Ergonomics evaluation tools for Physical Workload: the OCRA method to evaluate risks for the upper limbs in relation to relevant European Directive.

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Abstract. Various machine-related actions require repetitive handling at high frequency, which causes musculoskeletal strain and the risk of fatigue, discomfort and musculo-skeletal disorders. The designer of a machine should seek to minimise these health risks by taking into account a variety of risk factors including the frequency of actions, the force, postures, duration, lack of recovery and other additional factors .
This standard has been prepared to be a harmonized standard as defined by the Machinery Directive and associated EFTA regulations: fit presents a risk assessment method intended for risk reduction.

L Introduction

Within the life cycle of a machine various machine-related actions require repetitive handling at high frequency, which causes musculoskeletal strain and the risk of fatigue, discomfort and musculo-skeletal disorders. The designer of a machine should seek to minimise these health risks by taking into account a variety of risk factors including the frequency of actions, the force, postures, duration, lack of recovery and other additional factors .

The risk assessment method in this standard gives guadante to the designer how to reduce health risks for the operator.

This standard has been prepared to be a harmonized standard as defined by the Machinery Directive and associated EFTA regulations.

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 intended for risk reduction.

This standard applies only to designers of machinery and assembly lines for professional use operateti by the aduli working population.

2. **General recommendations**

Machines and related tasks shall 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 presente of recovery periods. In addition machines and related tasks shall be designed to alloca for variations in movements. Additional factors (like vibration ,cold, etc.), have to be considered.(Colombini,2000; Hagberg,1995; Silverstein ,1987;Schneider, 1987)

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 unii of time .

When designing machinery and work tasks ,the designer shall ensure that some ergonomics characteristic of well-designed work tasks are carried out: these characteristics take finto account the differences and dynamic characteristics of the intended operator population, and shall be pursued by designing machinery and work tasks in interaction.

3. Hazard identification

The adeguate 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

The risk evaluation of upper limbs WMSDs using machinery shall be considered in designing machinery and its relative task/s. The designer shall preliminarly performs a " hazard identification" to decide if to continue with a risk estimation. The " no hazard" option is present when machinery and the related task imply: no cycles or a cycle task in which perceptual of cognitive activities are clearly prevalent. For all the machinery/ 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 and frequency of recovery periods; consider the possibility of rotation on different tasks, when designing a machinery in the context of an assembly lire.

3. Simply risk estimation of machinery design (Method 1)

In Method 1 the presene of acceptable characteristics for all of the considered risk factors is verified. When the characteristics described are fully and simultaneously present, fit is possible to affirm that risk exposure to repetitive movements at high frequency 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 (Method 2). The lisi of acceptable characteristics of the risk factors are listed in table I.

***Tablel:** Lisi of acceptable characteristics of the risk factors*

LABSENCE OF FORCE, OR USE OF FORCE AT THE SAME CONDITIONS EXPOSED IN EN 1005-3
the values of the isometrie force to carry out the actions are 50 % of the values proposed for 15[1h] force percentile for professional use in the healthy aduli European population. Actions do not imply fast movements. The frequency of actions with force is equal to, or less than, 0.2 [min -'] and the action time is equal to, or less than, 0.05 min. The working time in similar actions is equal to, or less than, ore hour.
2.ABSENCE OF AWKWARD POSTURES AND MOVEMENTS AS EXPOSED IN PREN 1005-4
The upper arm elevation is egual to or less than 20 °. The articular movements of the elbow and wrist do not exceed 50 % of the maximum articular range (Drury 1987). The kinds of grasp are "power grip", or "pinch lasting not more than 1/3 of the cycle time" (Colombina ,2002; Eastman , 1983).
3.LOW REPETITIVENESS.
The cycle time is more than 30 seconds (Silverstein, 1987).
The cycle time is more than 30 seconds (Silverstein, 1987)..

4.FREQUENCY OF UPPER *LIME* ACTIONS (FOR EACH ARM) NOT HIGHER THAN 30 ACTIONSMN
5.ABSENCE OF ADDITIONAL FACTORS (PHYSICAL AND MECHANICAL FACTORS).

4. Analytical model for evaluating the adequacy of tasks and work platea: an application of OCRA method (method 2)

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

The evaluation of the acceptable frequency in a task, necessitates the introduction of multiplier factors specific to each risk factor considered: they will be stricter as the risk level increases (in this case the values of multiplier factors become closer to zero).

The multiplier factors described in detail below are for the following risk factors: awkward postures, force, additional factors. Multiplying the referente frequency of action (30) by the multiplier factors, it is possible to obtain respect the acceptable action frequency, suitable for operating the designed machinery even for the duration of 240-480 minutes of the task during the shift with at least 2-3 usual breaks of 7-10 minutes in a shift.

4.1 Posture Factor (Pol)

If the conditions described in method 1 for posture are present, the multiplier factor is I. If those conditions are not present, use the indications below for obtaining the specific multiplier factor:

Table 2: ***Multiplier factor for awkward postures***

	PREVALENCE IN THE CYCLE TIME		
AWKWARD POSTURE	113	213	313
ELBOW SUPINATION (+ 60 °) WRIST EXTENSION (+ 45 PALMAR GRIP HOOK GRIP	0.7	**0.5**	0.33
ELBOW PRONATION(+ 60 °) ELBOW FLEXION (+ 60 °) WRIST FLEXION (45 °) RADIO-ULNAR DEVIATION (+ 20 °) PINCH TIGHT GRIP	1	**0.6**	**0.5**

At the end of the analysis of awkward postures choose from the table 2 the lowest multiplier factor (PoF) corresponding to the worst condition.

The designer, at this step, shall consider allo shoulder postures and movements.

To this end the designer shall check that:

- the arm(s) is maintained or moved quite at shoulder level (about 80° or more) for no more than 10 % of cycle time and/or no more than 2 actions per minute involving extreme arm elevation (flexion or abduction at about 80 ° or more) are needed [17].
- the arm(s) is maintained or moved in mild elevation (flexion or abduction between > 20 and about 80 °) for no more than 1/3 of cycle time and/or no more than 10 actions per minute involving mild arra elevation are needed.

4.2 Repetitiveness factor (Ren

When the task requires the performance of the saure working gestures (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 (ReF) is 0.7.
Otherwise ReF is equal to I.

4.3 Additional facto (AdF)

If they are not present, or satisfy the conditions described in Method 1, the multiplier factor is I. Otherwise use the following outlines, each with a different multiplier factor.
0.95 One or more additional factors are present simultaneously for 1/3 of the cycle time.
0.90 One or more additional factors are present simultaneously for 2/3 of the cycle time.
0.80 One or more additional factors are present simultaneously for 3/3 of the cycle time.

4.4 Force Factor (Fon

If the criteria described in Method 1 are satisfied, the multiplier factor is I. If other conditions with use of force are given, use one of the following multiplier factors relative to the different use of force, considering the average level as a function of time.

The use of force is given as a percentage of maximum referente capacity of the target population (x) as referred to in EN 1005-3 or as a percentage of Maximum Voluntary Contraction (MVC) (y) or according to CR-10 Borg Scale values *(z)*

Table 3: Multiplier factor relative to the different use of force

% of force (X or Y)	5	10	20	30	40	> 50
CR-10 Borg Score (Z)	0.5 very, very weak	1 very weak	2 weak	3 moderate	4 somewhat strong	> 5 strong/very strong
Force Factor	**1**	**0,85**	**0,65**	**0,35**	0,2	**0,01**

Use a *FoF = 0,01* when technical actions require 'peaks' above 50 % of force or a score 5 in Borg scale for 10 % (or more) of the cycle time.

It is possible to use intermediate multiplier factors when intermediate average levels of force are estimated .

4.4 Final evaluation by Method 2

To calculate acceptable *(AF)* frequency of actions use the following formula (suitable for operating the designed machinery even for the duration of 240-480 minutes of the task during the shifi with at least 2-3 usual breaks of 7-10 minutes in a shiîi) :

AF = 30 *x PoFx ReFx AdFx FoF*

The acceptable frequency *(AF)* is defined in relation to the available literature regarding the occorrente of upper limb WMSDs in different working population not exposed to repetitive movements of the upper limbs (Colombina et al, 2002).

When the designer has already defined the number (for each upper limb) of technical actions (NTC) and the foreseen duration of the cycle time (FCT), at is possible to calculate the foreseeable frequency of actions/minute (FF) according to the formula:

FF = (NTC x 60)/FC

where : FF = foreseeable frequency of actions per minute; FCT = foreseeable duration of the cycle time in seconds; NTC = number of technical actions (for each upper limb) needed to carry out the task.

Comparing FF and AF it is possible to obtain a risk index (RI = FF/AF) for evaluation purposes according the criteria exposed in table 4:

Table 4. Risk index and its evaluation

RI	Traffie tight area	Risk evaluation
< i	Green	Acceptable
1.01-1.74	YCHOW	Conditionally acceptable
> 1.75	Red	Not acceptable

Every **RI** area corresponds to a different forecast of the upper limbs WMDSs occurrence in the adult working population .

5. Conclusion

The acceptable frequency is so defined in relation to the available literature regarding the occurrence of upper limb WMSDs in different working population noi exposed to repetitive movements of the upper limbs When the designer has already defined the number (for each upper limb) of technical actions and the foreseen duration of the cycle time, it is possible to calculate the foreseeable frequency of actions/minute. Comparing the real frequency and the acceptable frequency it is possible to obtain a risk index (RI).

Every **RI** area corresponds to a different forecast of the upper limbs WMDSs occurrence in the adult working population (Colombini et al.2000).

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