HANDBOOK OF HUMAN FACTORS AND ERGONOMICS METHODS

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The Handbook of Human Factors and Ergonomics methods will be a single compreliensive text that explains how ergonomics methods work, along with providing practìcal examples. The Handbook will include approxlmately 90-100 methods, covening the assessment and measurement of physìcal, environmental, physiologìcal, psychological, social and organisational phenomenon. Each member of the editorial team has responsibility for one area, as shown above. Each arca wili cover around 15 methods. Each contributor W111 wrIte an entry that describes the method compn'sing: background, applications, procedure, a worked example, related methods, standards, apprommate training and application times, rellabifity and validity, costs, tools needed, related methods, annotated bìbliography. The average length of a contribution wìll be around 2500 words - double spaced). Electronic subinissions in Microsoft Word will be encoumged.

The Handbook will be delivered to Taylor and Francis by November 2002, for publication in early 2003. The proposed coverage of the book is listed below. These heading are generai and authors will be able to tailor content to a specific method or methods within the topic arca.

Professor Alan Hedge (PHYSICAL METHODS)

l. Perceived exertion - Borg scale
2. Posture Targeting Rapid Upper Limb Assessment (RULA)
3. Posture Targeting Rapid Upper Limb Assessment (REBA)
4. Ovako Working Posture Analysis Tool (OWAS and Win OWAS)
5. Occupational Repetitive Actions Index (OCRA)
6. Standardized Nordic Questionnaire (SNQ)
7. Discomfort surveys NIOSH questionnaire
8. Dutch MS Questionnaire
9. Moore-Garg Strain index
10. Posture checklists (PDA)
11. Quick Exposure Checklist (QEC)
12. Rodgers Muscle Fatigue Assessment
13. Predictive models - NIOSH lifting equation
14. Snook tables (pushing, pulling, lifting etc.)
15. Dynarnic work analysis methods

The occupational repetitive action OCRA methods: OCRA index and OCRA cheeklist.

The OCRA methods have been progressively developed by Colombini and Occhipintì beginning in 1996 (Occhipinti et al, 1996).
The purpose of the methods is to analyse the exposure of workers to tasks featurina repetitive movements of the upper lìmbs, taking into account various risk factors (repetitiveness, force, awkward postures and movements, lack of recovery periods and others, defined as "additionals").
The techniques for analysing the different factors are largely based on a consensus document of the TC on Musculoskeletal Disorders by the International Ergonon-úcs Association (IEA) (Colombìni et al. 2001).
In comparison with this document, the OCRA methods generate synthetic indicators that also take into consideration the rotation of workers among different tasks and work stations.
The indexes, particularly the OCRA index, have to some extent turned out to be predictive of the risk of U.E. WMSDs in exposed populations.
The first method to be developed was the OCRA index, which is without a doubt the more analytical and complex of the two, but also the most reliable in terms of the results; today it is generally used for the design, redesign or in-depth analysis of workstatíons and tasks. (Colombini et al, 1998, 2002).

Later the same methodological approach was used to develop and test the OCRA checklist, which is simpler to apply and is generally recommended for the initial screening of work stations featuring repetitive tasks (Colombini et al, 2000, 2002).

Both OCRA methods are observational, in that they do not entail the use of sophisticated measuring instruments, and are largely designed to be used by corporate technical specialists (OSH operators, ergonomists, time and methods analysts, production engineers), who have proven in practice to be best suited to leaming and applying the methods for prevention and also for improving produetion processes in general.

The methods have been applied in a wide cross section of industrics and workshops where repetitive manual jobs are performed (manufacture of mechanical components, electrical appliances, automobiles, textiles and clothing, meat and food processing, ceramics, jewellery). It has been estimated that in Europe there are currently more than 5,000 jobs that fit these categorics involving over 20,000 employees.

The methods were designed to be applied to any jobs in manufacturing and the service sector that involve repetitive movements and/or efforts of the upper limbs, however they are not suitable for assessing jobs that use a keyboard and mouse, or other computerizcd data entry tools.

Procedures

General aspects

The two assessment methods are aimed at evaluating four main coliective risk factors considering respective duration repetitiveness, force, awkward posture and movements, lack of proper recovery periods.
In addition to these factors, others, grouped under the term "additional factors", should

be considered: these are mechanical , erivirorimental and organisational factors for which there is evidence of causai relationship with UE WMSDs.

Each identified risk factor is to be properly described and classified This allows to identify possible requirements and preliminary preventive intervention for each factor and to consider ali the factors contrìbuting to the overall "exposure" in a generai and mutually integrated frame.

To this end, the following definitions are important:

— The work (job) is composed of one or more tasks in one work shíft;
— within a single task, cycles are sequences of technical actions which are repeated over and over, always the same.
— within each cycle, several technical actions can be identified. These are elementary operations that enable the completion of the cycle operational requirements (i.e :take, piace, tum, push, pull, replace ...)

The suggested procedure for assessing the risk should follow the generai phases listed bercunder:

— pinpointing the repetitive tasks characterised by cycles with significant lengths of time,-
— finding the sequence of technical actions in a representative cycle of each task;
— describing and classifying the risk factors within each cycle
— assembly of the data concerning the cycles in each task during the whole work shift, taking into consideration the duration and sequences of the different tasks and of the recovery periods,-
— brief and structured assessment of the fisk factors for the job as a whole (exposure or risk index).

lhe OCRA Risk Index

The OCRA index is the result of the ratio between the number of technical actions actually carried out during the work shift, and the number of technical actions which is specifically recommended.

In practice, OCRA = $\frac{\text{Overall n' of technical actions carfied out in the shift}}{\text{Overall n' of technical actions recommended in the shift}}$

The technical actions should not be identified as the joint movements. To make action frequency analysis more accessible, a conventional measurement unit has been chosen, the *"technical actiotì'* of the upper limb. This definition is very similar to the MTM elements (Bames 1968).

The overall number of technical actions carried out within the shift (ATA) can be calculated by organisational analysis (n' of actions per cycle, n° of actions per n-únutes and this last multiplied for the net duration of the repetitive task/s analysed to obtain ATA).

The following generai formula calculates the overall number of technical actions recommended within a shift (RTA):

$$\text{N' Recommended technical actions} \quad \sum_{x=1}^{n} [CF \times (Ffi \times Fpi \times Fci) \times Di] \times Fr \times Fd$$

where n =nuniber of repetitive task/s performed during shift

ì = generic repetitive task

CF = frequency constant of technical actions (30).

Ff; Fp; Fc = multiplier factors with scores ranging from 0 io I. selected for "force' (Ff), "posture" (Fp) and "additional elements" (Fe) in cacb of tbc (n) tasks-,

D = net duration in "nutes of cach repetitive task.
Fr multiplier factor for lack of recovery perio«'
Fd multiplier factor according to the daily duration of repetitive tasks..

In practice, to determine the recommended overall number of actions within a shift (RTA), proceed as follows:

I. for each repetitive task, start from CF (30 actions/minute).
2. for each task, the frequency constant must be corrected for the presence and degree of the following risk factors: force, posture and additional.
3. multiply the weighted frequency, for cach task by the number of minutes of each repetitive task .
4. sum up the values obtained for the different tasks
5. the resulting value is multiplied by the multiplier factor for recovery periods.
6. apply the last multiplier factor that considers the total time spent in repetitive tasks
7. the value thus obtamed represents the total recommended number of actions (RTA) in the working shift.

A brief illustration and discussion follows reviewing the criteria and procedures involved in the determínation of the Ocra index calculation variables. For more operative details refer to the handbook prepared by the authors(Colombini et al. 2002).

I. <u>The action frequency constant (CF)</u> The literature, albeit not exphcitly, supplies suggestions of "linút" action frequency values, and these range from 10 to 25 actions/movements per minute.

On the basis of the above and practical considerations of the applicability of these proposals in the work place, the action frequency constant (CF) is fixed at 30 actions per minute.

<u>11. Force factor (Ff)</u> Force is a good direct representation of the biomechanical comn-útment which is necessary to carry out a given technical action, or sequence of actions.

It is difficult to quantify force in real working environments: for overcoming this difficulty one could recourse to the BorgIO Category Scale for the Rating of Perceived Exertion (Borg 1982).

Once the actions requiring exertion have been determined, operators will be asked to ascribe to each one(or homogeneous group) of them a progressive score from 1 to 10

The calculation of the average exertion weighted over time involves multiplying the Borg Scale score ascribed to each action by its percentage duration within the cycle: the partial results must then be added together.

When choosing the multiplier factor, it is necessary to refer to the average force value, weighted by cycle duration

<u>111. Postural factor (Fp).</u>

The description/assessment of the postures must be done over a representative cycle for each one of the repetitive tasks examined. This must be via the deseription of duration of the postures and/or movements of the four main anatomical segments (both right and lefi):shoulder, elbow, wrist and hand.

For classification purposes, it ìs enough to see that, within the execution of every action, the joint segment involved reaches an excursion greater than 50% of joint range for at least 1/3 of the cycle time: more the time, higher the score.

It is to be established the presence of stereotypy of certain movements which can be pinpointed by observing technícal actíons which are all equal to each other for at least

50% of cycle time or by a very short duration of the cycle (less than 15 seconds). The presence of the stereotypy increases scores to the joìnts involved.

All of these elements together lead to the design of a useful scherne to identify the values of the posture multiplier factor (Fp).

IV. "Additional elements" factor (Fc) .. They are defined as additional not because they are of secondary importance, but because cach one of them cari be present or absent in the contexts exaniined.

The list of these factors is not exhaustive and includes: the use of vibrating tools requirement for absolute accuracy ; localised compressions; exposure to cold or refrigeration,- the use of gloves which interfere with the required handling ability; objects handled liave a slippery surface; sudden movements, or "tearing", "ripping" movements, or fast movements; the repetìtive impacts (e.g., hammering, hitting, etc.).

There are some factors (psycho-social), that are concerned with the individual spliere, and cannot be included in methods considering a collective and occupational type of exposure: there are other factors definable as organisational (working pace determined by machine, working or moving object), which should be taken into consideration.

For every additional factor indicated, variable scores can be assigned according to the type of risk presence and duration.

V. "Recovery periods" factor (Frì A recovery period is a period during whìch one or more muscle-tendon groups are basically at rest.

The following cari be considered as recovery periods:

1 breaks including the lunch break
2. visual control tasks
3. pen'ods within the cycle that leave muscle groups totally at rest consecutively for at least 10 seconds almost every few minutes.

Using the indications supplied by some standards as a starting point , in case of repetitive tasks it is advisable to liave a recovery period every 60 minutes, with a ratio of 5 work: 1 recovery.

On the basis of this optímal distrìbution, it is possible to design criterìa to evaluate the presence of risk in a concrete situation: the overall risk is determined by the overall number of hours at risk.

For every hour without an adeguate recovery period, there is a corresponding multiplier factor.

VI. Duration factor (Fd) Within a working shift, the overall duration of tasks with repetitive and/or forced upper limb movements is important to determine overafi exposure. The index calculation model is based on scenarios where repetitive manual tasks continue for a good part (6-8 hours) of the shift.

The Table l supplies the necessary parameters for dealing with afi the multiplier factors and calculate before the recommended teclmical actions and after the Ocra index, The table IB reports some examples of Ocra index calculation in redesigning tasks.

Classification of OCRA index results

The studies and experiments carried out allow to identify different exposure areas (green, yellow and red) with key OCRA scores

By considering the trend of L'E WMSDs in reference to working populations which are not exposed to specific occupational risks, ìt is possible to define the following OCRA index classification criteria and to indicate the consequent preventive actions to be adopted:

I. the index values lower or equal to 1 mean full acceptability of the condition exanimed (green arca);
2- index values between 1 and 2 (yellow/green area) mean that exposure is still not relevant or not enough to foresee significant excesses in the occurrence of UE-WMSDs in the exposed group versus the reference groups
3. index values between 2.1 and 3.9 (yellow/red area) mean that exposure is not severe, but that there could be higher disease levels in the exposed groups with respect to a reference group of non-exposed. In these cases, it is advisable to introduce health surveillance, health education and training, and procecd to an improvement of working conditions.
4. Index values equal to, or greater than 4.0 (red area) mean significant exposure levels Working conditions must be improved in these and close monitoring of all effects must be set up.

The OCRA check-hst

The analysis system , suggested with the check-list. begins with the establishment of pre-assigned scores, for each of the 4 main risk factors (recovery periods, frequency, force, posture) and for the additional factors.
The sum total of the partíal values obtained in this way produces a final score which then enables the estimation of the actual exposure level,

The check-Iist descn'bes a work-place and estimates the intrinsic level of exposure, as if the work-place is used for the whole of the shift by one worker. This procedure makes it possible to find out quickly which work-piaces, in the company, imply a significant exposure level, being classified as "absent", "light", "medium", "high".
In a second stage it is possible to estimate the exposure indexes for the operators considering their rotation or$_i$ the different work places and applying the following formula:

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

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

The Table 2A presents the contents of the checklist for each risk factor and the corresponding scores: the more the risk, the hìgher the score. The tables 2B and 2C report a example of map of risk for an assembly line, for a department and for the all work places in a Company.

Since the numerical values indicated in the check-list have been calibrated to the multiplier factors supplied for calculation in the more exhaustive OCRA exposure índex, the final check-list value cari be interpreted in terms of its correspondence to the OCRA values.

CHECK LIST score	OCRA índex	EXPOSURE LEVEL	
UP TO A 6 6.1-11.9 12-18.9 >19	2 2.1-3.9 4-7.9 > 8	GREEN, YELLOW/GREEN YELLOWIRED RED VERY RED	= NO EXPOSURE = LOW EXPOSURE = MEDIUM EXPOSURE = HIGH EXPOSURE

1f the repetitive task lasts less than 6 hours within one shift (part-time work) it is possible to correct the value obtained according to actual duration. .

Advantages

The advantages of the two methods are, respectìvely, the following:

OCRA INDEX		OCRA CHECKLIST
Provides a detailed analysis of the main mechanical and organisational determinants of the fisk for U.E. WMSDs		Purely observational, easy and quick to use
Linked with mtm analysis and subsequent task design: language easily understood by technicians		Produces scores related to exposure level (green, yellow, red, very red)
Predicts (witl-ùn set limits) health effects (U.E **WMSDs)**		Produces an 4'exposure map" in the production unit referred to the total population and to males/females separately
C'ompares different work contexts (also pre/post intervention): can simulate different design or re-design solutions of the work place and job organisation		Useful for setting prioritics and planning job rotations, and for assessing previous exposures in relatìon to legal problems.
Considers all the repetitive tasks involved in a complex (or rotating) job, and estimates the worker's exposure risk level		Considers all the repetitive tasks involved in a complex (or rotating) job estimating the worker's exposure risk level

Disadvantages

The disadvantages of the two methods are, respectively, the follovving:

OCRA INDEX	OCRA CIHECKLIST
Can be time consumìng, especially for complex tasks and multiple-task jobs	Allows only a preliminary analysìs of the main risk determìnants with a pre-set overestimation
Value of multiplier factors determined using non- homogeneous approaches and data from the literature	Allows only an estimation of exposure per risk areas (green, yellow, red, very red) and not a precise risk evaluation (as per the OCRA index)
Initially difficult to learn the concept of "technical action" unless familiar with rntrn analysis	lf observers are not well trained, there is possibility of misclassiffing the risk factors
Does not consider all psychosocial factors related to the individuai sphere	Does not consider all psychosocial factors related to the individuai sphere
Requires a video camera (preferably digital) for performing the analysis in slow motion	Not useful for analytical design or redesign of tasks and workpIaces (for that purpose the OCRA index is preferable)

Related methods

The OCRA methods are based on and enlarge upon the indications contained in the IEA T.0 Musculoskeletal Disorders document entitled "Exposure assessment of Upper Limb Repetitive Movements : a consensus document" (Colombini et al., 2001).

Where the frequency of the technical actions of the upper limbs is analyzed, in the OCRA index approach there is a specific connection with the concepts envisioned in the Motion Time Measurament (MTM) method (Barnes,1968), whereas in the case of the OCRA checklist, there are similarities vAth a proposal put forward by a group of researchers from the University of Michigan, whìch was incorporated in the Hand Activity Level (HAL) proposed by the AICGH (2000).

The OCRA index compares a real variable (Le. the number of technical actions performed with one limb during the shift) with the corresponding recommended one, and was developed according to concepts similar to those of the Lifting Index method proposed by NIOSH (Waters et al. 1993).

Standards and regulations

The European Council Directive 89/331/EEC 'Introduction of measures to encourage improvements in the safety and health of workers at work" which is a framework directive that has been incorporated in the legislation of all the European State Members, requires, among others, employers to undertake a "risk assessment". Specifically the directive states that " the employers shall... evaluate the risks to the safety and health of workers._subsequent to this evaluation and as necessary, the preventive measures and the working and production methods implemented by the employer must assure an improvement in the level of protection— "

The OCRA methods, at different levels, are tools tailored for the assessment and management of risks associated with U.E. **WMSDs.**

Another European directive, n. 98/37/EEC and relevant modificafions, sets forth essential safety and ergonornic requirements in the design, construction and marketing of new machínes. The directive has given rise to the production by the European Committee for Standardization (CEN) of a large number of technical standards aimed at verifying compliance with these requirements. Among these standards, those belonging to the ENI005 series concem the use of manual force on machinery. Standard 1005-5, still in the draft stage, concems manual activities featuring low force and high frequency. The current draft is largely based on the evaluation procedures in the OCRA method.

Approximate length of training and application

Both methods, being closely related, generally require 2 days (16 hours) of training time.
Follow-up sessions to ensure the training efficacy (16 hours) are highly recommended.
The application time for the OCRA index is dependent on the complexity of the task/job. For a task with a cycle time of 30 seconds it takes about 30-45 minutes to complete the analysis. The analysis of a generic task/workplace using the checklist takes about 10-15 minutes.

Reliability and validity

Based on existing studies, Colombini et al.(2000, 2002) report that the OCRA index is highly associated with the prevalence of U.E. WMSDs in the exposed populations. In particular, the following linear regression equation can be used to predict the expected prevalence of diagnosed UE **WMSDs** (with 95% confidence limit):

$$\text{U.E.WMSDS\%} = (4{,}2 \pm 1) \times \text{OCRA MEX}$$

The association expressed by the regression equation shows $R^2 = 0{,}89$ and is statistically very signìficant ($p < 0.00001$).
Occhipinti et al. (2000) reported a very high concordance and a close association between the OCRA index and the checklist scores when the two methods are applied to the same work contexts by two different experts.
No formal studies on inter and intraobserver variability exist yet, however empirical data strongly suggests that the reliability and validity are highly dependent upon the training and expertise of the analyst.

Tools needed

Both methods can be carried out using just a pen and paper. The OCRA index method, however, often requires the use of a video camera that allows films to be viewed in slow motion.
The checklist, by definition, is completed directly at the work piace.
DotH methods have specialized software available for loading and processing the data and results (Colombini et al. 2002) – e.g. for creating risk maps throughout a entire factory or in a single department.

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