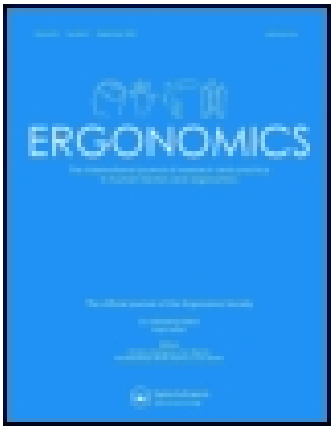
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Updating reference values and predictive models of the OCRA method in the risk assessment of work-related musculoskeletal disorders of the upper limbs

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Updating reference values and predictive models of the OCRA method in the risk assessment of work-related musculoskeletal disorders of the upper limbs

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A database has been established combining existing data for 23 groups of workers with different level of exposure to repetitive movements of the upper limbs. For all groups, data were available regarding an exposure index (OCcupational Repetitive Actions – OCRA index) and clinically determined UL-WMSDs outcomes (PA = Prevalence of workers affected by one or more UL-WMSDs; PC = Prevalence of single diagnosed cases of an UL-WMSDs). Using these data, new critical values of the OCRA index have been estimated for discriminating different exposure levels (green, yellow, red areas) and new forecasting models of expected PA and PC in exposed populations based on OCRA exposure indexes. The new critical values of the OCRA index were estimated by an original approach in which data for the effect variable (PA) in a reference population not exposed to the relevant risks are combined with the regression function between OCRA and PA. The best simple regression functions between OCRA exposure indexes and health outcomes variables (PA; PC) were researched to obtain forecasting models of effects starting from exposure. Discussion of the results obtained considers their intrinsic limitations, as they are based on prevalence studies, as well as providing recommendations and cautions in the use of the proposed classification system and forecasting models when the OCRA method is applied.

Keywords: Repetitive movements; UL-WMSDs; Risk assessment; Exposure index

1. Introduction

Upper limb work-related musculoskeletal disorders (UL WMSDs) are a 'family' of disorders having an association with jobs and tasks involving upper limb repetitive

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movements and exertions. Specific risk factors include: repetitiveness of actions, use of force, awkward postures, lack of recovery periods, etc., especially when such factors are present with one another (Hagberg *et al*. 1985, NIOSH 1997, Bao *et al*. 2006a, b).

A consensus document produced by a Technical Committee of the International Ergonomics Association (IEA), officially endorsed also by the International Commission on Occupational Health (ICOH) (Colombini *et al*. 2001), after identifying the general model, procedures and criteria for assessment of working exposure to upper limb repetitive movements, emphasizes the importance of 'synthetic' exposure indices, such as RULA (McAtamney and Corlett 1993), strain index (Moore and Garg 1995), OCRA (Occhipinti 1998) and the ACGIH TLV for mono-task hand work itself (ACGIH 2000). Such indices, however, also need to be validated as to their relationship with the clinical effects here considered.

In several previous publications (Colombini 1998, Occhipinti 1998, Occhipinti *et al*. 2000, Colombini *et al*. 2002), the authors presented the criteria, procedures and tools relating to the OCRA (OCcupational Repetitive Actions) method for estimating and evaluating exposure to the risk of UL-WMSDs in workers performing repetitive movements and exertions of the upper limbs. In particular, the tools consisted of the OCRA index and a 'shorter' OCRA checklist. The OCRA index, based on the collective exposure and health outcomes data that were gradually coming to hand at the time (Grieco 1998, Colombini *et al*. 2002), provided both preliminary reference values for classifying results in at least three risk areas (risk absent, uncertain or slight risk, risk present) as well as predictive models employing simple linear regression equations to estimate the expected prevalence of UL-WMSDs (up to now, expressed by the variable 'prevalence of individual cases of clinically diagnosed UL-WMSDs per 100 subjects exposed') based on the level of exposure. The scores derived from the application of the OCRA checklist were correlated with the classification per risk levels according to the OCRA index (Occhipinti *et al*. 2000, Colombini *et al*. 2002). Meanwhile, the OCRA method and its various analysis and classification tools, has been adopted extensively by many leading Italian and European manufacturing industries in a wide range of different sectors (mechanical, electronics, textiles, food, services). In some of these cases, it has been possible to gather data on the prevalence of UL-WMSDs in exposed workers, in addition to the exposure data derived from the application of the OCRA method.

Essentially, in addition to the historic data that have already been published (Grieco 1998, Colombini *et al*. 2002), a large amount of further data have recently become available, thus forming a new general database featuring both exposure indexes and effect variables (based on clinically diagnosed UL-WMSDs in different groups of exposed workers).

It has to be added that the current OCRA method forms the basis for two technical standards currently being developed by CEN (pr EN 1005-5) and ISO (ISO DIS 11128-3). Both organizations have asked the authors to supply updates, based on clinical surveys, on the criteria for classifying the results of the OCRA method (according to risk areas) and predictive models for the outcomes, as a function of the different exposure levels.

Accordingly, the aim of this work is to use the newly expanded database for the following purposes:

(a) to develop new 'critical' values for the OCRA index, in order to classify the risks associated with repetitive movements and exertions of the upper limbs;

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(b) to design new and more valid predictive models for the occurrence of UL-WMSDs in exposed worker populations, based on relevant OCRA index values.

2. Methods

2.1. *Database*

The database that was created for the purposes of this study is based on data already published and employed on previous occasions for similar purposes (Grieco 1998, Colombini *et al*. 2002) and includes new data reported in another paper (Colombini and Occhipinti 2004).

Table 1 summarizes the relevant data in the database. Data for 22 groups of exposed workers (No. total = 4624; No. males = 1879; No. females = 2745) includes: number of subjects (total and by gender); mean value of the OCRA index; prevalence values for two different health effect variables (PC = No. of individual diagnosed cases of UL-WMSDs per 100 exposed workers; PA = No. of subjects affected by one or more UL-WMSDs diagnosed per 100 exposed workers). Table 1 also shows similar data for a reference group (No. total = 749; No. males = 310; No. females = 349) consisting of workers never exposed to jobs and tasks associated with the risk of UL-WMSDs, as reported in a previous paper (Battevi *et al*. 1998).

For the reference group, the OCRA index was assigned 'arbitrarily' (OCRA index = 0.5), as for a very low (almost absent) risk.

Table 1. Main characteristics of the groups examined: total number, composition by gender, OCRA index, prevalence of individual diagnosed cases of UL-WMSDs (PC) and prevalence of subjects affected by one or more UL-WMSDS (PA).

Type of job/task	Subjects No. total	Subjects No. males	Subjects No. females	OCRA index	PC (% cases)	PA (% affected)
Electric motors assembly 1	431	126	305	4.7	20.4	11.4
Electric motors assembly 2	288	173	115	3.4	19.4	8.7
Freezer assembly	374	264	110	3.2	16.0	8.6
Refrigerator assembly A	350	270	80	4.5	24.6	15.4
Refrigerator assembly B	42	32	10	3.8	23.8	14.3
Refrigerator assembly C	31	31	0	4.3	32.3	19.4
Refrigerator assembly D	118	63	55	4.6	22.9	15.3
Refrigerator cablage	42	22	20	7.2	69.0	31.0
Oven assembly	650	150	500	2.8	21.8	13.2
Shock-absorber assembly	242	158	83	7.3	60.3	24.0
Meat processing (chickens)	943	0	943	7.7	31.5	22.4
Ceramics finishing	22	0	22	21.0	109.1	63.6
Sandpapering vehicle parts	121	55	66	13.0	18.2	17.4
Sandpapering wooden doors	25	0	25	24.7	108.0	72.0
Supermarket cashiers	100	0	100	7.0	53.0	26.0
Packaging pickled food	29	0	29	21.0	217.2	72.4
Upholstering of car seat	59	33	26	41.7	203.4	79.7
Pork slaughtering	86	67	19	23.8	224.4	47.7
Tile sorting	46	0	46	41.0	315.2	93.5
Motors assembly 1	467	355	112	3.4	8.6	3.9
Motors assembly 2	53	37	16	3.9	13.2	7.5
Stators assembly	105	42	63	5.8	24.8	13.3
Reference group	749	310	439	0.5	5.6	4.4

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As regards the data pertaining to the database reported in table 1, please note the following:

(1) The only data entered into the database were for groups for which there was a minimum set of reliable information concerning the number of subjects, OCRA indexes and clinical data (clinical diagnoses) collected for the whole population of exposed workers.
(2) For the groups considered, in some cases, there was no reliable information on important personal details, such as age and time since starting the specific job. Therefore, these variables have not been entered and will not be considered in this study.
(3) The OCRA indexes were reviewed by the authors case by case, based on the available videos and paper documentation; often, however, these indexes are group mean values for tasks and jobs featuring similar but not identical exposure; but any further fragmentation of the groups would have altered the reliability of the effect variables because they would have been calculated in reference to excessively small groups.
(4) In previous studies, the focus was on an effect variable represented by the prevalence of diagnosed cases (1 disorder = 1 case) of UL-WMSDs versus the number of exposed workers (Grieco 1998, Colombini *et al.* 2002). In the present study, this effect variable was maintained; however, another effect variable, which showed to have a more immediate impact, was also considered, i.e. the prevalence of affected workers (with one or more UL-WMSDs) versus the total exposed population. This latter variable has therefore been recalculated for the reference group (Battevi *et al.* 1998) and used primarily for developing the new OCRA critical values.
(5) In studying the effect variables for all groups, only clinically proven cases have been considered (i.e. patient history, specialist examination + instrumental examinations) for upper limb disorders, as defined in the list shown in table 2. Cases diagnosed exclusively on the basis of reported symptoms or other syndromes or pathologies of uncertain classification (and not listed in table 2) were excluded.

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Table 2. UL-WMSDs: list of upper limb musculoskeletal disorders considered in this study.

Tendon, sheath and bursa disorders
Shoulder
Rotator cuff tears; bicipital tendonitis; calcific tendonitis; bursitis.
Elbow/forearm
Lateral epicondylitis; medial epicondylitis; olecranon bursitis.
Wrist/hand/finger
Tendinitis and tenosynovitis of the flexor and extensor muscles; De Quervain's syndrome; tendon cysts (ganglions); trigger finger.
Peripheral compression neuropathies
Thoracic outlet syndrome; cubital tunnel syndrome; pronator teres syndrome; Carpal tunnel syndrome; Guyon's canal syndrome.
Other disorders
Acromioclavicular arthritis; carpometacarpal arthritis.

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2.2. *Determining OCRA index critical values*

The OCRA index critical values that allow to identify the different risk levels (acceptable, uncertain, present) were determined on the basis of the general model shown schematically in figure 1

(a) using the regression function (derived from the database) between the OCRA index and the prevalence of workers affected by one or more UL-WMSDs (PA) and the relative 90% confidence limits which can define the 5° and the 95° percentiles of the same function.
(b) using the PA data obtained from the reference group and relative 90% confidence limits (given the relative sample size), which can define the 5° and the 95° percentiles of PA in the same group.
(c) having determined the possible critical values of the OCRA index according to the specifications indicated below and illustrated schematically in figure 1, the values were used (with EPIINFO® software) to calculate the Odds Ratio (Armitage 1975) and relative 95% confidence limits for groups with different levels of exposure, which were consequently re-aggregated in the database, versus the group with negligible exposure.

Specifically, as regards point (b) in which, hypothetically, the prevalence of the effect variable (PA) in a generic 'non-exposed' working population is estimated, it seemed

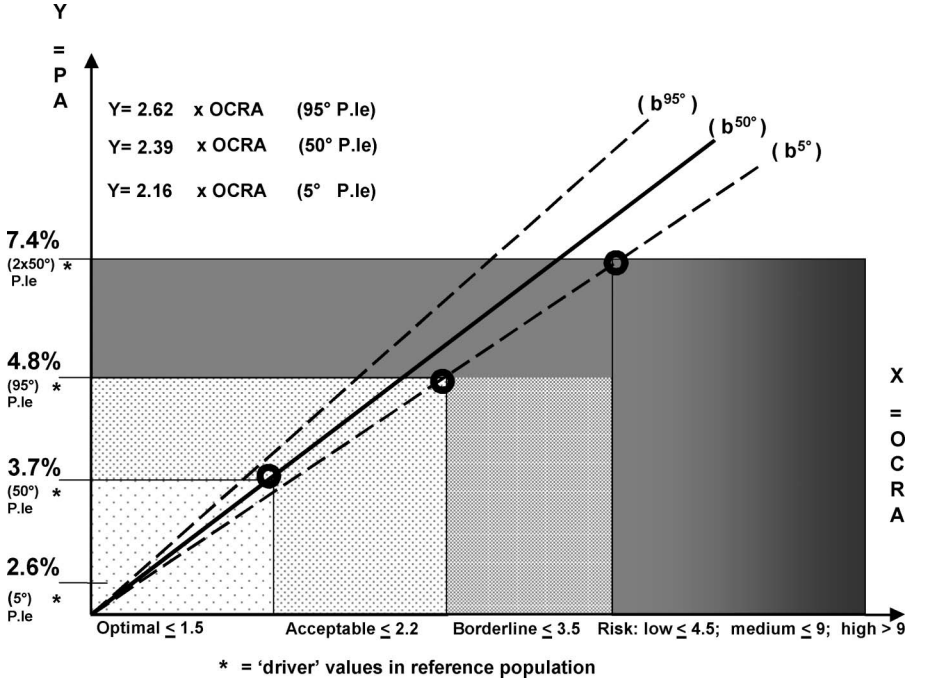


Figure 1. General model and applicative results in determining OCRA index 'critical' values by using selected values of PA (prevalence of workers with one or more UL-WMSDs) in a reference population and the regression equation OCRA/PA (with its 90% confidence limits), as resulted in this study.

preferable not to use the rough rate obtained in the sample examined, but rather to calculate a standardized rate (Armitage 1975), taking into account the structure by the same 4 age and gender sub-groups (*Age*: <35 years; ≥ 35 years. *Gender*: males; females), used for the sample as it resulted in the Italian working population in 1999.

Based on those data, it was possible to obtain the standardized rate of PA for a non-exposed group that accurately reflects the age and gender composition of the entire Italian working population. The resulting standardized PA rate (3.7%) is shown in table 3. Using routine statistical methods to estimate the sample variability of a 'normally' distributed proportion and taking into account the size of the sample examined, relevant percentiles (5°, 95°) of the standardized PA rate were also calculated.

Going back to the general model, the authors decided to first look for OCRA index critical values using the OCRA/PA regression equation and the relevant percentiles of the standardized PA rate derived from the reference group according to the following criteria.

(1) The optimal OCRA index value corresponds to the point where the regression function (central value) intersects the central standardized PA rate in the reference group.
(2) The acceptable OCRA index value corresponds to the point where the regression equation, at its 5° percentile, intersects the 95° percentile of the standardized rate in the reference group (4.8%). In this situation, the minimum PA (the lower limit, at 90%, of the regression equation) estimated on the basis of the corresponding value of the OCRA index in a potentially exposed population, is similar to the 95° percentile of the PA distribution that can be found in a population of non-exposed workers.
(3) The limit of the OCRA index values which, with reasonable certainty, represent a clear condition of risk can be found at the intersection between the regression function (at the lower 90% confidence limit) and twice the standardized rate of PA in the non-exposed population (7.4%). Beyond this value, there is a strong likelihood that the estimated minimum PA value using the OCRA index in exposed workers is significantly 'higher' with respect to the standardized rate of PA recorded in a reference population of non-exposed workers.
(4) The resulting range of OCRA index values between point 2) and point 3), as referred above, represents an uncertain or borderline area, between an acceptable situation and the presence of an overt risk.
(5) Additional OCRA index critical values in the risk area can be identified at the intersections of the regression function (central value) and the points corresponding to an increasing number of times the standardized rate of PA (central value), as reported in the reference population.

Table 3. Standardized rates of PC (prevalence of individual diagnosed cases of UL-WMSDs) and PA (prevalence of workers with one or more UL-WMSDs) in the reference group: values corresponding to 5°, 50° and 95° percentile.

Health effect	5° P.le	50° P.le	95° P.le
Prevalence of individual diagnosed cases of UL-WMSDs (PC)	3.2	4.4	5.6
Prevalence of workers with one or more UL-WMSDs (PA)	2.6	3.7	4.8

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2.3. *Determining predictive models*

The second aim of this paper involved determining (by SPSS for Windows® statistical software) simple regression functions between the OCRA index and the two effect variables (PA = No. of workers suffering from one or more UL-WMSDs × 100/No. of exposed workers; PC = No. of individual cases diagnosed with UL-WMSDs × 100/No. of exposed workers) and verifying the corresponding strength of association (Armitage 1975). Consequently, the 'best' functions were selected based on the twofold criterion of the strength of association and the 'interpretative simplicity' of the function.

Multiple regression functions (Armitage 1975) were also determined, only for the main selected effect variable (PA), with an additional independent variable (SEXRATIO = No. of women × 100/No. total), which is representative of the composition by gender of the 23 groups examined.

For all the regression functions, which take into consideration all the 23 groups examined, it was assumed that for an exposure index (actually theoretical) of 0, the prevalence of the effects analysed was nil and therefore the best function was determined without a constant. In determining the regression functions, the 'weight' of the various groups considered was also taken into account, in relation to the correspondent number of subjects examined.

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3. Results

3.1. *OCRA index critical values*

To identify the OCRA index critical values, figure 1 shows the results actually obtained when the available data (table 1) are applied to the general model previously described.In particular, as also indicated in table 7 below, the best simple regression function between OCRA index and PA is linear and expressed by the general equation:

$$PA = 2.39\ (\pm 0.14) \times \text{OCRA INDEX} \quad (1)$$

This function presents a high degree of association between the two variables (R^2 adjusted = 0.92) that is also statistically significant ($p < 0.00001$). Using this equation (and relative 90% confidence limits) and the PA 'drivers' values defined in the reference group according to the general model included in figure 1, data were obtained about the different OCRA index critical values that separate areas at different risk for (prevalence of) workers affected by UL-WMSDs as shown in same figure 1.

These critical values were used to re-aggregate the data in the database into groups of workers with different exposure levels and to calculate the odds ratios (with relative 95% confidence limits) deriving from a comparison between the PA of each re-aggregated group with that of the low exposure group. The results are shown in table 4.

It should be noted that in the re-aggregation of the groups, for this particular purpose, the low exposure group (OCRA index ≤ 2.2) is represented only by the reference group.

Results reported in table 4 are really important in that they confirm the results obtained for identifying the OCRA index critical values according to the general model depicted in figure 1. The table shows how applying the new OCRA index critical values to the available database, there is a constant increase in the Odds Ratio values in the gradual passage from low exposure levels to medium, high or very high

exposure levels. Using the X^2 tests according to Mantel-Haenszel (Armitage 1975), for each individual level of exposure, the high statistical significance of the comparisons is confirmed.

Taking into account on the one hand the results obtained so far, it is possible to define a classification scheme for 6 different exposure levels, based on OCRA index critical values, as specified in table 5. Table 5 shows each of the six levels identified and for each indicates possible actions following a risk assessment using the OCRA index method.

3.2. *Forecasting models*

As regards the second aim of the present paper, which is to identify forecasting models for health outcomes (prevalence of UL-WMSDs in exposed workers) based on OCRA index, reference has already been made to the results of the analysis to find the 'best' model for associating OCRA index and PA. The relative regression equation has already been used to identify the OCRA critical values. The same equation, with its confidence limits, provides an estimate of the PA outcome (prevalence of exposed workers clinically diagnosed as having one or more UL-WMSDs) based on the OCRA index values obtained in different working contexts. In practice, using the OCRA index values and the regression function with its confidence limits, it is possible to formulate assumptions on the PA 'expected' in any given work context. For instance, in table 6, for each of the

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Table 4. ODDS RATIO (with relative 95% confidence limits) considering PA (prevalence of workers with one or more UL-WMSDs) when comparing re-aggregated groups with different exposure levels according to the OCRA index and a low exposure group (OCRA $\leq$ 2.2).

OCRA index class	Odds ratio lower 95% limit	Odds ratio central value	Odds ratio upper 95% limit	*P*-value
Up to 2.2	#	#	#	#
2.3–3.5	1.45	2.16	3.23	0.00006
3.6–4.5	2.38	3.74	5.89	0.00000
4.6–9.0	3.63	5.30	7.78	0.00000
Over 9.0	15.99	24.31	37.11	0.00000

Table 5. Classification of the OCRA index according to increasing risk areas and brief identification of consequent possible actions.

Area	OCRA index values	Risk classification	Consequent possible actions
Green	1.5 and lower	Optimal	None
Green–Yellow	1.6–2.2	Acceptable	None
Yellow-red	2.3–3.5	Uncertain or very low	Check again, if possible improve work conditions
Red-light	3.6–4.5	Light	Improve work conditions, health surveillance, training
Red-medium	4.6–9.0	Medium	Improve work conditions, health surveillance, training
Red-high	9.1 and higher	High	Improve work conditions, health surveillance, training

different OCRA index critical values previously identified, the expected PA is estimated by calculating the central value and the confidence limits (in this case at 90%), and consequently also the 5th and 95th percentile of the estimate.

The 'best' models for estimating the two health outcomes analysed (PA and PC) based on the OCRA index are shown in table 7. This table shows: the effect variable (PA or PC), the exposure variable (OCRA index), the type of function and equation expressing the 'best' model of association, the standard error of regression coefficient (b) in the equation, the adjusted R^2 and the level of statistical significance of the association. Both the derived models showed a very high association between the independent variable (exposure) and the dependent variable (health outcome).

Lastly, the derived variable 'SEXRATIO' (No. of women × 100/No. total), expressing the gender composition in the different groups, together with the OCRA index, was used to find a model of association (multiple regression) between 2 independent (or predictive) variables and the effect variable PA, which in this analysis has been chosen as the simplier to explain to potential users.

The result is the predictive model for PA based on OCRA and SEXRATIO shown in table 8 and expressed by the multiple linear regression equation:

$$PA = [(2.02 \times \text{OCRA INDEX}) + (0.075 \times \text{SEXRATIO})] \quad (2)$$

Table 8 also indicates the data relative to the confidence limits (90%) of this equation, along with the R^2 values indicative of the strength of association between the predictive variables and the effect variable. The resulting model of association is statistically highly significant ($P < 0.0001$).

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Table 6. Estimated PA (prevalence of workers with one or more UL-WMSDs) as a function of OCRA index 'critical' values through the OCRA/PA simple linear regression function (central value and 90% confidence limits).

OCRA index value	Estimated PA 5° P.le	Estimated PA 50° P.le	Estimated PA 95° P.le
1.5	3.24	3.58	3.93
2.2	4.75	5.26	5.76
3.5	7.56	8.36	9.17
4.5	9.72	10.75	11.79
9	19.44	21.51	23.58

Table 7. Simple regression functions between an exposure variable (OCRA index) and effect variables (PA and PC) in the whole sample.

Exposure variable (X)	Health effect variable (Y)	Type of function (b = regression coefficient)	Equation	Std error (b)	R^2 adj.	P-value
OCRA index	PA[a]	Linear $Y = bX$	PA = 2.39 × OCRA	0.14	0.92	0.00001
OCRA index	PC[b]	Linear $Y = bX$	PC = 6.01 × OCRA	0.48	0.87	0.00001

[a]PA = prevalence (%) of workers with one or more UL-WMSDs.
[b]PC = prevalence (%) of individual diagnosed cases of UL-WMSDs.

Table 8. Multiple regression function between OCRA index and SEXRATIO (predictive variables) and PA (effect variable): central value and 90% confidence limits.

$PA^a = [(2.02 \times OCRA) + (0.075 \times SEXRATIO^b)]$ $R^2 = 0.96$	
5° and 95° percentile of the function (confidence limits AT 90%)	
5°	$PA^a = [(1.72 \times OCRA) + (0.035 \times SEXRATIO^b)]$
95°	$PA^a = [(2.32 \times OCRA) + (0.115 \times SEXRATIO^b)]$

[a]PA = prevalence (estimated) of persons affected by one or more UL-WMSDs.
[b]SEXRATIO = No. of females × 100/No. total.

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4. Discussion

The analysis that has been presented here is based exclusively on 'prevalence' studies. The authors are fully aware that when data coming from such studies are used to explore possible relationships between exposure conditions (in this case, to a work risk factor) and corresponding collective health outcomes, several uncontrollable distortions may occur. Controlled incidence studies (prospective and retrospective) would certainly have been more suitable, but they would also have been more challenging and slower, and therefore at the present time do not represent a viable option.

However, it would be a mistake to overlook the usefulness of prevalence studies such as those used for this investigation. These studies are numerous and use highly homogeneous criteria for classifying exposure and health outcomes. Moreover, the results are extremely consistent and therefore can be used at least as a basis for classifying exposure and, ultimately, also risk (the 'collective' probability of disorders), when the OCRA method for assessing exposure to repetitive exertions of the upper limbs is adopted.

Having emphasized the intrinsic limits of this study, it is possible to discuss briefly some of the results obtained.

(1) The general model shown in figure 1, which identifies the OCRA index critical values, is based on authors' partly 'arbitrary' decisions. Those regard, in particular, the choice of certain percentiles for the PA distribution in the reference population as 'drivers' values for determining OCRA index critical values, and the choice of certain variants of the OCRA/PA regression equation, obtained from the database. Clearly, if the same data is used but different criteria and parameters are chosen, for different and perfectly legitimate reasons, the resulting critical values will partly vary. In this case, the choices defined as 'arbitrary' were prevalently made on the basis of a discussion in CEN and ISO technical groups which are producing two specific technical standards; they were, on the other side, confirmed by subsequent concrete data elaborations with particular reference to those estimating the Odds Ratio for homogeneous and growing exposure groups. However, the originality of the general model is undeniable: of course, other models may well use different criteria for choosing their critical values, for different but equally justified technical, scientific, ethical or social reasons.

(2) Based on the data and analytical model, it was possible to identify a classification system for the OCRA index involving several levels, but substantially based on the 'traffic light' system (green, yellow, red). It is worth noting that all the OCRA index values defined as acceptable (and not just optimal) are classed as *green*; these do not generally require preventive actions to be taken.
The *yellow* level includes OCRA index values (2.3–3.5), which may, based on the existing records, be associated with an hypothetical risk of UL-WMSDs. However, this association is still either uncertain or minimal (PA estimated in the exposed is less than twice the one estimated in the reference population). Essentially, this is a borderline exposure level, where the risk, if it exists at all, is very slight.
The *red* level, associated with definite risk, is divided into three sub-levels: light red, medium red and high red, where the estimated PA in the exposed population is (as largely confirmed by the Odds Ratio calculated on the available database) respectively between 2 and 3 times, between 3 and 6 times and more than 6 times higher than the PA estimated in the reference population.

(3) The arrangement of exposure' classification system into different risk levels, as discussed in the previous paragraph, helps to better frame the risk assessment and more effectively guide any consequent preventive actions, also in compliance with regulatory requirements; however, if improperly used, it may also lead to a distorted interpretation of the OCRA index values: this could happen particularly for OCRA index values around critical values.
For instance, though it is theoretically fair to state that an OCRA index value of 3.4 represents an uncertain risk and 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 users should pay due attention to trends in OCRA results (also using the forecasting models supplied), rather than simply splitting values into 'risk' or 'no risk'.
Since the OCRA method is employed widely in an extensive range of situations for monitoring purposes and also for medico-legal reasons, it should be underlined that the proposed classification is to be considered a guide to the correct interpretation of the risk assessment and the adoption of appropriate preventive measures, rather than a rigid standard to be applied without criticism for purposes other than those specifically stated here.

(4) The forecasting models concerning the specific health outcomes in exposed workers, based on the OCRA index, take into account the intrinsic limits typical of prevalence studies already mentioned above. The aim is primarily to supply occupational safety and health (OSH) operators and their dialog partners (e.g. management) with a tool for assessing priorities, in the light of technical and economic factors associated with the cost of preventive actions and, alternatively, the cost of 'non-prevention'.
Practical experience has shown that forecasting models are a very useful tool for negotiating with decision-makers, especially in business environments, where action plans need to be established on the basis of risk assessments.
From the purely technical, scientific and statistical standpoint, forecasting models can, at the moment, only roughly estimate the possible occurrence of UL-WMSDs over a multi-year time horizon, given certain levels of exposure to repetitive movements and exertions of the upper limbs. However, from the viewpoint of risk management, these models represent a fundamental tool for negotiations between OHS operators and decision-makers.

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5. Conclusions

The availability of new information on the results of the OCRA method applications and the results of parallel UL-WMSDs prevalence studies has enabled to update the classification criteria for the OCRA index.

To do this, a model for the selection of OCRA index critical values was adopted prevalently by CEN and ISO work groups involved in producing technical standards for repetitive manual activities. The criteria were based on prevalence studies, whose intrinsic limits have been extensively discussed and underlined, in the knowledge that these studies are now numerically representative (over 5000 individuals examined, in 23 different exposure groups). The prevalence studies, which employed highly homogeneous criteria and methods, were consistent with similar preliminary studies carried out by the authors (Grieco 1998, Colombini *et al*. 2002).

Based on the results of this study, the OCRA index developed by previously published analytical procedures (Occhipinti 1998, Colombini *et al*. 2002), has been reclassified into six levels of increasing exposure.

Alongside this, by studying the models and functions that associate exposure variables and (collective) health outcome variables, particularly the prevalence of individuals suffering from one or more clinically diagnosed UL-WMSDs (PA), it was possible to develop mid- to long-term forecasting models for these effects, based on known OCRA index values. Though taking into account the intrinsic limits of the prevalence studies on which they are based, these models have displayed a high level of association between the variables investigated, especially when it was possible to take into account the numerical composition per gender of the groups under examination.

The proposed classification schemes and forecasting models developed here are of significance for the assessment and management of occupational risks associated with repetitive upper limb movements and exertions, for the resulting decision-making and ongoing monitoring of the improvements introduced.

The reference criteria already published in previous articles and here further developed and detailed, increase the OCRA method ability to discriminate among different levels of exposure to the specific risks described here.

The authors confirm both the intrinsic limits of the study and the recommended methods of use, as examined briefly above in the discussion section, and state their intention to critically review the contents of this paper in light of new studies, if possible including incidence data and new and diversified applications of the OCRA method.

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