IV

Design and Evaluation of Manual Material Handling Tasks

13

Repetitive Actions and Movements of the Upper Limbs

Enrico Occhipinti
Daniela Colombini
Research Unit "Ergonomics of Posture and Movement''—EPM

INTRODUCTION

Working tasks that require manual repetitive actions at high frequency may cause the risk of fatigue, discomfort, and musculoskeletal disorders. A proper risk assessment and management should seek to minimize these health effects by taking into account a variety of risk factors including, in relation to the duration of exposure, the frequency of actions, the use of force, the postures and movements of the body segments, the lack of recovery periods, and other additional factors (Colombini et al., 2001).

To this regard, two parallel Standards are in preparation by CEN and ISO:

- PrEN 1005-5: Safety of Machinery—Human Physical Performance—Part 5: Risk Assessment for Repetitive Handling at High Frequency (CEN, 2004).
- ISO CD 11228-3: Manual Handling—Part 3: Handling of Low Loads at High Frequency (ISO, 2004)

Though the two mentioned drafts are devoted to different targets, they are conceptually similar and can be presented in the same context.

They are at an advanced stage of development from a technical point of view; at the moment writing, the CEN draft underwent a first positive official enquiry, and a second draft has been prepared taking into account the different official comments by CEN members. This second draft is expected now to undergo a second enquiry to be approved as a "harmonized" standard. The ISO draft is now ready to undergo a first official enquiry.

SCOPE OF THE STANDARDS

PrEN 1005-5: Risk Assessment for Repetitive Handling at High Frequency

This European (draft) Standard presents guidance to the designer of machinery or its component parts in controlling health risks due to machine-related repetitive handling at high frequency.

The Standard has been prepared to be a harmonized standard as defined by the European Union "Machinery Directive" and associated European Free Trade Association (EFTA) regulations. It applies only to designers of new machinery and assembly lines for professional use operated by the healthy adult working population. The machinery designer has to specify reference data for action frequency of the upper limbs during machinery operation: The Standard presents a risk-assessment method and gives guidance to the designer on how to reduce health risks for the operator.

ISO CD 11228-3: Handling of Low Loads at High Frequency

This International (draft) Standard establishes ergonomics recommendations for repetitive work tasks involving the handling of low loads at high frequency. The Standard will provide information for all those involved in the desig or redesign of work, jobs, and products. It is designed to provide guidance on several task variables, allowing the health risks for the working population to be evaluated. It applies to the adult working population; the recommendations will give reasonable protection for nearly all healthy adults.

MAIN DEFINITIONS

Work task. An activity or activities required to achieve an intended outcome of the work system (e.g., stitching of cloth and the loading or unloading of pallets).
Repetitive task. Task characterized by repeated cycles.
Cycle. A sequence of technical actions that are repeated always the same way.
Cycle time. The time elapsing from the moment when one operator begins a work cycle to the moment that the same work cycle is repeated (in seconds).
Technical action (mechanical). Elementary manual actions required to complete the operations within the cycle, such as holding, turning, pushing, and cutting.
Repetitiveness. Quality of task when a person is continuously repeating the same cycle, technical actions, and movements in a significant part of a normal workday.
Frequency. The number of technical actions per minute.
Force. The physical effort of the operator required to execute the operations (related to the machinery).
Posture and movements. The positions and movements of body segment(s) or joint(s) required to execute the operations related to the machinery.
Recovery time. The period of rest following a period of activity in which restoration of a muscle can occur.
Additional risk factors. Other factors for which there is evidence of a causal or aggravating relationship with work-related musculoskeletal disorders of the upper limbs (e.g., vibration, local pressure, and cold).

CONTENTS OF THE STANDARDS

General Recommendations

Manual repetitive tasks, if unavoidable, should be designed in a way so that activities demanding high frequency can be performed adequately with respect to the force required, the posture of the limbs and the foreseeable presence of recovery periods. In addition tasks and related machines should be designed to allow for variations in movements. Additional factors (like vibration, cold, etc.) have to be considered.

Data from recent epidemiological studies on workers exposed to repetitive movements of upper limbs allow those involved in the design or redesign of workplaces, task and jobs to forecast, from exposure indexes, the occurrence of the consequent upper-limb work-related musculoskeletal disorders (UL-WMSDs); (Colombini et al., 2002; Occhipinti & Colombini, 2004). The adequate situation occurs when the exposure index corresponds to a forecast of occurrence of WMSDs as observed in a working population not exposed to occupational risks for the upper limbs (Colombini, Grieco, & Occhipinti, 1998; Hagberg et al., 1995; NIOSH, 1997).

Risk Assessment

When manual repetitive tasks are unavoidable, then a risk-assessment approach should be adopted. This should follow a four-step approach:

1. Hazard identification
2. Risk estimation by simple methods
3. Risk evaluation by detailed methods (if necessary)
4. Risk reduction

The international literature reports the "frequency of upper limbs action" as connected to other risk factors like force (the more the force, the lower the frequency), posture (the more the joint excursion, the longer the time necessary to carry out an action), and recovery periods (if well distributed during the shift, they increase the recovery of muscles; Colombini et al., 2001). The technical action is identified as the specific characteristic variable relevant to repetitive movements of the upper extremities. The technical action is factored by its relative frequency during a given unit of time.

The hazard identification and simple risk estimation procedures are largely based on different experiences and proposals of the literature (Colombini, Occhipinti, & Grieco, 2002; Keyserling, Stetson, Silverstein, & Brower, 1993; Silverstein, Fine, & Armstrong, 1987; Schneider, 1995); the detailed risk evaluation procedures are substantially based on the OCRA Index method proposed by the Authors (Colombini et al.; Occhipinti, 1998)

Due to the different scopes and targets, the two mentioned Standards have slight differences when presenting specific procedures for risk assessment: Those aspects will be separately and synthetically detailed in the following paragraphs.

PrEN 1005-5

Hazard Identification

The first stage 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 is necessary.

In *PrEN 1005-5*, the "no-hazard" option (for the designer) is present when machinery and the related task imply: No cycles or a cyclic task in which perceptual of cognitive activities are clearly prevalent. For all the machinery and task combinations in which cyclic manual activities are foreseen, risk estimation shall be applied. To this end, the designer shall identify and count the technical actions (for each upper limb) needed to carry out the task (NTC); define the foreseeable duration of the cycle time (FCT); consider the foreseeable duration of work and frequency of recovery periods (generally duration of 240–480 minutes of a task during one shift with at least two usual breaks of 10 minutes are to be considered); consider the possibility of rotation on different tasks, when designing a machinery in the context of an assembly line.

Risk Estimation by Simple Methods (Method 1)

The presence of acceptable characteristics for all of the considered risk factors is verified. When the characteristics described are fully and simultaneously present, it is possible to affirm that exposure to repetitive movements is acceptable. Where one or more of the listed characteristics for the different risk factors are not satisfied, the designer shall use a more detailed evaluation. The acceptable characteristics of the risk factors are listed in Table 13.1. It is to be underlined that the final acceptable frequency of action per minute was set to 40, given that the designer should consider a reference organizational scenario (task duration of 240–480 minutes of with at least two usual breaks of 10 minutes plus meal break during the shift) and not

TABLE 13.1
List of Acceptable Characteristics of the Risk Factors

Absence of force, or use of force at the same conditions exposed in EN 1005-3
Absence of awkward postures and movements considering the same conditions exposed in prEN 1005-4 as summarized below:
• The upper-arm postures and movements are in the range between 0° and 20°. • The articular movements of the elbow and wrist do not exceed 50% of the maximum articular range. • The kinds of grasp are "power grip," or "pinch" lasting not more than 1/3 of the cycle time." **Low repetitiveness.** This occurs when: • The cycle time is more than 30 seconds. • The same kinds of action are not repeated for more than 50% of the cycle time. **Absence of additional factors (physical and mechanical factors).** This occurs when: • The task should not include hand/arm vibration, shock (such as hammering), localized compression on anatomical structures due to tools, exposure to cold, use of inadequate gloves for grasping, etc. **Frequency of upper-limb actions (for each arm) is less than 40 actions/min.** • In order to compute the frequency of actions/min, use the following formula: **FF = NTC × 60/FCT**, where: FF is the foreseeable frequency of actions per minute. FCT is foreseeable duration of the cycle time in seconds. NTC is the number of technical actions (for each upper limb) needed to carry out the task.

the "best" scenario (almost one break of 10 minutes every hour of repetitive work) that should lead to an higher acceptable frequency of actions per minute.

Risk Evaluation by Detailed Method (Method 2)

If the acceptable conditions underlined in the previous step are not satisfied, the designer shall describe more analytically each risk factor that interferes with the frequency of actions. Because different risk factors can be present in different combinations and degrees, it is possible to expect many levels of risk.

The level of risk is assessed with reference to the OCRA method (Colombini et al., 2002). The OCRA Index, when assessing a single repetitive task in a shift (monotask job), is given by the ratio between the foreseeable frequency **(FF)** of technical actions needed to carry out the task, and the reference frequency **(RF)** of technical actions, for each upper limb. This is a particular procedure for monotask jobs. For multitask jobs, one can refer to a specific annex (see also OCRA Index in ISO draft).

In this context, **OCRA Index = FF/RF**.

The foreseeable frequency (number per minute) of technical actions needed to carry out the task (**FF**) is given by the formula already reported in Table 13.1.

The following formula calculates the reference frequency (numbers per minute) of technical actions (**RF**) on a work cycle base:

$$RF = CF \times Po_M \times Re_M \times Ad_M \times Fo_M \times (Rc_M \times Du_M),$$

where:

CF = "constant of frequency" of technical actions per minute = 30,
$Po_M; Re_M; Ad_M; Fo_M$ = multipliers for the risk factors postures, repetitiveness, additional, force,
Rc_M = multiplier for the risk factor "lack of recovery period,"
Du_M = multiplier for the overall duration of repetitive task(s) during a shift.

When designing a machinery-related task, evaluate reference frequency of the technical actions within a work cycle that is representative of the task under examination. The analyses shall include the main risk factors that the designer can influence with the consequent choice of a specific multiplier for each risk factor. These multipliers will decrease from 1 to 0 as the risk level increases. The risk factors and the corresponding multiplier, influenced by the designer, are:

- Awkward or uncomfortable postures or movements (posture multiplier) (Po_M)
- High repetition of the same movements (repetitiveness multiplier) (Re_M)
- Presence of additional factors (additional multiplier) (Ad_M)
- Frequent or high-force exertions (force multiplier, Fo_M).

The other factors considered in the formula ($\mathbf{Rc_M \times Du_M}$) are generally out of the direct influence of the designer, and consequently they will be considered in this context as a constant, reflecting a common condition of repetitive task duration of 240 to 480 minutes/shift with two breaks of 10 minutes plus the lunch break. If other "daily repetitive task duration" or "breaks or recovery periods" scenarios are foreseen (less duration; more recovery periods) reference action frequency can be higher: Special tables are provided to this aim in an annex.

In practice, to determine the reference frequency (per minute) of technical actions (**RF**), proceed as follows:

- Start from CF (30 actions/minute).
- CF (the frequency constant) has to be weighted (by the respective multipliers) considering the presence and degree of the following risk factors: force ($\mathbf{Fo_M}$), posture ($\mathbf{Po_M}$), repetitiveness ($\mathbf{Re_M}$), and additional factors ($\mathbf{Ad_M}$).
- Apply the constant that considers the multiplier for repetitive task duration ($\mathbf{Du_M}$) and the multiplier for recovery periods ($\mathbf{Rc_M}$).
- The value obtained represents the reference frequency (per minute) of technical actions (**RF**) for the examined task in the common condition of at least two breaks of 10 minutes (plus the lunch break) in a shift of maximal 480 minutes.

Posture Multiplier (Po_M). If the conditions described in Method 1 for posture are present, the multiplier factor is 1. If those conditions are not present, use the indications in Table 13.2 for obtaining the specific multiplier.

At the end of the analysis of awkward postures, choose the lowest multiplier Po_M (that corresponds to the worst condition) between the posture and the movements of elbow, wrist, and hand (type of grip).

The designer, at this step, shall consider also shoulder postures and movements. To this end, the designer shall check that:

- The conditions in ISO EN 14738 and prEN 1005-4 are satisfied
- The arms are not held or moved at about shoulder level for more than 10% of cycle time (Punnett, Fine, Keyserling, & Chaffin, 2000)

If one of those two conditions occurs, a risk of shoulder disorders exists and should be accurately considered. However, at this moment there are no available data for identifying a

TABLE 13.2
Multiplier for Awkward Postures (Po_M)

	Portion of the Cycle Time			
Awkward Posture	*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 Pinch or Hook Grip or Palmar Grip (Wide Span)				
Elbow Pronation (≥60°) or Flexion/Extension (≥60°)				
Wrist Radioulnar Deviation (≥20°)	1	1	0.7	0.6
Hand Power Grip With Narrow Span (≤2 cm)				

specific Po_M for shoulders: Consequently Po_M for shoulders cannot be included in the OCRA computation procedure.

Repetitiveness Multiplier (Re_M). When the task requires the performance of the same technical actions of the upper limbs for at least 50% of the cycle time or when the cycle time is shorter than 15 seconds, the corresponding multiplier factor (Re_M) is 0.7. Otherwise Re_M is equal to 1.

Additional Multiplier (Ad_M). The main additional factors are (nonexhaustive list) use of vibrating tools, gestures implying countershock (such as hammering), requirement for absolute accuracy, localized compression of anatomical structures, exposure to cold, use of gloves interfering with handling ability, high pace completely determined by the machinery. If additional factors are absent for most of the task duration, the multiplier factor equals 1. Otherwise the additional factor multiplier Ad_M equals:

- 1 if one or more additional factors are present for less than 25% of the cycle time
- 0.95 if one or more additional factors are present for 1/3 (from 25%–50%) of the cycle time
- 0.90 if one or more additional factors are present for 2/3 (from 51%–80%) of the cycle time
- 0.80 if one or more additional factors are present for 3/3 (more than 80%) of the cycle time

Force Multiplier (Fo_M). If the criteria described in Method 1 are satisfied, the multiplier is 1. If these conditions are not met, use Table 13.3 to determine the force multiplier (Fo_M) that applies to the average level of force, as a function of time.

The force level (upper row) is given as a percentage of the Maximal Isometric Force (F_b) as determined in EN 1005-3 (step A). As an alternative, a value derived from the application of the CR-10 Borg-scale can be used (second row; Borg, 1998). Use a $Fo_M = 0.01$ when the technical actions require "peaks" above 50% of F_b or a score of 5 (or more) in CR-10 Borg scale for almost 10% of the cycle time. The values in the Table 13.3 can be interpolated if intermediate results are obtained.

Predetermined Value (Constant) for the Repetitive Task Duration Multiplier (Du_M) and the Multiplier for Recovery Periods (Rc_M). Because the multipliers (Du_M and Rc_M),

TABLE 13.3
Multiplier Relative to the Different Use of Force (Fo_M)

Force Level in % of F_b	*5*	*10*	*20*	*30*	*40*	*≥50*
CR-10 Borg Score	0,5 Very, very weak	1 Very weak	2 Weak	3 Moderate	4 Somewhat strong	≥5 Strong/very strong
Force Multiplier (Fo_M)	**1**	**0.85**	**0.65**	**0.35**	**0.2**	**0.01**

considered in the formula, are generally out of the direct influence of the designer, they are here considered as unique constant, reflecting a common condition as:

$Du_M = 1$ (multiplier for overall repetitive task duration of 240–480 minutes)
$Rc_M = 0.6$ (for a foreseeable presence of two breaks of 10 minutes and a lunch break in a repetitive task duration of 240–480 minutes per shift). Therefore: $(\mathbf{Rc_M} \times \mathbf{Du_M}) = \mathbf{0.6}$.

Final Evaluation by Method 2 and Criteria for Risk Reduction. For jobs with a single repetitive task, the OCRA Index is obtained by comparing, for each upper limb, the foreseeable frequency (FF) of technical actions needed to carry out the repetitive task and the reference frequency (RF) of technical actions, as previously calculated. Table 13.4 supplies the relevant values of the OCRA Index to assess the risk in relation to the 3-zone rating system (green, yellow and red) and to decide for consequent actions to be taken.

The criteria of Table 13.4 were defined in relation to the available literature regarding both the occurrence of UL-WMSDs in working populations not exposed to repetitive movements of the upper limbs and the association between OCRA Index and the prevalence of persons affected (PA) by (one or more) UL-WMSDs. Details about the procedure used for identifying the critical values of OCRA Index are given in a specific annex of the draft. In synthesis, on the basis of recent studies (Occhipinti & Colombini, 2004), the association between the OCRA Index (independent variable) and the prevalence of persons affected (PA) by one or more UL-WMSDs (dependent variable) can be summarized by the following simple regression linear equation:

$$\mathbf{PA} = \mathbf{2.39}\ (\pm\ \mathbf{0.14}) \times \mathbf{OCRA}.$$

On the other side, by using the PA variable in a reference not exposed population, reference limits were established starting from the 95th percentile (PA = 4.8%) as the "driver value" for the so-called green limit and from twice the 50th percentile (PA = 7.4%) as the "driver value" for the so-called red limit. Those "driver" values of PA expected in a reference working population (not exposed) have been compared with the regression equation at the level corresponding to the 5th percentile: 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 discriminating green, yellow, and red areas as reported in Table 13.4.

In practice:

- The green limit means that, just above that level, in the exposed working population are forecasted, almost in 95% of cases, PA values higher than the 95th percentile (PA = 4.8%) expected in the reference (not exposed) population.

TABLE 13.4
Classification of OCRA Index Results for Evaluation Purposes

OCRA Risk Index	*Zone*	*Risk Evaluation*
≤2.2	Green	Acceptable
2.3 to 3.5	Yellow	Conditionally acceptable
>3.5	Red	Not acceptable

- The red limit means that, just above that level, in the exposed working population are forecasted, almost in 95% of cases, PA values higher than twice the 50th percentile expected in the reference (not exposed) population.

Annexes

The prEN 1005-5 draft is completed by the following annexes:

- Annex A (informative): Identification of technical action
- Annex B (informative): Posture and types of movements
- Annex C (informative): Force
- Annex D (informative): Association between the OCRA Index and the occurrence of UL-WMSDs: criteria for the classification of results and forecast models
- Annex E (informative): Influence of recovery period and work time duration in determining the overall number of reference technical actions within a shift (RTA) and, consequently, the OCRA Index
- Annex F (informative): An application example of risk reduction in a monotask analysis
- Annex G (informative): Definition and quantification of additional risk factors
- Annex H (informative): Risk assessment by Method 2 when designing multitask jobs

ISO CD 11228-3

Hazard Identification

When determining whether hazard is present, attention should be given to the following factors: Repetition, Posture and Movement, Force, Duration and Insufficient Recovery, Additional Risk Factors (Object Characteristics, Vibration, Impact Forces, Environment, Work Organization, and Psychosocial Factors). For each factor, a brief statement explains when it is to be considered as a hazard.

Simple Risk Assessments

This method is useful for performing a simple assessment of monotask jobs. The risk-assessment procedure uses a specific checklist and evaluation model given in an annex.

There are four parts in the estimation procedure: (Part A) preliminary information describing the job task, (Part B) hazard identification and risk estimation checklist, (Part C) overall evaluation of the risk, and (Part D) remedial action to be taken.

The checklist adopts a six-step approach taking into account the four primary physical risk factors (repetition, high force, awkward posture and movements, and insufficient recovery) as well as any other additional risk factors that may be present. Initial consideration is given to the prevalence of work-related health complaints or work changes that may have been implemented by the operator or supervisor.

As a result of the overall classification of risk (Part C), the following action should be taken:

Green Zone: No action is required.
Yellow Zone: The risk shall be further estimated, analyzed together with contributing risk factors, and followed as soon as possible by redesign. Where redesign is not possible, other measures to control the risk shall be taken.
Red Zone: The work could be harmful. It is advisable to evaluate more accurately the task by Method 2. Action to lower the risk (e.g., re-design, work organization, and worker instruction and training) is necessary.

Risk Evaluation by Detailed Method

If the risk assessed by Method 1 is in the yellow or red zone, it is recommended to perform a more detailed risk assessment also for a better choice and follow-up of the remedial measures to be taken. If the job is composed of two or more repetitive tasks (multitask job), it is recommended to use the present method.

The risk evaluation is performed using the same procedures (OCRA method) presented for the prEN 1005-5 draft: The only relevant difference regarding the fact that here, as in the original OCRA method, the actual number of technical actions (ATA) carried out during the work shift and the number of reference technical actions (RTA; for each upper limb) are directly computed taking into account multipliers for "daily duration of repetitive work" and "recovery periods." In practice, the OCRA Index is given by the fomula:

$$\textbf{OCRA Index} = \frac{\text{number of technical actions actually carried out in the shift } \textbf{(ATA)}}{\text{number of reference technical actions in the shift } (\textbf{RTA})}.$$

The overall actual number of technical actions carried out within the shift (ATA) can be calculated multiplying F_j for the net duration (D_J in minutes) of each repetitive task/s analyzed and summing the results of each repetitive task.

$$\mathbf{ATA} = \Sigma(\mathbf{F_j} \times \mathbf{D_j}),$$

where:

D_j is the net duration (in minutes) of the task j;
F_j is the frequency of actions per minute of task j.

The following general formula calculates the overall number of *reference* technical actions within a shift: RTA

$$\mathbf{RTA} = \sum_{\mathbf{J=1}}^{\mathbf{n}} [\mathbf{CF} \times (\mathbf{Fo_{Mj}} \times \mathbf{Po_{Mj}} \times \mathbf{Re_{Mj}} \times \mathbf{Ad_{Mj}}) \times \mathbf{D_j}] \times (\mathbf{Rc_M} \times \mathbf{Du_M}),$$

where:

n = number of repetitive task/s performed during the shift.
j = generic repetitive task.
CF = "constant of frequency" of technical actions per minute = 30.
$Fo_{Mj}; Po_{Mj}; Re_{Mj}; Ad_{Mj}$ = multipliers for the risk factors, force, postures, repetitiveness, additional in each j repetitive task.
Dj = net duration (in minutes) of the repetitive task j.
Rc_M = multiplier for the risk factor "lack of recovery period."
Du_M = multiplier according to the overall duration of all repetitive tasks during a shift.

All the multiplier factors are identical to those given in prEN 1005-5, with the exception of the Rc_M and Du_M multipliers that are determined by the criteria given in the following and detailed in Table 13.5 and Table 13.6.

TABLE 13.5
Elements for the Determination of the Recovery Period Multiplier (Rc_M)

Number of Hours Without Adequate Recovery	0	1	2	3	4	5	6	7	8
Multiplier Rc_M	1	0.90	0.80	0.70	0.60	0.45	0.25	0.10	0

TABLE 13.6
Elements for the Determination of the Duration Multiplier (Du_M)

Total Time (in Minutes) Devoted to Repetitive Tasks During Shift	<120	120–239	240–480	>480
Duration Multiplier Du_M	2	1.5	1	0.5

Recovery Period Multiplier (Rc_M)

A recovery period is a period during which one or more muscle–tendon groups are basically at rest.

The following can be considered as recovery periods:

1. Breaks (official or non official) including the lunch break
2. Visual control tasks
3. Periods within the cycle that leave muscle groups totally at rest consecutively for at least 10 seconds 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 8 to 10 minutes consecutively or, for working periods lasting less than 1 hour, in a ratio of 5:1 between work time and recovery time.

In relation to these reference criteria, it is possible to consider how many hours, during 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 working shift: For each hour, a check must be made if there are repetitive tasks and if there are adequate recovery periods. 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 counted: Conseqently it is possible to determine the Rc_M multiplier according to Table 13.5.

Overall Duration of Manual Repetitive Tasks and Duration Multiplier (Du_M). Within a working shift, the overall duration of manual repetitive tasks is important to determine the overall risk for upper limbs. When repetitive manual tasks last for a relevant part (4 hours or more) of the shift, the Du_M is equal to 1. In some contexts, however, there may be differences with respect to this more "typical" scenario (e.g., regularly working overtime, part-time work, and repetitive manual tasks for only a part of a shift); the multiplier (Du_M) considers these changes with respect to usual exposure conditions. Table 13.6 gives the values of Du_M in relation with the overall duration of manual repetitive tasks.

Risk Index Calculation and Risk Evaluation. The OCRA Index is obtained by comparing, for each upper limb, the ATA carried out during the work shift and the RTA.

The risk classification criteria (green, yellow, and red) are identical to those given in prEN 1005-5 and reported in Table 13.4.

Annexes

The ISO CD 11228-3 draft is completed by the following annexes:

- Annex A (informative): Method 1. Simple risk assessment
- Annex B (informative): Details on the OCRA method as used in this Standard (similar to most of annexes in prEN 1005-5)
- Annex C (informative): Risk reduction
- Annex D (informative): Scientific evidence

REFERENCES

Borg, G. A. V. (1998). *Borg's Perceived Exertion and Pain Scales*, Human Kinetic Europe.

CEN. (2004). PrEN 1005-5: Safety of machinery—Human physical performance—Part 5: Risk assessment for repetitive handling at high frequency. *Doc CEN/TC 122/WG4/Version 04/2004*.

Colombini, D., Grieco, A., & Occhipinti, E. (Eds). (1998). *Occupational musculo-skeletal disorders of the upper limbs due to mechanical overload. Ergonomics 41*(9) (Special Issue).

Colombini, D., Occhipinti, E., Delleman, N., Fallentin, N., Kilbom, A., & Grieco, A. (2001). Exposure assessment of upper limb repetitive movements: A consensus document. In W. Karwowski (Ed.), *International Encyclopaedia of Ergonomics and Human Factors* (pp. 52–66). London and New York: Taylor and Francis.

Colombini, D., Occhipinti, E., & Grieco A. (2002). *Risk assessment and management of repetitive movements and exertions of upper limbs: Job analysis, Ocra Risk Index, prevention strategies and design principles* (Vol. 2). Elsevier Ergonomics book series. Amsterdam: Elsevier.

Hagberg, M., Silverstein, B., Wells, R., Smith, M. S., Hendrick, H. W., Carayon, P., et al. (1995). *Work-related musculoskeletal disorders. A reference book for prevention.* I. Kuorinka & L. Forcier (Eds.), London/Philadelphia: Taylor and Francis.

Keyserling, W. M., Stetson, D. S., Silverstein, B., & Brower, M. L. (1993). *A checklist for evaluating ergonomic risk factors associated with upper extremity cumula tive trauma disorders. Ergonomics 36*, 807–831.

ISO CD 11228-3. (2004). Manual handling. Part 3: Handling of low loads at high frequency. *ISO/TC 159/SC3/ Version 07/2004.*

NIOSH, Center for Diseases Control and Prevention. (1997). *Musculoskeletal disorders and workplace factors. A critical review of epidemiologic evidence for WMSDs of the neck, upper extremity and low back* (second printing). Cincinnati: U.S. Department of Health and Human Services.

Occhipinti, E. (1998). OCRA, a concise index for the assessment of exposure to repetitive movements of the upper limbs. *Ergonomics*, *41*(9), 1290–1331.

Occhipinti, E., & Colombini, D. (2004). *Metodo OCRA: Aggiornamento dei valori di riferimento e dei modelli di previsione dell'occorrenza di UL-WMSDs nelle popolazioni lavorative esposte a movimenti e sforzi ripetuti degli arti superiori*. La Medicina del Lavoro, *95*(4), 305–319. Milano (JT).

Punnett, L., Fine, L. J., Keyserling, W. M., & Chaffin, D. B. (2000). Shoulder disorders and postural stress in automobile assembly work. *Scandinavian Journal of Work Environ Health*, *26*(4), 283–291.

Schneider, S. (1995). OSHA's draft standard for prevention of work-related musculoskeletal disorders. *Appl. Occup. Environ. Journal*, *10*(8), 665–674.

Silverstein, B. A., Fine, L. J., Armstrong, T. J. (1987). Occupational factors and carpal tunnel syndrome. *American Journal of Industrial Medicine*, *11*, 343–358.