{\mathrm{RTA}} = n_{\mathrm{RPA,tot}} \times R_{\mathrm{cM}} \times t_{\mathrm{M}} \quad \text{(C.7)}$$

## C.5 Step 3

Obtain the OCRA Index risk by comparing, for each upper limb, the number of ATA carried out during a work shift (obtained in step 1) and the number of RTA (determined in step 2) using Equation (C.1). Then use Table C.5 to evaluate the risk and determine the consequences to be acted upon.

**Table C.5 — Final assessment criteria**

| Zone | OCRA Index value [a] | Risk level | Consequences |
|---|---|---|---|
| Green | ⩽ 2,2 | No risk<br>UL-WMSD (PA) forecast not significantly different from that expected in the reference population | Acceptable: no consequences |
| Yellow | 2,3–3,5 | Very low risk<br>UL-WMSD (PA) forecast higher than previous but lower than twice that expected in the reference population | Improve structural risk factors (posture, force, technical actions, etc.) or take other organizational measures |
| Red | > 3,5 | Risk<br>UL-WMSD (PA) forecast more than twice that expected in the reference population | Redesign tasks and workplaces according to priorities |

[a] The higher the value, the higher the risk.

The OCRA Index “critical values” reported in Table C.5 should be used to assist in better framing the risk assessment and to guide any consequent preventative actions more effectively, rather than being treated as rigid numbers splitting results between “risk” or “no risk”. For instance, although it is theoretically fair to state that an OCRA Index value of 3,4 represents an uncertain risk, and that an OCRA Index value of 3,6 represents a definite risk, it is equally fair to say that the difference between these two values is negligible, and that the user should pay due attention to trends in OCRA results (also using the forecasting methods supplied).

See C.10 for the criteria to be adopted for OCRA Index classification as well as information on forecast models of the expected PA by one or more UL-WMSD.

## C.6 Identifying technical actions

### C.6.1 General

Technical actions, TA, imply musculoskeletal activity of the upper limbs. They should not be identified by a single joint movement, but rather with a complex movement involving one or more joints and segments in the completion of a simple working task [10], [11]. The task analysis methods generally used in industry identify the elementary movements of a given operation to determine the time required to accomplish it. The two most common methods, covered in References [3], [4], [5], [14], [15], [19], [20], [22], [23], [24], [25], [30], [33], [36], [44], [46], [47], [49] and [50], are

— chronometer analysis, and

— predetermined time systems, PTS, such as MTA (motion time analysis), MTS (motion time system), WF (work factor), the methods/time measurement systems MTM 1, MTM 2, MTM 3, MTM V, MTM MEK and MTM UAS, and MODA PTS (modular analysis predetermined time systems).



The technical actions are similar (even if not identical) to the elements considered in the task analysis methods listed above. Thus, they are more easily recognized by technicians since their identification and the task analysis methods both aim towards the description of the technical movements carried out by the operator to complete a work cycle. Table C.6 gives the criteria for counting actions as technical actions.

**Table C.6 — Criteria for counting technical actions**

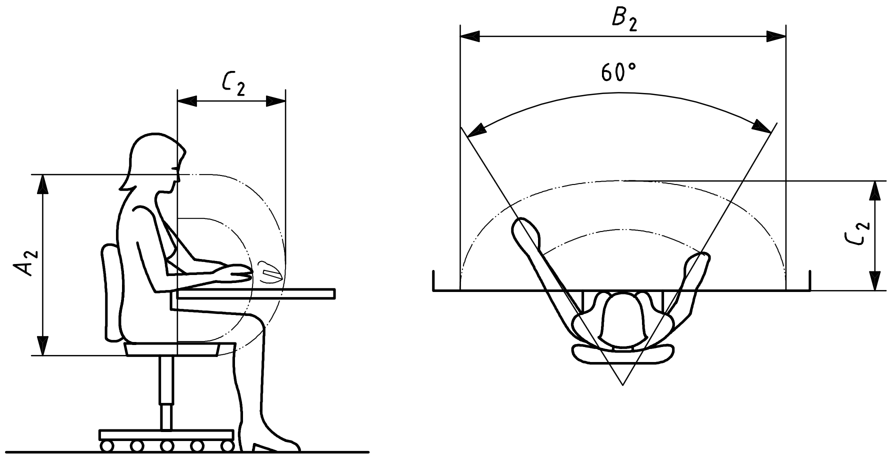
| Technical action | Criteria |
|---|---|
| Move | Only when<br>— the object moved weighs more than 2 kg (with the hand in grip) or 1 kg (with the hand in pinch), and<br>— the upper limb has a wide movement covering a distance of > 1 m. |
| Reach | Only when the object is positioned beyond reach of working area limits $A_2$, $B_2$ and $C_2$, shown here.<br><br>$A_2$ maximum working area height: 730 mm<br>$B_2$ maximum working area width: 1 170 mm<br>$C_2$ maximum working area depth: 415 mm<br>NOTE Adapted from ISO 14738. |
| Grasp | Grasping of an object with hand or fingers in order to carry out an activity or task.<br>Synonyms: take, hold, grip, grip again, take again, etc. |
| Grasp with one hand<br><br>Grasp again with other hand | The action of passing an object from hand to hand is considered two separate technical actions:<br>— one TA for the right hand (grasp with one hand);<br>— the other TA for the left (grasp with other hand). |
| Position | Positioning an object or tool at a pre-established point.<br>Synonyms: position, lean, put, arrange, put down; equally, re-position, put back, etc. |
| Putting in<br>Pulling out | Only when use of force required.<br>Synonyms: to insert, to extract. |
| Push/Pull | Considered TA because of need to apply force (even if only little) in order to obtain a specific result.<br>Synonyms: to tear, to press. |
| Release,<br>Let go | Considered TA except where, once object is no longer necessary, it is simply “released” by opening the hand or the fingers. |

**Table C.6** (*continued*)

<table>
<tr><th>Technical action</th><th>Criteria</th></tr>
<tr><td>Start-up</td><td>Start-up of a tool requires the use of a push-button or lever by parts of the hand, or by one or more fingers.<br>If start-up done repeatedly, count one technical action for every start-up.<br>Synonyms: press button, lift/lower lever.</td></tr>
<tr><td>Specific actions during a phase</td><td>Other actions that specifically describe the processing of a part/object:<br>— to bend or fold;<br>— to bend or curve, deflect;<br>— to squeeze, rotate, turn;<br>— to settle, to shape;<br>— to lower, hit, beat;<br>— to brush (count each brush passage on part to be painted);<br>— to grate (count each passage on part to be grated);<br>— to smooth or polish (count each passage on part to polish);<br>— to clean (count each passage on part to clean);<br>— to hammer (count each single hit on part);<br>— to throw;<br>— etc.<br>Identify and count each action once for every repetition.<br>EXAMPLE "Turn twice" equals two technical actions, "lower three times" equals three technical actions, "four brush strokes" equals four technical actions.</td></tr>
<tr><td>Carry</td><td>Carrying an object shall be considered as a TA only when<br>— the object weights more than 2 kg with the hand in grip or 1 kg with the hand in pinch, and<br>— the walking distance is $>$ 1m</td></tr>
<tr><td colspan="2">Walk and visual inspection are not considered technical actions, as they do not imply any activity of the upper limbs.<br>Count identical actions each and every time they are repeated.<br>When defining the frequency, $f$ (number of technical actions per minute), count the single technical action, not its duration.</td></tr>
</table>

### C.6.2 Examples of counting and identifying

#### C.6.2.1 Example 1 — Pick and place

The operation described here is the picking up of a workpiece (a cylinder) from a container and its placing in a hole on the workbench close to the body — a so-called pick (first technical action) and place (second technical action) operation. In this example, only the right upper limb is being worked and the two technical actions present in the cycle are only for that limb (see Table C.7) [57].

After identifying the technical actions, count their number in the cycle and, timing the cycle length in seconds, calculate using Equation (C.8), for the right and left upper limbs separately, with their frequency expressed as the number of technical actions per minute:

$$f = n_{TC} \times \frac{60}{t_C} \qquad \text{(C.8)}$$

**Table C.7 — Counting technical actions — Pick and place**

| | Technical action | |
|---|---|---|
| | **Left upper limb** | **Right upper limb** |
| | — | Pick up cylinder |
| | — | Place cylinder in hole |
| **Total number of technical actions,** $n_{TC}$ | 0 | 2 |
| **Cycle time,** $t_C$, s | 6 | 6 |
| **Frequency,** $f$, TA/min | — | 20 |

When it becomes necessary for the operator to re-grasp and reposition the workpiece, this counts as two new technical actions (see Table C.8).

**Table C.8 — Counting technical actions — Pick and place, re-grasp and reposition**

| | Technical action | |
|---|---|---|
| | **Left upper limb** | **Right upper limb** |
| | — | Pick up cylinder |
| | — | Place cylinder in hole |
| | — | Re-grasp |
| | — | Reposition |
| **Total number of technical actions,** $n_{TC}$ | 0 | 4 |
| **Cycle time,** $t_C$, s | 6 | 6 |
| **Frequency,** $f$, TA/min | — | 40 |

### C.6.2.2 Example 2 —Pick and place with transfer from left hand to right and visual inspection

The operation described here is a pick and place operation with transfer of the workpiece from one hand to the other and a visual inspection. The operator grips the cylinder with the left hand, passes it to the right hand, rotates it for a visual inspection and, still with the right hand, positions it in the required place. When counting technical actions, visual inspection is not normally considered, because it does not require any mechanical action of the upper limbs. However, when the operator actually physically *rotates* the cylinder for the purposes of visual inspection — a mechanical action — this is counted as a technical action (rotation) (see Table C.9).

**Table C.9 — Counting technical actions — Pick and place with transfer from hand to hand and visual inspection**

| | Technical action | |
|---|---|---|
| | **Left upper limb** | **Right upper limb** |
| | Take cylinder | — |
| | — | Grasp cylinder |
| | — | Rotate cylinder |
| | — | Position cylinder |
| **Total number of technical actions,** $n_{TC}$ | 1 | 3 |
| **Cycle time,** $t_C$, s | 6 | 6 |
| **Frequency,** $f$, TA/min | 10 | 30 |

### C.6.2.3 Example 3 — Pick, carry and place load

In this example, the operator carries a load weighing 4 kg from a container, which is at a distance of more that 1 m from the workbench, to the workbench itself. The technical actions are grip the part, carry the load and place it. (see Table C.10).

NOTE Carry is counted as a technical action of the upper limb(s) only under the conditions specified in Table C.6.

**Table C.10 — Counting technical actions — Carry and place load**

| | Technical action | |
|---|---|---|
| | **Left upper limb** | **Right upper limb** |
| | — | Grasp load |
| | — | Carry load with one arm |
| | — | Position load on bench |
| **Total number of technical actions,** $n_{TC}$ | 0 | 3 |
| **Cycle time,** $t_C$, s | 6 | 6 |
| **Frequency,** $f$, TA/min | 0 | 30 |

### C.6.2.4 Example 4 — Cyclical use of tool with repeated and identical actions

In this example, using a drill, the operator makes a hole at three different points. After gripping the drill with the right hand (technical action 1), he places it over the point where the hole is to be drilled, pushes the button to start the drill, pushes the drill to obtain the hole, then extracts the drill.

These four actions are each repeated three times (total of 12 technical actions) before the drill is put down. The total number of technical actions is therefore 14, all of them performed using the right upper limb.

NOTE If the tool is suspended and returned to its original position passively, the release action is not counted.

See Table C.11.

**Table C.11 — Counting technical actions — Cyclical use of tool with repeated and identical actions**

| | **Technical action** | |
|---|---|---|
| | **Left upper limb** | **Right upper limb** |
| | — | Grasp drill |
| | — | Place on 1st hole |
| | — | Operate by pressing button |
| | — | Push to make 1st hole |
| | — | Remove drill |
| | — | Place on 2nd hole |
| | — | Operate by pressing button |
| | — | Push to make 2nd hole |
| | — | Remove drill |
| | — | Place on 3rd hole |
| | — | Operate by pressing button |
| | — | Push to make 3rd hole |
| | — | Remove drill |
| | — | Replace drill |
| **Total number of technical actions,** $n_{TC}$ | 0 | 14 |
| **Cycle time,** $t_C$, s | 14 | 14 |
| **Frequency,** $f$, TA/min | 0 | 60 |
| *Operate* describes the action of using the hand or finger(s) to operate the drill | | |
| *Push* indicates the need to apply force, even if minimal | | |
| *Remove* indicates the need to perform the operation using force, even if minimal | | |
| *Place* describes the need to place the tool in a predetermined spot | | |

#### C.6.2.5 Example 5 — Technical actions not carried out in every cycle

There are cases where some of the technical actions are not carried out in every cycle, but only once every few cycles. These actions are counted within each of the cycles as fractions of technical actions. In this example, re-grasp and reposition are done every two cycles: each is counted as 0,5 of a technical action per cycle.

See Table C.12.

**Table C.12 — Counting technical actions — Technical actions not carried out in every cycle**

| | Technical action | |
|---|---|---|
| | **Left upper limb** | **Right upper limb** |
| | Take cylinder | — |
| | — | Take cylinder |
| | — | Place cylinder in hole |
| | — | Re-grasp [a] |
| | — | Reposition [a] |
| **Total number of technical actions,** $n_{TC}$ | 0 | 3 |
| **Cycle time,** $t_C$, s | 6 | 6 |
| **Frequency,** $f$, TA/min | — | 30 |

[a] Counts as half an action.

## C.7 Determination of force levels

### C.7.1 General

Force represents the biomechanical involvement necessary to carry out a given action or sequence of actions. Force can be intended as an external, applied force, or an internal tension developed in the muscle, tendon and joint tissues. The need to develop force during work-related actions can be related to moving or keeping still the tools and objects, or to keeping a part of the body in a given position. The use of force can also be related to static or dynamic actions, both of which are contractions. When the first occurs, it is generally described as a static load, which some authors describe as a distinct risk element [17].

The need to use force repetitively is scientifically considered as a risk factor for tendon and muscle disorders. Furthermore, a multiplicative interaction has been shown between force and (action) frequency, especially for disorders affecting tendons or nerves.

Force quantification in actual work situations is difficult. Some scientists use a semi-quantitative estimation of external force via the weight of the objects being handled. In other cases, it has been suggested that mechanical or electronic dynamometers be used. Surface electromyography techniques can be used to quantify internal forces exerted by muscles. All of these methods present implementation difficulties. Effects of physical loads will be estimated by force multipliers, $F_M$. Force multipliers can be determined in two different ways depending on whether or not workers are known individually. Accordingly, two different procedures may be applied: a biomechanical approach based on user group strength distributions, and a psychophysical approach using the CR-10 Borg scale [6], [7].

### C.7.2 Procedure 1 — Biomechanical approach based on user group strength distributions

The following procedure enables the determination of force multipliers, $F_M$, for optional but well-defined working populations in anonymous situations, where the operators are not known individually.

a) Analyse a given work cycle to detect major workloads.

b) Obtain a set of 100 % MVC reference distribution functions for each workload, $i$, detected.

c) Adjust all 100 % $MVC_i$ reference distributions to the demographic profile (age and gender) of the envisaged user population.

d) Determine percentile force limits, $F_L$, (e.g. 15th percentile) for each major activity, $i$, allowing a majority (e.g. 85 %) to work at $F_{Li}$ levels.

e) Normalize actual loads, $L_i$, using $F_{Li}$. This yields % $MVC_i$ values that are not exceeded by the majority selected (e.g. 85 %).

f) Calculate an average $\overline{\%\,MVC}$ value integrating all of the major workloads of a cycle using Equation (C.9):

**Error! Objects cannot be created from editing field codes.** (C.9)

where

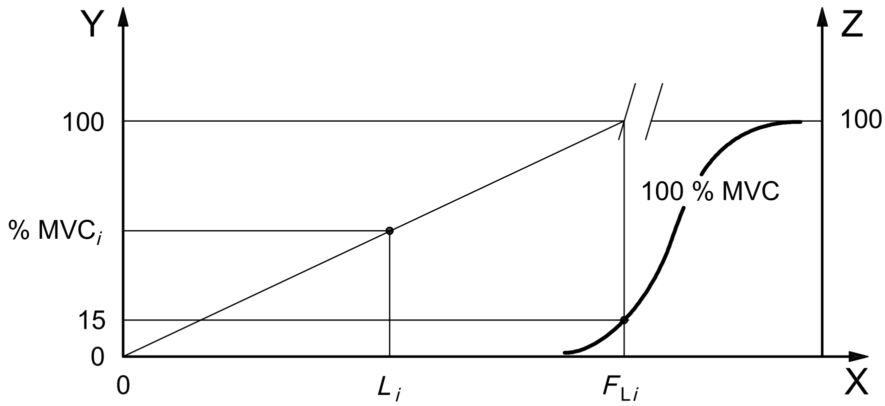
$t_C$ is the cycle time;

$\Delta t_i$ is the duration of exposure to workload $i$;

% $MVC_i$ is the % MVC value under workload $i$.

See Figure C.4 which illustrates steps a) to f).

g) Find the appropriate $F_M$ for each work cycle, as shown in Figure C.5.




**Key**

X strength or load, N

Y % MVC

Z strength distribution function, %

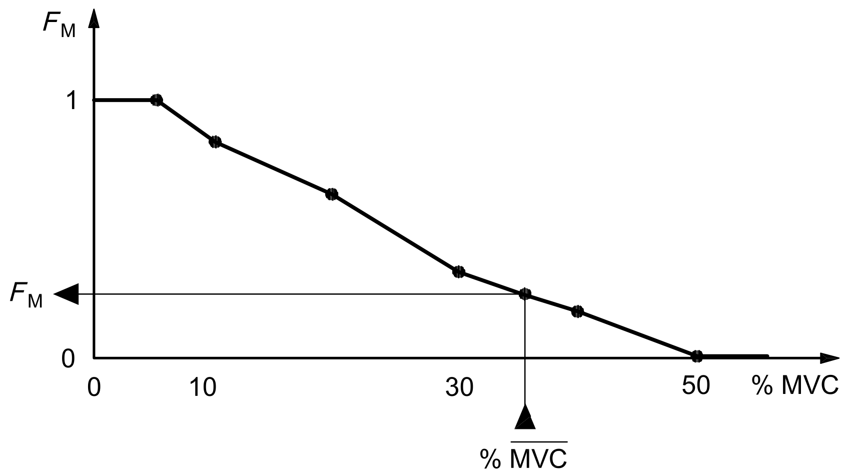
$F_{Li}$ force limit of activity, $i$, N

$L_i$ actual load under activity, $i$, N

% MVC$_i$ relative load given by activity, $i$, N

NOTE Illustrates C.7.2, a) to f).

**Figure C.4**




**Key**

$F_M$ force multiplier

% MVC percentage of maximum voluntary contraction

NOTE Illustrates C.7.2, g).

**Figure C.5**

### C.7.3 Procedure 2 — Psychophysical approach using CR-10 Borg scale

Applied forces may be estimated individually by a specific scale proposed by Borg (category scale for the rating of perceived exertion, CR-10 scale, see References [6] and [7]). This scale can be used to describe muscular effort perceived in any body region. The results of the implementation of the CR-10 scale, when assessed with an adequate number of workers, have an accuracy roughly comparable to that of surface electromyography. The relationship between CR-10 scale results and exerted force (in maximum % MVC) is: 10*CR – 10 ≅ force, in percent [16].

Quantification of the effort perceived by the whole upper limb should theoretically take place for every single action that makes up a cycle. For practical reasons, the actions that require minimal muscle involvement could be identified as having a 0,5 value in Borg's scale. Then the description procedure could only consider those actions, or groups of actions, that require more force than the minimal amount, always using Borg's scale. Once this procedure has been carried out, the average weighted score for the whole of the cycle must be calculated (see Table C.13).

Based on practical experience, the following is recommended.

a) The study on force should come after that on technical action frequency: one must already know how the cycle works and, especially, the order and intensity of the successive force requirements inside the cycle.

b) Ask the worker (user) whether there are technical actions inside the cycle that require muscle effort of the upper limbs. It is important to put the question in this way, because the worker often confuses muscle effort with the general tiredness that he/she feels at the end of a shift.

c) Once the actions, which imply the use of force, have been exemplified, ask the worker for a rating between 0 and 10 on a scale form. Ascribe the relevant duration to each of the strength exertions — in seconds and then as a percentage of the cycle time. Since exposure assessment procedures are also intended to be preventive, it is important to ask the worker to explain the reason for strength exertions. This is information of immediate practical interest because the presence of force when carrying out an action could be due to a technical defect in the product or tools used, or to a breakdown or a wrong choice of mechanical aids. Such problems are usually easily solvable.

d) Once the actions requiring force have been pinpointed and ranked according to Borg's scale, by ascribing to them a duration within the cycle, then all other technical actions in the remaining cycle time can be given the same score.

e) It is important that the worker does the scoring of the perceived physical effort in a given action him or herself, as, if this were done by an external observer, there would be major errors. In fact — and this is especially true of actions made by the smaller joints or for specific joint positions (pushing a button or a lever with the fingers, pinching, etc.) — the use of force is rarely perceivable by an external observer, even if he or she is highly trained.

f) Once all information is obtained from the worker, record any action requiring "peaks" (above 5 on Borg's scale), and calculate the average weighted score for all actions in the cycle as in the example of Table C.13.

**Table C.13 — Example calculation of average % MVC value (procedure 1) and average score of perceived effort (procedure 2) considering all technical actions in a 35 s work cycle**

| Subdivision in time within 35 s cycle<br>s | (A) | (B1) | (B2) | A × B1 | A × B2 |
|---|---|---|---|---|---|
| | Percentage subdivision of level of exertion in time | Percentage of MVC or $F_L$ | Borg scale score | % MVC or $F_L$ | perceived effort |
| 20 | 57 | 5 | 0,5 | 2,85 | 0,285 |
| 8 | 23 | 20 | 2 | 4,60 | 0,460 |
| 7 | 20 | 40 | 4 | 8,00 | 0,800 |
| **Final score** | | | | **15,45** | **1,545** |

## C.8 Analysis of posture, types of movements and their repetitiveness

Upper limb postures and movements during repetitive tasks are of fundamental importance in contributing towards the risk of various musculoskeletal disorders. Much agreement can be found in the technical literature as to the potential damage from awkward postures and movements of each joint, from postures maintained for a long time (even if not extreme), and from specific, repetitive movements of the various segments. The analysis of postures and movements will concentrate on each single segment of the upper limbs (hand, wrist, elbow, shoulder) and is aimed at checking the presence and time pattern in the cycle (frequency, duration) of static postures and dynamic movements involving each of the segments/joints considered. The description may be more or less analytical but shall at least address

a) technical actions requiring postures or movements of a single segment beyond a critical level of angular excursion (the angular excursion critical level can be determined according to criteria available in the literature),

b) technical actions involving static postures and/or movements which, even in acceptable angular excursion, are maintained or repeated in the same way (repetitiveness), and

c) the duration, expressed as a fraction of cycle/task time, of each of the conditions of a) and b).

The combination of these descriptive factors (posture/time) will provide the classification of effort for each segment considered.

In order to identify the so-called angular excursion critical levels (awkward postures and movements), reference should be made to ISO 11226 and, if necessary, to data and proposals available in the literature (see References [2], [8], [10], [12], [17], [29], [34], [35] and [45]) which are quite convergent, though differing in the level of analytical detail (inclusion/exclusion of some kinds of movement, critical excursion values of main movements, etc.).

An accurate description of posture and movements can also be considered a predictive element for specific pathologies of the upper limbs, which can be foreseen for exposed operators in the presence of other risk elements (frequency, force, duration, etc.).

The description/assessment of the postures and movements shall be done over a representative cycle for each of the repetitive tasks examined. This shall be via the description of the duration of the postures and/or movements of the four main anatomical segments (both right and left):

— posture and movements of the arm with respect to the shoulder (flexion, extension, abduction);

— movements of the elbow (flexions-extensions, pronosupinations of the forearm);

— postures and movements of the wrist (flexions-extensions, radio-ulnar deviations);

— postures and movements of the hand (mainly the types of grip).

In order to simplify the analysis of postures and movements, for the action to be defined as heavy, it is necessary to identify that when moving, the joint segment travels over an angle greater than 40 % to 50 % of joint range (or an awkward position for gripping with the hand).

Heavy joint involvement is quantified with different scores extrapolated from the data on the subjective perception of joint involvement [10].

When studying the postures and movements of the shoulder, of mention is a study [42] that shows an increased risk of shoulder disorders when the arm is moved or maintained at about shoulder level (extreme elevation) for more than 10 % of the cycle time.

As far as the types of handgrip are concerned, some of them (pinch, palmar grip, hook grip, narrow span) are considered to be less favourable than the power grip, and are therefore classified as implying medium/high involvement.



The following figures illustrate the main joint movements of the upper limbs (see Figure C.6 and Figure C.7) and, for the hand, the different types of grip (see Figure C.8)

NOTE Table C.2 summarizes the degrees beyond 40 % to 50 % of joint excursion range.

Posture evaluation involves the following five operating steps.

a) Describe the postures and/or movements, separately for the right and left joints.

b) Establish whether there is joint involvement in a “risk” area (awkward postures and/or movements), and its timing within the cycle:

— 1/10 from 10 % to 24 % of the cycle time;

— 1/3 from 25 % to 50 % of the cycle time;

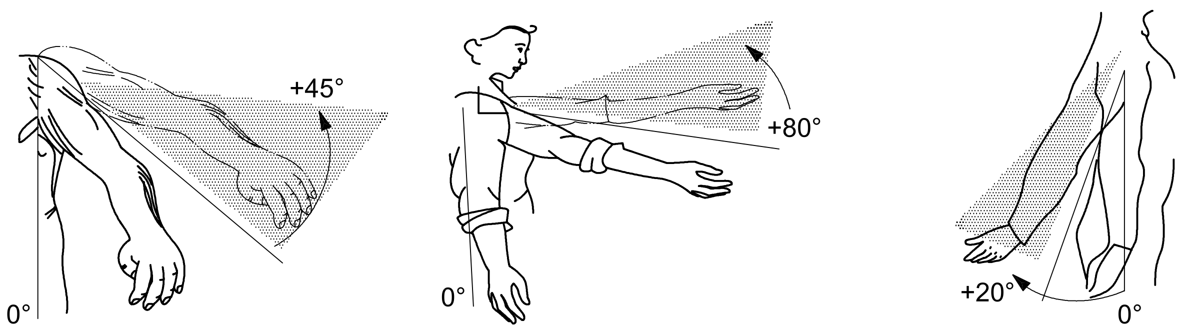
— 2/3 from 51 % to 80 % of the cycle time;

— 3/3 more than 80 % of the cycle time.

c) Find the corresponding posture multiplier, $P_M$ (see Table C.2).

d) Establish the presence of repetitiveness in certain movements which can be pinpointed by observing technical actions or groups of technical actions that are all equal to each other for at least 50 % of the cycle time, or by the presence of static positions maintained for at least 50 % of the cycle time, or by a very short duration of the cycle (less than 15 s but obviously characterized by the presence of actions of the upper limbs).

e) Consider the corresponding repetitiveness multiplier, $R_{eM}$.



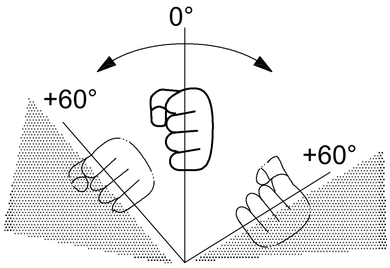

a) Lateral elevation — Abduction/adduction
100 % joint range is 90°;
awkward posture > 45º

b) Frontal elevation — Flexion
100 % joint range is 180°;
awkward posture > 80°

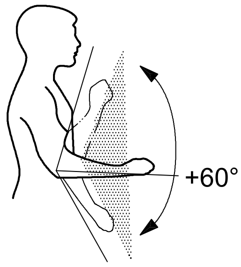
c) Extension
100 % joint range is 40°;
awkward posture > 20°

**Shoulder postures and movements**

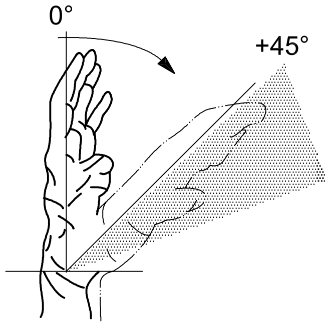
**Figure C.6**



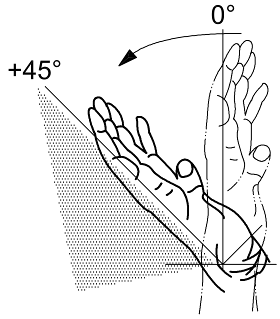

a) Elbow — Pronosupination
100 % joint range is 90°;
awkward posture > 60°



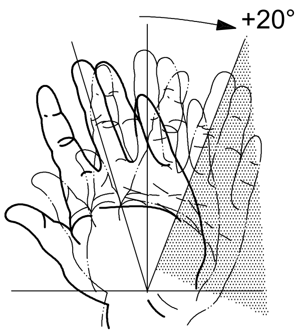

b) Elbow — Flexion, extension
100 % joint range is + 150°;
awkward posture > 60°



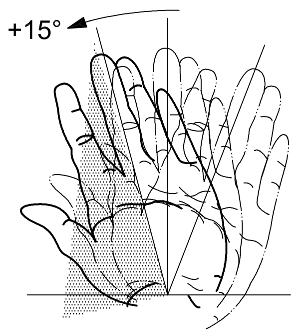

c) Wrist — Palmar flexion
100 % joint range is 90°;
awkward posture > 45°




d) Wrist — Dorsal extension
100 % joint range is 90°;
awkward posture > 45°



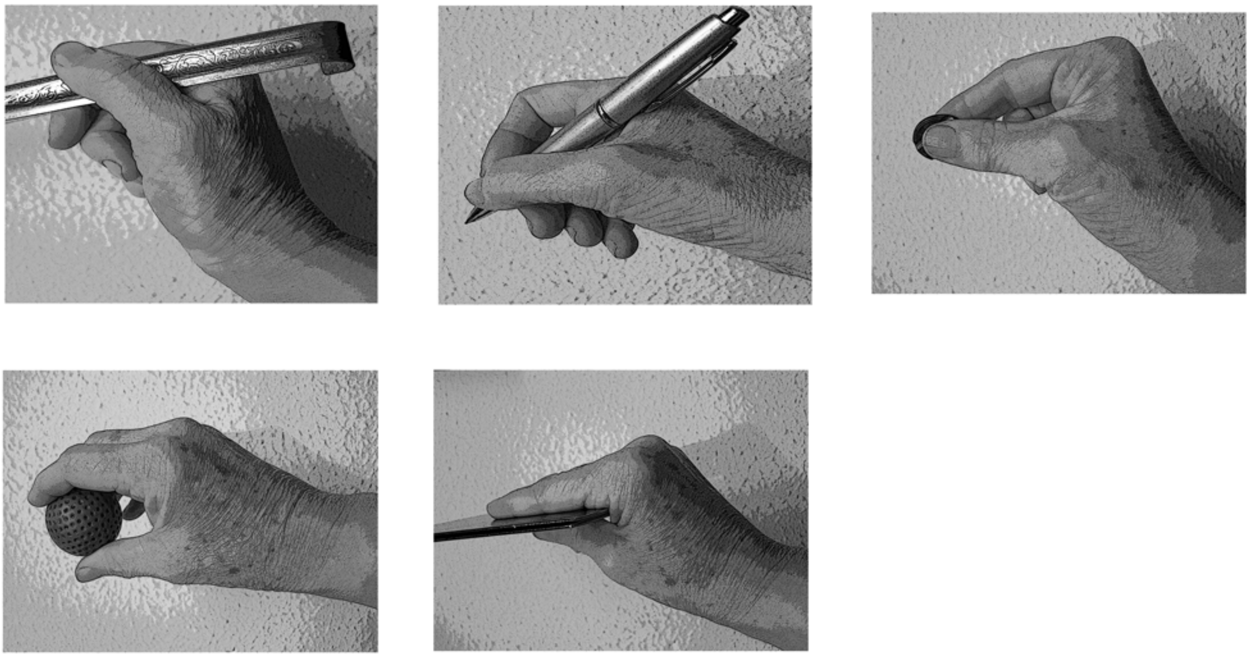

e) Wrist — Ulnar deviation
100 % joint range is + 40°;
awkward posture > 20°




f) Wrist — Radial deviation
100 % joint range is + 30°;
awkward posture > 15°

**Elbow and wrist postures and movements**

**Figure C.7**



Five examples of pinch grips

Two examples of hook grips

Power grip

Palmar grip

**Figure C.8**

## C.9 Definition and quantification of additional risk factors

Besides the main risk factors, there are others factors of an occupational nature that should also be taken into consideration when exposure is assessed [10], [17]. They are defined here as additional risk factors — not because they are of secondary importance, but because each of them can, from time to time, be either present or absent in the contexts examined.

The following list of these factors, which is only concerned with factors of a physical or mechanical nature, is not necessarily exhaustive:

- the use of vibrating tools (even if only for part of the actions);
- requirement for absolute accuracy (tolerance 1 mm to 2 mm in positioning a piece or object);
- localized compressions on anatomical structures of the hand or of the forearm with tools, objects, or working areas;
- exposure to cold or refrigeration;
- the use of gloves which interfere with the handling ability required by the task;
- objects handled having a slippery surface;
- sudden movements, “tearing” or “ripping” movements, or fast movements required;
- the required technical actions implying a countershock (hammering, hitting with a pick over hard surfaces, using the hand as a tool, etc.).

Other factors, which are listed under the general term of psycho-social, have also been called into play for determining the onset of UL-WMSD. Among these are some which are concerned with the individual sphere, and cannot, therefore, be included in general methods considering a collective and occupational type of exposure of a target group.

Conversely, there are factors — definable as organizational (work pace determined by machine, working on fast moving objects) — which should be taken into consideration, at least from the descriptive point of view.

The description of additional factors can take place in parallel with that of technical actions or of postures and movements.

For each of the physical/mechanical risk factors, it is necessary to specify the length of time (as a portion of the cycle/task time, 1/3, 2/3, 3/3) during which the factor is present, or to describe the frequency of occurrence of actions where the factor is present (especially for sudden movements and movements with countershocks).

A partial exception is represented by the factor vibrations, as transmitted to the hand/arm system. In this part of ISO 11228, such vibrations are only considered to be either present or not present (for a fraction of the cycle and task time).

NOTE For a detailed exposure assessment, the user is referred to ISO 2631-1, ISO 5349-1 and ISO 5349-2, or to national legislation.

The presence of organizational additional risk factors in the examined task needs to be mentioned: once it has been established that they are present (one or more), they influence the whole task (3/3 of cycle time).

The assessment of additional risk factors begins with a definition of optimum conditions, as represented by the absence, or very limited presence, of additional risk factors: in this scenario, the additional multiplier, $A_{\mathrm{M}}$, is equal to 1; any discrepancy with respect to this optimal condition represents a contribution of additional risk factors to the overall exposure level, which grows with that growing portion of the cycle time during which additional risk factors (one or more) are present, as specified in C.4.6.

## C.10 Association of the OCRA index with UL-WMSD — Classification of results and forecast models

On the basis of the studies given in References [39], [40], the association between the OCRA index (independent variable) and the prevalence of persons affected, PA, by one or more UL-WMSD (dependent variable) can be summarized by the following simple regression linear equation:

$$\mathrm{Y\,(PA)} = 2{,}39 \pm 0{,}14\ \mathrm{(SE)} \times \mathrm{OCRA} \qquad \text{(C.10)}$$

where

$$\mathrm{Y}\left(\mathrm{PA}\right) = n_{\mathrm{pa}} \times \frac{100}{n_{\mathrm{ep}}} \qquad \text{(C.11)}$$

$n_{\mathrm{pa}}$ is the number of persons affected by one or more UL-WMSDs;

$n_{\mathrm{ep}}$ is the number of exposed individuals;

SE is the standard error (= 0,14).

This regression equation is calculated without the constant, e.g. if OCRA is 0, then no UL-WMSD are supposed to be present.

In this context, the UL-WMSD considered are all entrapment syndromes, tendonitis, peritendinitis of the upper limbs (shoulder included), confirmed by clinical examination and specific instrumental tests.

If Equation (C.10) is used as a forecast model, the OCRA index becomes a tool for forecasting the collective risk, for a given exposed population, of contracting UL-WMSD (in terms of PA), as shown in Table C.14.

**Table C.14 — Forecast of PA (central tendency) for a group of exposed individuals, given specific OCRA index values**

| OCRA value | Central tendency<br>% |
|---|---|
| 1 | 2,39 |
| 2 | 4,78 |
| 4 | 9,56 |
| 8 | 19,12 |

Furthermore, other available data on the trends of PA in a reference working population which is never exposed to occupational risks of the upper limbs are relevant for the purposes of this part of ISO 11228 in defining the OCRA index critical values.

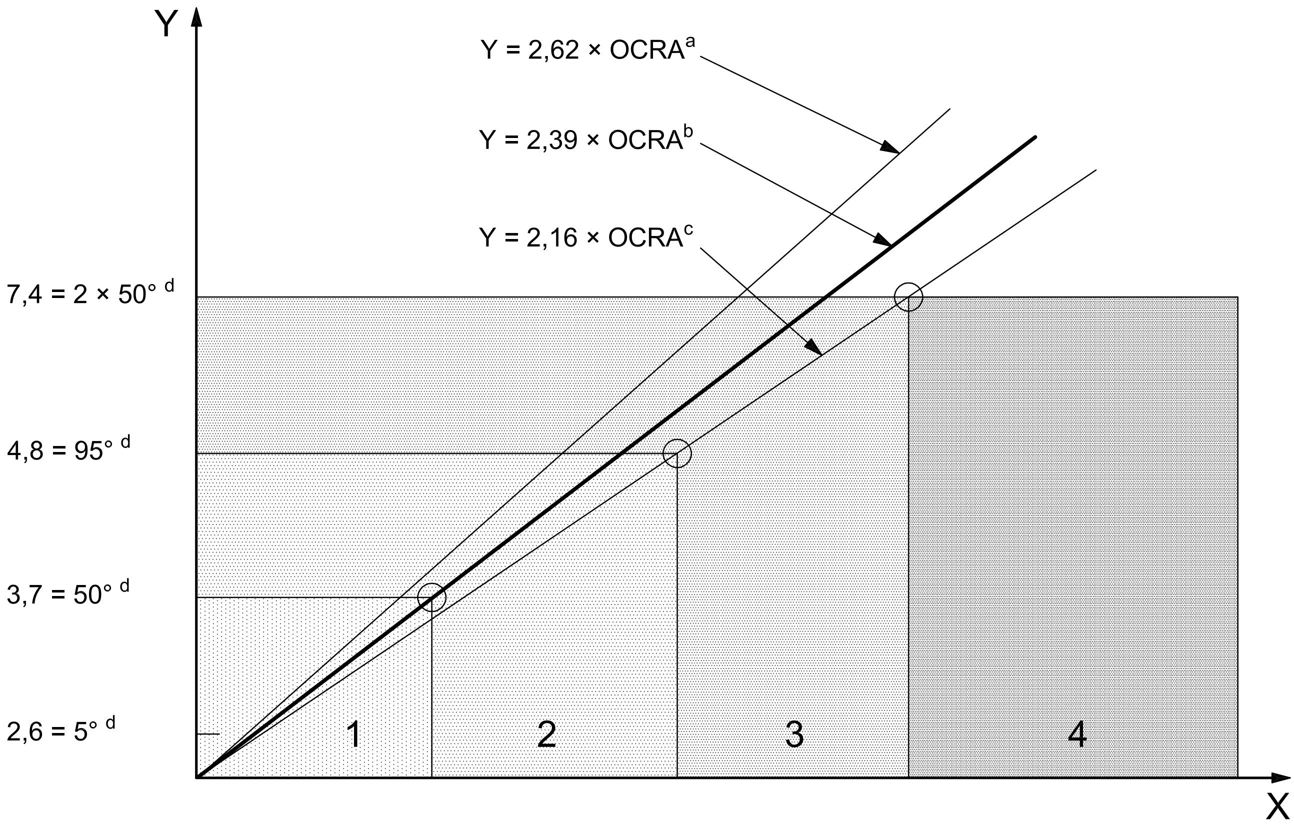
EXAMPLE In a sample reference group of 749 subjects (310 males and 439 females) [8], general and specific age and gender PA rates were computed. Considering the partial values of PA in different age and gender subgroups of this sample, it was possible to compute a standardized (for age and gender) rate, PA, with reference to the age and gender composition of a total national (Italian) workforce. Using statistical inferential procedures, the 90 % confidence limits and 5$^{th}$ and 95$^{th}$ percentiles of the standardized PA distribution were computed, as reported in Table C.15.

Using the PA variable in the reference unexposed population, OCRA index reference limits were established starting from the 95$^{th}$ percentile as the "driver value" for the so-called green limit and from twice the 50$^{th}$ percentile as the driver value for the so-called red limit.

Those driver values of PA expected in the reference working population (not exposed) were compared with the regression equation [Equation (C.10)] at the level corresponding to the 5$^{th}$ percentile (obtained using the SE): in such a way, by adopting a prudential criterion of assessment of not acceptable (yellow) or at risk (red) results, it was possible to find the OCRA values corresponding, respectively, to the green and red limits and to the discriminating green, yellow and red areas as schematically shown in Figure C.9.

**Table C.15 — PA values distribution as estimated in a working population never exposed to occupational risks for upper limbs**

| Health effect | $5^{th}$ percentile | $50^{th}$ percentile central value | $95^{th}$ percentile |
|---|---|---|---|
| **PA** | 2,6 | 3,7 | 4,8 |




**Key**

X OCRA

Y PA, %

1 optimal (GREEN) ⩽ 1,5

2 acceptable (GREEN) ⩽ 2,2

3 borderline (YELLOW) ⩽ 3,5

4 risk: low (RED) ⩽ 4,5; medium (RED) ⩽ 9; high (RED) > 9

[a] Equation (C.10) $95^{th}$ percentile.

[b] Equation (C.10) $50^{th}$ percentile.

[c] Equation (C.10) $5^{th}$ percentile.

[d] Driver value in the reference population.

NOTE Schematic representation of the OCRA procedure adopted to define OCRA green and red limits based on PA in the reference population and using Equation (C.10).

**Figure C.9**



In practice:

— the green limit means that, at that level, in the exposed working population, are forecast, in almost in 95 % of cases, PA values higher than the 95$^{th}$ percentile (PA = 4,8 %) expected in the reference (unexposed) population;

— the red limit means that, at that level, in the exposed working population, are forecast, in almost 95 % of cases, PA values higher than twice the 50th percentile (PA = 3,7 $\times$ 2 = 7,4 %) expected in the reference (unexposed) population.

Following this approach, and using the data that have been presented, it becomes possible to identify the different risk zones (green, yellow and red) with "critical" OCRA index values and to indicate the consequent preventive actions as given in Table C.5.

## C.11 Application examples of OCRA analysis and consequent risk reduction

### C.11.1 Recapitulation

Before presenting the examples, it could be useful to resume the time units proposed in the OCRA analysis:

— shift duration, in minutes;

— cycle time, $t_C$, in seconds;

— technical action duration, in seconds;

— technical action frequency, $f$ (number of actions per minute).

NOTE The software midaOCRAmultitask can be used to calculate the OCRA index (see Reference [57]).

### C.11.2 Example 1 a

This example describes the analysis of a task (in an assembly line) which consists of completing a piece in 5 s.

With the right hand, the worker takes and places the first component: this component arrives at his left side. With the left hand, the worker takes and places the second component: this component is on a plane in front of him. The pace is completely determined by the machinery. See Figure C.10.

**First phase: analyse organized work**

This involves the examination of the working shift, the selection of the task or tasks (repetitive or not), the presence of scheduled pauses, waiting times or dead times.

It is necessary first of all to pinpoint the presence of repetitive tasks characterized by the presence of cycles with technical actions of the upper limbs. One or more repetitive tasks can be carried out during a working shift: they must be singly assessed and described, with their duration in number of minutes within the whole shift. In the same way, all the non-repetitive tasks must also be described in terms of their duration in minutes within the working shift. Examples of such tasks are materials supply, preparation, cleaning or transport.

There are tasks that do not imply any action of the upper limbs, such as, for instance, visual control operations. Such tasks can be considered as a recovery period for the upper limbs, and their duration must be quantified attentively, in minutes, together with their distribution within the shift.

The physiological pause and/or rest period must be signed as a recovery period when expressed as pauses and/or interruptions lasting at least five consecutive minutes.

Right: take first piece on left side

Right: wait while maintaining the piece in pinch

Left: take the second piece

Right: position the first piece

Left: position the second piece

**Figure C.10**

The distribution of physiological pauses and/or rest periods within the shift requires the study of the total duration of their distribution within the shift itself. If the pauses and/or interruptions of activity are distributed subjectively, it is important to report accurately on the average worker's behaviour in respect of their application within the shift.

See Table C.16.

**Table C.16 — Analysis of organized work**

| Workplace | Description | Duration min |
|---|---|---|
| Shift duration | Official (from 8:00 to 17:00) | 480 |
| | Real | |
| Official breaks | Official (15 min at 10:00 and 15 min at 16:00) | 30 |
| Others breaks | Real | |
| Lunch break | Official (60 min not included in the shift) | |
| | Real | |
| Work time considered as recovery | Official | 0 |
| | Real | |
| Non-repetitive tasks | Official (clean = 15 min) | 15 |
| | Real | |
| **Net duration of repetitive task** | | 435 |
| **Number of units per shift** | Official | 5 220 |
| | Real | |
| **Net duration of cycle time** | | 5,0 s |
| **Observed duration of cycle time or duration of observed period** | | 5,0 s |
| **Percentage difference** | | 0 % |

**Second phase: calculate frequency of the technical actions**

The worker takes the piece in pinch, waiting until the machinery sited in front of him is ready, then positions the two pieces, one with the right hand and the other with the left. Positioning needs an elbow flexion/extension and the fingers in pinch.

The technical actions necessary to complete a cycle and their duration, in seconds, and frequency are described in Table C.17.

Calculate the action frequency, for each upper limb, using Equation (C.2) and with $n_{TC}$ the number of technical actions in a cycle for each arm.

The action frequencies resulting are 24 technical actions per minute for the right upper limb and 24 per minute for the left.

**Table C.17 — Identification of technical actions in cycle for each upper limb**

| Right upper limb | Number of technical actions (and duration) | Left upper limb | Number of technical actions (and duration) |
|---|---|---|---|
| Take first component | 1 (3 s) | Take second component | 1 (1,6 s) |
| Position it | 1 (2 s) | Position it | 1 (2,4 s) |
| Total technical actions | 2 | Total technical actions | 2 |
| Cycle time | 5 s | Cycle time | 5 s |
| Frequency | 24/min | Frequency | 24/min |

**Third phase: evaluate force**

The technical actions requiring force (right upper limb) are shown in Table C.18. For each technical action the following parameters are indicated:

— the duration, $x$;

— the proportion of its duration in the cycle, $j = x$/cycle time;

— the force level required, using either the Borg scale score, $y$, or the percentage of $F_B$ or of MVC (Z).

By multiplying $y$ by $j$ and summing the results, the average force level is obtained. The result using the Borg scale is 0,7 for the right upper limb and 0,76 for the left upper limb. The data proposed by Table C.1 determine the force multiplier, $F_M$, corresponding to the average force level estimated: $F_M$ is equal to 0,94 and 0,92 (interpolated value for right and left respectively).

The software [57] calculates the average force level and the corresponding $F_M$ by inserting for each technical actions (or group of identical actions) the duration, in seconds, and the corresponding score (percentage $F_B$ or percentage MVC or CR-10 Borg score).

**Fourth phase: evaluate awkward postures and/or movements**

The following awkward postures and/or movements are to be described for the different joints of both the upper limbs, as reported in Table C.19.

When the duration of each technical action and the distribution of the technical actions in the cycle are similar, it is possible to estimate the duration, in percentage of cycle time, of an awkward posture and/or movement, dividing the number of technical actions found in that specific awkward posture and/or movements by the total number of technical actions.

When duration and distribution of each technical action in the cycle are different, it is more precise to estimate the duration, in percentage of cycle time, dividing the duration, in seconds, of the technical actions found in a specific awkward posture and/or movement by the total duration of the cycle time in seconds.

The software calculates the percentage duration of the awkward postures or movements by entering the number and durations, in seconds, of each action and their duration in awkward postures and/or movements (as proposed in Table C.19).

Using Table C.2, for the right upper limb:

— for elbow in flexion/extension (⩾ 60°) for 40 % of the cycle time, $P_M$ = 1;

— for hand in pinch for 96 % of the cycle time, $P_M$ = 0,6.

The $P_M$ that represents the final posture evaluation is the lower score: 0,6.

Using Table C.2, for the left upper limb:

— for elbow in flexion/extension (⩾ 60°) for 40 % of the cycle time, $P_M$ = 1;

— for hand in pinch for 72 % of the cycle time, $P_M$ = 0,7.

The $P_M$ that represents the final posture evaluation is the lower score: 0,7.

**Fifth phase: evaluate repetitiveness**

For repetitiveness, the cycle time is very short and the task requires the performance of the same working movements for more than 50 % of the cycle time. The repetitiveness multiplier, $R_{eM}$, will be 0,7 (see C.4.5). The software enters $R_{eM}$ in the OCRA index computation. This is done by writing “yes” when it is present; “no” when repetitiveness does not occur.

**Table C.18 — Analysis of force of right upper limb**

| **Upper limb technical action**<br>**Task A** | **Technical actions (dynamic)** | | **Force** | | | |
|---|---|---|---|---|---|---|
| | Duration<br>s | Total per cycle | Borg scale scores<br>$y$ | Duration<br>$x$<br>s | Proportion of force duration in cycle time<br>$j$ | $y \times j$ |
| Take | 3 | 1 | 0,5 | 3,0 | 0,6 | 0,3 |
| Position | 2 | 1 | 2 | 1,0 | 0,2 | 0,4 |
| **Force score** | | | | | 0,70 | |
| **Force multiplier**, $F_M$ | | | | | 0,94 | |

**Table C.19 — Evaluation of proportional duration (percentage of cycle time) of joint in awkward postures and/or movements**

| Upper limb technical action | Technical actions (dynamic) | | Shoulder postures and movement | | | Elbow movements | | | Wrist postures and movements | | | | Hand postures and movements | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Task A | Technical actions duration s | Total technical actions per cycle | Flexion and/or abduction more than 80° | Abduction between 45° ÷ 80° | Extension more than 20° | Pronation > 60° | Supination > 60° | Flexion–extension > 60° | Flexion > 45° | Extension > 45° | Radial deviation > 15° | Ulnar deviation > 20° | Power grip | Grip with narrow span | Pinch | Palmar grip | Hook grip | Fine movements |
| **Right** | | | | | | | | | | | | | | | | | | |
| Take | 3 | 1 | | | | 1,0 | | 1,0 | | | | | | | 2.8 | | | |
| Position | 2 | 1 | | | | | | 1 | | | | | | | 2 | | | |
| Percentage cycle time | | | 0 % | 0 % | 0 % | **20 %** | 0 | **40 %** | 0 % | 0 % | 0 % | 0 % | 0 % | 0 % | **96 %** | 0 % | 0 % | 0 % |
| **Left** | | | | | | | | | | | | | | | | | | |
| Take | 1,6 | 1 | | | | 1,0 | | 1,0 | | | | | | | 1,6 | | | |
| Position | 2.4 | 1 | | | | | | 1 | | | | | | | 2 | | | |
| Percentage cycle time | | | 0 % | 0 % | 0 % | **20 %** | 0 % | **40 %** | 0 % | 0 % | 0 % | 0 % | 0 % | 0 % | **72 %** | 0 % | 0 % | 0 % |
| NOTE Computed using the software *midaOCRAmultitask* (see Reference [57]). | | | | | | | | | | | | | | | | | | |

**Sixth phase: evaluate recovery periods**

Referring to Table C.16, in a scenario with a lunch break and two breaks of 15 min each — one before and the other after the lunch break (in the last hour of the shift) — the distribution of recovery periods will be as shown in Figure C.11.

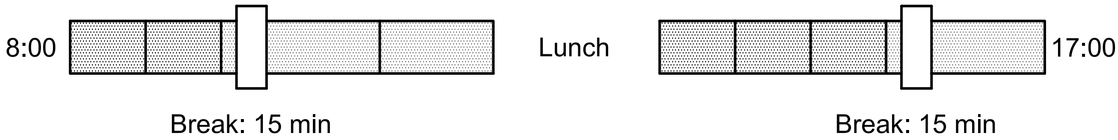



**Figure C.11**

As reported in C.4.8, the reference condition is represented by the presence, for each hour of repetitive task, of a work break of at least ten consecutive minutes or, for working periods of less than 1 h, in a ratio of 5:1 between work time and recovery time [1], [8], [48].

In relation to these reference criteria, it is possible to consider how many hours in the work shift do not have an adequate recovery period. It requires the observation, one by one, of the single hours that make up a work shift: for each hour, a check must be made for the presence of repetitive tasks and adequate recovery periods. For the hour preceding the lunch break (if it is present), and for the hour before the end of the shift, the recovery period is represented by these two events.

On the basis of the presence or absence of adequate recovery periods within every hour of repetitive work, the number of hours with "no recovery" is in this case 5 (one of the two breaks is in the last hour of the shift in which recovery is in any case present).

Considering the data presented in Table C.3, recovery period multiplier is $R_{cM}$ = 0,45 (corresponding to 5 h without an adequate recovery period).

**Seventh phase: evaluate duration multiplier**

The net duration of the repetitive task, $t$, considering in addition the presence of a non-repetitive task (cleaning for 15 min) is 435 min.

According to Table C.4: $t_M = 1$.

**Eighth phase: Calculate OCRA index**

Equation (C.3) is used to calculate the overall number of ATA carried out within the shift.

In the present example, $t = 435$ and $f = 24$, thus:

$n_{ATA}$ equals 10 440 for both upper limbs.

The following formula is used for calculating the overall number of RTA in a shift:

$$n_{RTA} = (k_f \times F_M \times P_M \times A_M \times R_{eM} \times t) \times (R_{cM} \times t_M)$$

As, in the present example, $t$ = 435 min and $t_M$ is equal to 1, thus

for the right upper limb:

$$n_{RTA} = (30 \times 0{,}94 \times 0{,}60 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}45 \times 1) = 1\,971$$



for the left upper limb:

$$n_{RTA} = (30 \times 0{,}92 \times 0{,}70 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}45 \times 1) = 2\ 255$$

The OCRA index is obtained by comparing, for each upper limb, the number of ATA carried out in the shift with the overall number of RTA within the shift, using Equation (C.1). In the example, the risk evaluation leads to an OCRA index in the red zone (see Table C.20):

OCRA index (left) = 10 440/2 255 = 4,6

OCRA index (right) = 10 440/1971 = 5,3

**Table C.20 — Example 1 a — Result of OCRA index evaluation**

| | | |
|---|---|---|
| Repetitive work net time for each task | 435 | |
| Units per shift | 5 220 | |
| Hours without recovery | 5 | |
| Recovery multiplier, $R_{cM}$ | 0,45 | |
| Constant of frequency, $k_f$ | 30 | 30 |
| | **Right** | **Left** |
| Force multiplier, $F_M$ | 0,94 | 0,92 |
| Posture multiplier, $P_M$ | 0,60 | 0,70 |
| Additional multiplier, $A_M$ | 0,85 | 0,85 |
| Repetitiveness multiplier, $R_{eM}$ | 0,70 | 0,70 |
| Cycle time, $t_C$, s | 5,0 | 5,0 |
| Frequency, $f$, TA/min | 24 | 24 |
| Technical actions in cycle, $n_{TC}$ | 2,0 | 2,0 |
| Total ATA | 10 440 | 10 440 |
| Total RTA | 1 971 | 2 255 |
| Duration multiplier, $t_M$ | 1,0 | 1,0 |
| **OCRA index** | **5,3** | **4,6** |

### C.11.3 Example 1 b — Risk reduction by optimizing break distribution

We can use different solutions to reduce the risk evaluated in Example 1 a.

Reducing the number of cycles and thereby increasing the cycle time means proposing to significantly reduce production: the least desirable means of risk reduction. One alternative is to rearrange the distribution of breaks, considering the possibility of optimizing the recovery periods. In example 1 a, there is a lunch break and two breaks each of 15 min each — one before, and the other after, the lunch break (last hour of the shift). The number of hours with “no recovery“ is in this case 5 h (one of the two breaks is in the last hour of the shift in which a recovery is already considered, as represented by the end of the shift). It is possible to obtain a significant risk reduction by simply dividing the 30 min of breaks into three breaks of 10 min each and correctly distributing them in the shift. See Figure C.12.

Redistribution of breaks for optimizing recovery periods.

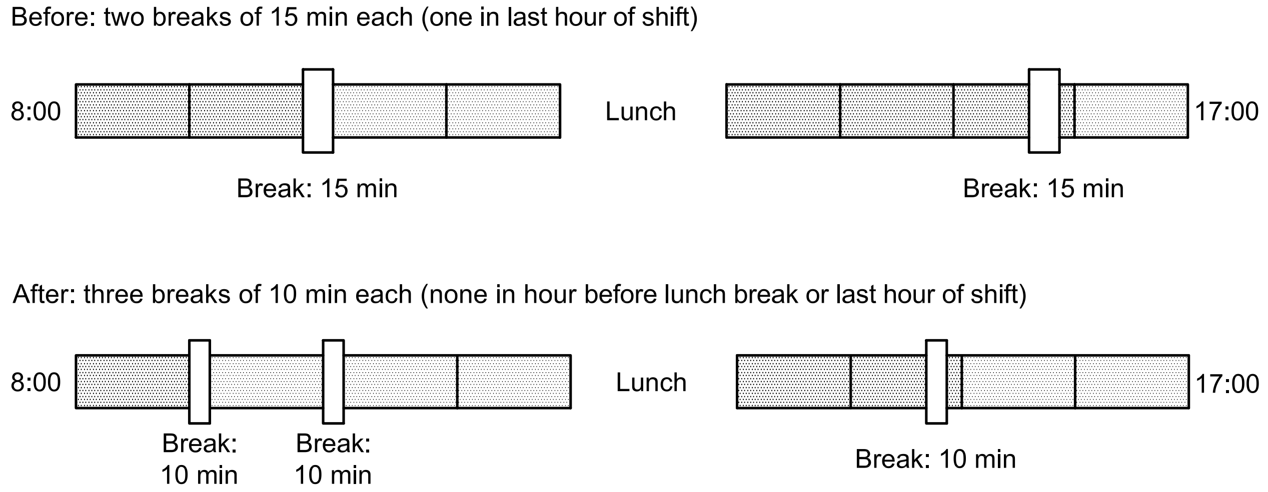



**Figure C.12**

Considering the new recovery distribution the reference multiplier is recovery period multiplier $R_{cM} = 0{,}7$ (corresponding to 3 h without an adequate recovery period).

Following this redesign of the break distribution, with the same break duration, $n_{RTA}$ is now higher.

***Before* redesign of break distribution**

For the right:

$$n_{RTA} = (30 \times 0{,}94 \times 0{,}60 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}45 \times 1) = 1\,971$$

For the left:

$$n_{RTA} = (30 \times 0{,}92 \times 0{,}70 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}45 \times 1) = 2\,255$$

***After* redesign of break distribution**

For the right:

$$n_{RTA} = (30 \times 0{,}94 \times 0{,}60 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}70 \times 1) = 3\,066$$

For the left:

$$n_{RTA} = (30 \times 0{,}92 \times 0{,}70 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}70 \times 1) = 3\,508$$

The OCRA Index consequently shifts into the yellow zone.

OCRA Index (left) = 10 440/3 508 = 3 OCRA Index (right) = 10 440/3 066 = 3,4

This example shows that, in some situations, only optimization of recovery distribution can obtain a risk reduction without cost.



### C.11.4 Example 1 c — Risk reduction by improving postures

In order to improve the results obtained in Example 1 b, an improvement in the workplace layout is conceivable. As shown in Figure C.10, a conveyor belt leaves the first pieces at the left side of the worker. In re-designing this workplace, it could be useful to stop the belt closer to the worker (simple and cheap solution) and to train the worker in a better way of assembling the two pieces.

The worker has first to take the first piece from his left side with the left hand instead with the right and consequently the second piece with the right hand. Taking and positioning both with this strategy, the worker can avoid to maintaining the pieces in his hand, consequently reducing the percentage of time spent in pinch posture).

The posture multiplier for the right upper limb will now be:

— for elbow in flexion/extension ($\geqslant$ 60°) for 40 % of the cycle time, $P_M$ = 1;

— for hand in pinch for $<$ 50 % of the cycle time, $P_M$ = 1.

The $P_M$ that represents the final posture evaluation is the lower score: 1.

The posture multiplier for the left upper limb will now be:

— for elbow in flexion/extension ($\geqslant$ 60°) for 40 % of the cycle time, $P_M$ = 1;

— for hand in pinch for $<$ 50 % of the cycle time, $P_M$ = 1.

The $P_M$ that represents the final posture evaluation is the lower score: 1.

With the redesign of the break distribution (see Example 1 b), together with the posture improvement made in this example, $n_{RTA}$ is now even higher.

***Before* redesign of break distribution**

For the right:

$$n_{RTA} = (30 \times 0{,}94 \times 0{,}60 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}45 \times 1) = 1\,971$$

For the left:

$$n_{RTA} = (30 \times 0{,}92 \times 0{,}70 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}45 \times 1) = 2\,255$$

***After* redesign of break distribution**

For the right:

$$n_{RTA} = (30 \times 0{,}94 \times 0{,}60 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}70 \times 1) = 3\,066$$

For the left:

$$n_{RTA} = (30 \times 0{,}92 \times 0{,}70 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}70 \times 1) = 3\,508$$

***After*** **redesign of break distribution and workplace**

For the right:

$$n_{RTA} = (30 \times 1 \times 1 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}70 \times 1) = 5\ 435$$

For the left:

$$n_{RTA} = (30 \times 0{,}92 \times 1 \times 0{,}85 \times 0{,}70 \times 435) \times (0{,}70 \times 1) = 5\ 109$$

The OCRA index is now in the green zone:

OCRA index (left) = 10 440/5 109 = 2 OCRA index (right ) = 10 440/5 435 = 1,9

## C.11.5 Example 2 a — Task analysis

This example describes the analysis of a task (in an assembly line) consisting of checking, at the end of the assembly line, an electrical engine part by visual control, only by rotating the piece. The final operation is to store the pieces in a box. During a work cycle four pieces are checked.

To complete a cycle of four pieces, the worker uses 21 technical actions for the right hand and 12 for the left, with a cycle time of 20,5 s for the four pieces. The technical actions necessary to complete a cycle with the right hand are given in Table C.21.

The action frequencies will be 61,36 actions per minute for the right and 35 actions per minute for the left upper limb.

**Table C.21 — Example 2 a — Technical actions and frequency calculation**

| Technical actions in cycle | | | |
|---|---|---|---|
| **Right upper limb** | **Number of technical actions** | **Left upper limb** | **Number of technical actions** |
| Pull four pieces together | 1 | — | — |
| Grasp piece (1st) | 1 | Grasp piece (1st) | 1 |
| Turn it for visual inspection (1st) | 1 | Turn it for visual control (1st) | 1 |
| Turn it again (1st) | 1 | Turn it again (1st) | 1 |
| Grasp piece (2nd) | 1 | Grasp piece (2nd) | 1 |
| Turn it for visual inspection (2nd) | 1 | Turn it for visual inspection (2nd) | 1 |
| Turn it again (2nd) | 1 | Turn it again (2nd) | 1 |
| Grasp piece (3rd) | 1 | Grasp piece (3rd) | 1 |
| Turn it for visual control (3rd) | 1 | Turn it for visual inspection (3rd) | 1 |
| Turn it again (3rd) | 1 | Turn it again (3rd) | 1 |
| Grasp piece (4th) | 1 | Grasp piece (4th) | 1 |
| Turn it for visual inspection (4th) | 1 | Turn it for visual inspection (4th) | 1 |
| Turn it again (4th) | 1 | Turn it again (4th) | 1 |
| Take (1st) | 1 | — | — |
| Position (1st) | 1 | — | — |
| Take (2nd) | 1 | — | — |
| Position (2nd) | 1 | — | — |



**Table C.21** (*continued*)

| Technical actions in cycle | | | |
|---|---|---|---|
| **Right upper limb** | **Number of technical actions** | **Left upper limb** | **Number of technical actions** |
| Take (3rd) | 1 | — | — |
| Position (3rd) | 1 | — | — |
| Take (4th) | 1 | — | — |
| Position (4th) | 1 | — | — |

| | Right | Left |
|---|---|---|
| **Total technical actions** | 21 | 12 |
| **Cycle time,** s | 20,5 | 20,5 |
| **Frequency,** actions/min | 61,36 | 35 |

Using the values of Table C.22, the posture multiplier is:

— for elbow in flexion/extension (⩾ 60°) for 76 % of the cycle time, $P_M$ = 0,7;

— for hand in pinch and palmar grip for 97 % of the cycle time, $P_M$ = 0,5.

The $P_M$ that represents the final posture evaluation is the lower score: 0,5.

**Table C.22 — Example 2 a — Proportional duration in awkward postures or movements of joint**

| Awkward postures/movements | Proportional duration |
|---|---|
| Elbow flexion/extension | 76 % |
| Hand palmar grip and pinch | 97 % |

For repetitiveness, the task requires the performance of the same working movements for more than 50 % of the cycle time. The repetitiveness multiplier, $R_{eM}$, will be 0,7 (see C.4.5).

The technical actions requiring force are shown in Table C.23. The data proposed therein determine the force multiplier, $F_M$, corresponding to the average force level, estimated at 0,95 using the Borg scale and 9,49 using the percentage of $F_B$ or of MVC.

The corresponding $F_M$ is 0,88 (interpolated value).

**Table C.23 — Example 2 a — Evaluation of average force level**

| Technical action (right) | Technical actions per cycle | (A) Proportional duration | (B) Borg scale score | (C) % $F_B$ | A × B | A × C |
|---|---|---|---|---|---|---|
| **Pull** | 1 | 0,03 | 2 | 20 | 0,06 | 0,64 |
| **Grasp** | 4 | 0,22 | 0,5 | 5 | 0,11 | 1,08 |
| **Turn** | 4 | 0,22 | 0,5 | 5 | 0,11 | 1,08 |
| **Turn** | 4 | 0,22 | 0,5 | 5 | 0,11 | 1,08 |
| **Take** | 4 | 0,16 | 0,5 | 5 | 0,08 | 0,8 |
| **Place** | 4 | 0,16 | 3 | 30 | 0,48 | 4,81 |
| **Total** | **21** | | | | **0,95** | **9,49** |

Referring to a standard shift duration of 480 min, with a meal break and two breaks of 10 min each, one before and the other after the lunch break (the lunch is outside the shift duration of 480 min), the net duration of repetitive task, $t$, is 460 min.

Considering Tables C.3 and C.4, the reference multipliers will be:

— recovery period multiplier, $R_{cM}$ = 0,60 (corresponding to 4 h without an adequate recovery period);

— duration multiplier, $t_M$ = 1 (corresponding to a net repetitive task duration of 460 min).

The following formula is used for calculating the overall number of RTA in a shift:

$$n_{RTA} = (k_f \times P_M \times R_{eM} \times A_M \times F_M \times t) \times (R_{cM} \times t_M)$$

In the present example, considering the right upper limb:

$$n_{RTA} = (30 \times 0{,}5 \times 0{,}7 \times 1 \times 0{,}88 \times 460) \times (0{,}6 \times 1) = 2\,550$$

The OCRA Index is then calculated using Equation (C.1). See C.2.

In the example, the risk evaluation of the right upper limb leads to an OCRA Index in the red zone (see Table C.24):

OCRA Index = 28 224/2 550 = 11,1

**Table C.24 — Example 2 a — Result of OCRA Index evaluation**

| | |
|---|---|
| Shift duration | 480 |
| Breaks, min | 20 |
| Non repetitive work time, min | 0 |
| Repetitive work net time | 460 |
| Number of cycles per shift | 1 344 |
| Number of hours without an adequate recovery period, h | 4 |
| Recovery multiplier, $R_{cM}$ | 0,6 |
| Constant of frequency, $k_f$ | 30 |
| Force multiplier, $F_M$ | 0,88 |
| Posture multiplier, $P_M$ | 0,5 |
| Additional multiplier, $A_M$ | 1 |
| Repetitiveness multiplier, $R_{eM}$ | 0,7 |
| Cycle time, $t_C$ | 20,5 |
| Frequency, $f$, TA/min | 61,4 |
| Number of technical actions in the cycle | 21 |
| Total ATA | 28 224 |
| Total RTA | 2 550,24 |
| Duration multiplier, $t_M$ | 1 |
| **OCRA Index** | **11,1** |

## C.11.6 Example 2 b — Increase cycle time considering Example 2 a

Different solutions can now be chosen to reduce the risk. By reducing the number of cycles and consequently increasing the cycle time, as shown in Table C.25, the production will be significantly reduced. However, this represents the only way to obtain a risk reduction without any organizational or structural intervention.

**Table C.25 — Example 2 b — Reduction of number of pieces, increasing cycle time, for yellow and green zones**

| Number of cycles per shift | Frequency | Cycle time<br>s | OCRA Index | Risk |
|---|---|---|---|---|
| 1 344 | 61,2 | 20,5 | 11,1 | RED |
| 430 | 19,6 | 64 | 3,5 | YELLOW |
| 270 | 12,3 | 102,2 | 2,2 | GREEN |

### C.11.7 Example 2 c — Reduction of technical actions starting from Example 2 a

In order to avoid reducing the production, in Example 2 a it is important to try to reduce the number of technical actions, optimizing their distribution and/or introducing more automation.

For instance, the four pieces could arrive automatically at the workstation and a new mechanical device allow the worker to control two pieces at the same time. A pneumatic aid could be introduced to lift together the four pieces at the end of the task to put them in the final container: this reduces both the number of actions and the use of force.

The technical actions necessary to complete a cycle will now be only 9 (see Table C.26) for each upper limb.

**Table C.26 — Example 2 c — Reduction of technical actions in cycle**

| Technical actions in cycle | | | |
|---|---|---|---|
| **Right upper limb** | **Number of technical actions** | **Left upper limb** | **Number of technical actions** |
| Grasp two pieces (1st) (2nd) | 1 | Grasp piece (1st) | 1 |
| Turn them for visual inspection (1st) (2nd) | 1 | Turn it for visual inspection (1st) | 1 |
| Turn them again (1st) (2nd) | 1 | Turn it again (1st) | 1 |
| Grasp the last two pieces (3rd) (4th) | 1 | Grasp piece (2nd) | 1 |
| Turn them for visual inspection (3rd) (4th) | 1 | Turn it for visual inspection (2nd) | 1 |
| Turn them again (3rd) (4th) | 1 | Turn it again (2nd) | 1 |
| Position the aids on four pieces | 1 | — | 1 |
| Position the aid on the container | 1 | — | 1 |
| Release the four pieces | 1 | — | 1 |

| | Right | Left |
|---|---|---|
| **Total technical actions** | 9 | 9 |
| **Cycle time,** s | 20,5 | 21 |
| **Frequency,** actions/min | 26,3 | 26,3 |

By introducing an aid, the force is now practically absent, corresponding to $F_M$ = 1 (absence of force).

According to Table C.2, the new posture multipliers are:

— for elbow in flexion/extension for 1/3 of the cycle time, $P_M$ = 1;

— palmar grip for 1/3 of the cycle time, $P_M$ = 0,7.

The $P_M$ that represents the final posture evaluation is the lower score: 0,7.

The task now does not require the performance of the same working gestures for more than 50 % of the cycle time. In fact, the technical actions grasp, turn and turn are repeated only twice and last 44 % of the cycle time. The repetitiveness multiplier will be $R_{eM}$ = 1. In the example given, the cycle time is again 20,5 s, maintaining the same production, but the frequency of the technical actions is now only 26,3 actions/min: the OCRA index will now be in the green zone:

$n_{ATA} = 26,3 \times 460 = 12\,098$

$n_{RTA} = 30 \times 1 \times 0,7 \times 1 \times 1 \times (460 \times 0,6 \times 1) = 5\,796$

OCRA index = 12 098/5 796 = 2,1

Using the software, it is possible to observe what happens if the production increases (see Table C.27).

By increasing the number of cycles in the shift by 1 344 to 1 700, the OCRA Index risk will be 2,6 (yellow zone). However, by changing the job organization (for example, adding two other breaks of 10 minutes each) the OCRA Index risk will be 2,1 (green zone).

In conclusion, when a workplace gives rise to hazards and high OCRA Index values, the workplace, the equipment and the procedures for performing the task have to be reviewed, primarily as follows.

— Are the observed awkward postures and movements unavoidable? It must be the first duty of the designer, at this stage of the development of a machine and related task, to try to eliminate those postures or replace them by harmless ones.

— The parts of the equipment requiring the use of unsuitable handgrips can be redesigned as can the forces to be used.

— The number of technical actions and the pace of the machinery can be re-engineered.

— By using this analysis, task and workplaces can be (re)designed in order to reduce to an acceptable level the risk of repetitive handling at high frequency, while maintaining the same production level or even increasing it.

**Table C.27 — Example 2 c — OCRA Index in redesigned workplace — Result in green zone while maintaining same production — Right upper limb**

| | Increase in productivity | Increase in productivity and breaks |
|---|---|---|
| Shift duration | 480 | 480 |
| Breaks, min | 20 | 40 |
| Non repetitive work time, min | 0 | 0 |
| Repetitive work net time | 460 | 440 |
| Number of cycles per shift | 1 700 | 1 700 |
| Number of hours without an adequate recovery period, h | 4 | 2 |
| Recovery multiplier, $R_{cM}$ | 0,6 | 0,8 |
| Constant of frequency, $k_f$ | 30 | 30 |
| Force multiplier, $F_M$ | 1 | 1 |
| Posture multiplier, $P_M$ | 0,7 | 0,7 |
| Additional multiplier, $A_M$ | 1 | 1 |
| Repetitiveness multiplier, $R_{eM}$ | 1 | 1 |
| RTA | 5 796 | 7 392 |
| Cycle time, $t_C$, | 16,2 | 15,5 |
| ATA | 15 300 | 15 300 |
| Frequency, $f$, TA/min | 33,3 | 34,8 |
| Number of technical actions in the cycle | 9 | 9 |
| Duration multiplier, $t_M$ | 1 | 1 |
| **OCRA Index** | **2,6** | **2,1** |

# Annex D
(informative)

# Other methods for detailed risk assessment

## D.1 Introduction

There are a few other methods (see Table A.1) that allow for a detailed risk assessment corresponding to the general reference model given in Annex A. Essentially, they are the strain index and the HAL//ACGIH TLV (for monotask handwork). Those two methods are presented in this annex, taking into account their potential limits in respect to the model [9], [10].

## D.2 Strain index

The Strain Index (SI) [35] is a semi-quantitative job analysis method that involves the measurement or estimation of six task variables: intensity of exertion, duration of exertion per cycle, efforts per minute, hand/wrist posture, speed of work, and duration of task per day. An ordinal rating is assigned for each variable according to exposure data (see Table D.1.), then a multiplier value is assigned for each variable (see Table D.2). The SI is the product of these six multipliers:

$$\mathrm{SI} = A \times B \times C \times D \times E \times F$$

In order to analyse a job using the Strain Index, it is important to observe or videotape a representative sample of the job. It is easier to perform the analysis from videotape, and there is free software available to facilitate the analysis from digitized video files.

NOTE Detailed and useful information on the application of this method can be found on the Web site given in Reference [68].

The right and left sides are analysed separately. The higher score should be used to characterize the job as a whole.

There are five steps in the procedure:

a) collect data on the six task variables;

b) assign ordinal ratings using the ratings table (Table D.1);

c) determine multiplier values using the multiplier table (Table D.2);

d) calculate the SI score (the product of the six multiplier values);

e) interpret the result.

The simplest analysis, described here, occurs when the job involves a single task and the intensities and postures for each hand exertion are approximately equal.

**Table D.1 — SI — Finding rating values for each task variable**

| Rating value | Intensity of exertion<br>*A* | Duration of exertion<br>%<br>*B* | Efforts per minute<br>*C* | Hand/wrist posture<br>*D* | Speed of work<br>*E* | Duration per day<br>h<br>*F* |
|---|---|---|---|---|---|---|
| 1 | light | < 10 | < 4 | very good | very slow | ⩽ 1 |
| 2 | somewhat hard | 10–29 | 4–8 | good | slow | 1–2 |
| 3 | hard | 30–49 | 9–14 | fair | fair | 2–4 |
| 4 | very hard | 50–79 | 15–19 | bad | fast | 4–8 |
| 5 | near maximal | ⩾ 80 | ⩾ 20 | very bad | very fast | > 8 |

**Table D.2 — SI — Multiplier table for finding multipliers for each task variable**

| Rating value | Intensity of exertion<br>*A* | Duration of exertion<br>%<br>*B* | Efforts per minute<br>*C* | Hand/wrist posture<br>*D* | Speed of work<br>*E* | Duration per day<br>h<br>*F* |
|---|---|---|---|---|---|---|
| 1 | 1 | 0,5 | 0,5 | 1,0 | 1,0 | 0,25 |
| 2 | 3 | 1,0 | 1,0 | 1,0 | 1,0 | 0,50 |
| 3 | 6 | 1,5 | 1,5 | 1,5 | 1,0 | 0,75 |
| 4 | 9 | 2,0 | 2,0 | 2,0 | 1,5 | 1,00 |
| 5 | 13 | 3,0 | 3,0 | 3,0 | 2,0 | 1,50 |

For classification purposes according to the three-zone model, it can be assumed that, for a job or a task with a Strain Index higher than 7, the risk is present (red zone) and should be considered “hazardous”. Intermediate values of the strain index (score 3 to 7) are classified as a borderline or very low risk (yellow zone). When a hazard is predicted, examination of the multiplier values can reveal intervention strategies that would make the job or task safer.

Its authors summarize the foundations, limitations and assumptions of the SI method as follows:

— it only applies to the distal upper extremity (hand/forearm);

— it predicts a spectrum of upper limb disorders (disorders of muscle–tendon units as well as carpal tunnel syndrome), not specific disorders;

— it assesses jobs and not individual workers;

— the relationships between exposure data and the multiplier values are not based on explicit mathematical relationships between the task variables and the physiological, biomechanical, or clinical responses.

Besides these observations, other aspects of this method should be carefully considered when interpreting results:

— force is the most relevant factor considered (see Table D.2), but it is generally assessed by an external observer by means of an empirical scale;

— the maximum level (5) of efforts per minute is given for more than the 20 efforts/min that is very common in manufacturing;

- the postures considered are mainly at wrist level; types of hand grip are less considered;
- additional factors are not considered;
- recovery periods, in terms of macro-breaks, are partially neglected;
- it applies to simple tasks and for monotask jobs, also if in the near future developments for a multitask analysis are expected.

## D.3 HAL/ACGIH TLV

The ACGIH (American Conference of Governmental Industrial Hygienists) TLV (threshold limit value) is based on epidemiological, psychophysical and biomechanical studies and is intended for assessing monotask jobs (i.e. jobs in which only one repetitive task is present) performed for 4 h or more per day [1].

The TLV specifically considers average hand activity level (HAL) and peak of hand force and identifies conditions for which nearly all workers may be repeatedly exposed without adverse health effects.

The measure of HAL is based on the frequency of hand exertions and the duty cycle (relative durations of work and rest). HAL can be determined with ratings by a trained observer using the scale given in Table D.3. or can be (better) calculated by observing actions or exertions and using information on the frequency of exertions and the work/recovery ratio (see Table D.4).

Peak hand force is normalized on a scale of 0 to 10, which corresponds to 0 % to 100 % of the applicable population’s reference strength. Peak force can be determined with ratings by a trained observer, rated by workers (using CR-10 Borg scale) or measured using instrumentation or biomechanical methods. Peak force requirements can be normalized by dividing the force required to perform the job by the maximum strength capability of the work population for that activity, which is determined (when useful) through relevant databases.

Some combinations of force and hand activity are presumed to be associated with a significantly elevated prevalence of musculoskeletal disorders. Therefore, a threshold limit as well as an action limit (see Table D.5) are suggested. A three-zone classification system is derived and, consequently, different proactive measures are recommended.

a) Red zone — TLV and action limit exceeded: control program including engineering controls recommended;

b) Yellow zone — Above action limit: education, surveillance, job improvements recommended;

c) Green zone — Below action limit as long as exposure to other factors, e.g. postures, contact stress and vibration is not excessive.

NOTE On the web site given in Reference [65], detailed and useful information on the application of this method can be found.

**Table D.3 — HAL (hand activity level) rating scale**

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

**Table D.4 — HAL (0–10) calculated in relation to exertion frequency and duty cycle (percentage of work cycle where force greater than 5 % of maximum)**

| **Frequency** exertions/s | **Period** s/exertion | **Duty cycle** % | | | | |
|---|---|---|---|---|---|---|
| | | 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 |

**Table D.5 — ACGIH (2000) TLV and action limit based on hand activity level and normalized peak hand force (on 0–10 scale corresponding to 0 %–100 % of the applicable population's reference strength)**

| **HAL** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Normalized peak force: TLV** | 7,2 | 6,4 | 5,6 | 4,8 | 4,0 | 3,2 | 2,4 | 1,6 | 0,8 | 0 |
| **Normalized peak force: action limit** | 5,4 | 4,8 | 4,2 | 3,6 | 3,0 | 2,4 | 1,8 | 1,2 | 0,6 | 0 |

NOTE The values in the table are estimated from the original figure in ACGIH (2000). See Reference [1].

The ACGIH (2000) [1] TLV method mainly considers two important risk factors: repetition (frequency of exertions) and the use of force. In presenting this method, ACGIH (2000) underlines that other factors (i.e. posture stress, contact stress or vibration) should be assessed by a trained observer (an expert) and considered when interpreting the final results.

Moreover, ACGIH (2000) underlines the need for work standards that allow workers to pause as necessary, with a minimum of one break (recovery period) per hour.

Besides those observations, other aspects of this method should be carefully considered when interpreting results:

— its use is actually restricted to monotask jobs lasting almost 4 h and for no more than 8 h per shift;

— its full application is restricted to experts (in ergonomics) since relevant factors (like working postures, additional factors and task duration) which are not considered in computing the TLV should be discretionally assessed by those experts;

— recovery periods are considered only indirectly as a remedial measure but not in assessing actual risk levels;

— further developments of the method are expected, especially for what concerns the inclusion in the final score (TLV or AL) of aspects related to postures and movements, to additional factors and to recovery periods; more epidemiological data validating the actual dose-response model are equally expected.

# Annex E
(informative)

# Risk reduction

## E.1 Introduction

Scientific knowledge stresses the importance of an ergonomic approach in removing or reducing the risks of repetitive handling of loads. Ergonomics focuses on the design of work and its accommodation of human needs and physical and mental capacities. An ergonomic approach considers repetitive handling tasks in their entirety, taking into account a range of relevant factors, including the nature of the task, the characteristics of the object, the work environment and individual's limitations and capabilities.

A proper risk assessment is the basis for appropriate choices in risk reduction.

## E.2 Avoidance of repetitive handling

In seeking to avoid injury from repetitive handling, it is pertinent to ask whether repetitive handling could be eliminated altogether. Designers of work, machines or plants should consider introducing a powered or mechanical handling system rather than a manual system.

It should, however, be remembered that the introduction of automation or mechanization may create new risks. All equipment should be well maintained, compatible with the rest of the work system, effective, appropriately designed and easily operated. Workers should be trained properly to use the equipment safely and effectively. Operating instructions and safety concerns should be placed on the equipment.

## E.3 Design of work — Tasks, workplace and work organization

### E.3.1 Tasks

The tasks should be designed in a way that extreme ranges of joint movement, prolonged static postures and/or repetitive movements, combined with external forces, are avoided.

Musculoskeletal loading of the shoulders can increase when the object handled is far away from the body or at a high level. Stress levels of the neck increase when the viewing point or angle is too low or high, especially when the head position can hardly be varied. Stress levels of the elbow and wrist increase when the task involves extreme joint movements. Therefore, in the planning of tasks it is relevant to avoid extreme ranges of joint movements.

Another aspect that has to be taken into account is the possibility of recovering by regular micro-breaks (a few seconds in which the muscles can rest) within the task.

### E.3.2 Workplace

The workplace should be designed in such a way that working postures and their sequences can be optimised. The amount of work undertaken in fixed postures is also an important consideration. Recommendations on this issue are made in ISO 11226 concerning working postures.

Awkward postures and movements (see C.8) should be prevented by optimal positioning of the furniture, machines and material used. The working height (seat and desk or machine) should be adjusted (or adjustable) to the individual body height and work demands. The objects handled should be close to, and in front of, the body to minimize upper arm elevation and twisting of the body.

Variation of sitting and standing or walking should be made possible, for example by using a sit-stand workstation.

The working areas should be large enough to allow adequate room to manoeuvre. Sufficient space is a prerequisite for carrying out work efficiently and in appropriate working postures.

The presence of obstacles such as used wrapping materials can also pose slipping hazards and should be cleared (for details on workplaces, see ISO 14738).

### E.3.3 Work organization

The work should be organized in such a way that:

a) the task duration is not too long (no more than 1 h without a break or no more than 8 h per day);

b) the frequency of movements and or force exertions is not too high and can be adjusted by the worker to his/her own individual capabilities;

c) there are sufficient recovery periods (the ratio between recovery and task duration being at least 1:5).

Recovery can be induced by introducing regular breaks from work (i.e. for some minutes to give the worker the opportunity to leave the work place). Another way to recover is by variation of the repetitive work with other hazardless tasks. These tasks should involve the use of a different set of muscles.

Job enrichment, job enlargement and job rotation have a key role to play in countering potential hazards and maintaining levels of production output.

The worker should be able to adjust the rate of his/her work to his own capabilities. Work with a fixed rate is not recommended.

The amount of work undertaken in fixed postures is also an important consideration. Recommendations on this issue are made in ISO 11226 concerning working postures.

## E.4 Design of object, tool or material handled

The object to be handled may constitute a hazard because of its size or shape. In determining if a load represents a risk, proper account must also be made of the circumstances in which the load is handled; for example postural recommendations, frequency and duration of handling, workplace design and aspects of work organization such as incentive schemes and piecework should be considered.

The shape and way of using an object, tool or machine handle will affect the way in which it is held. The size of handgrips should suit size of the hand of both women and men. The design should enable a safe range of joint angles, especially for the elbow, wrist and fingers.

The operating mechanism should minimize static load (the duration of holding a posture for a sustained period of time), should optimize the amount of force needed and should allow the worker sufficient recovery periods. Therefore, the necessity of pressing controls for a sustained period should be avoided.

In addition, there may be physical or chemical hazards which should also be indicated, e.g. the object may have sharp edges, be too hot or too cold to touch or contaminated, or contain materials or substances which may be hazardous if spilled.



## E.5 Design of work environment

General environmental conditions, including illumination, noise and climate should be within tolerable levels. It is recommended that ISO 7730 be applied for thermal comfort requirements. Extra care should be taken if work has to be done at extremes of temperature. For example, high temperatures or humidity can cause rapid fatigue; work at low temperatures may require gloves to prevent numbness of the hands, but can also lead to a loss of manual dexterity. Air circulation (indoor and outdoor) is also a factor that influences body temperature. Rapid air circulation cools the body and should be avoided as far as possible. In very hot climates or working conditions, rapid air circulation may be desirable.

It is important that there should be sufficient light to enable the workers to see clearly what they are doing and also prevent poor working postures. High noise levels may lead to reduced vigilance and increased work stress.

For out-of-door work, account needs to be taken of the effects of changing weather conditions.

## E.6 Worker capabilities

Work should be adapted to the worker's physical and mental capabilities. The worker should be made aware of possible risks that are involved in the work and of his/her own possibilities and responsibilities to reduce these risks. For more demanding tasks, the worker should be supported by appropriate education and training and, if needed, medical monitoring and technical aids.

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