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Repetitive movements of upper limbs in agriculture: set up of annual exposure level assessment models starting from OCRA checklist via simple and practical tools.

Abstract

Risks of upper extremity musculoskeletal disorders are not well investigated in farmers. This study performed risk assessment in some farms in Italy (Tuscany, Piedmont and Marches). To obtain an exposure index in vine–growing and in peach cultivation, we previously analysed work organization recording all the tasks. Then we performed the analysis using the OCRA checklist. In both cultivations, task analysis showed an intrinsic high risk. The aim of this study is to define alternative analytical methods to establish the cumulative exposure level to agricultural work tasks typical of an annual distribution, given that quality and duration of the work depend on the month.

The first survey results, though still preliminary and concerning a small case-report, evidenced that two of the alternative analytical methods proposed show a good association between high values of the OCRA check list and the development of musculoskeletal disorders.

The future objective of the research (once more epidemiological data have been obtained) will be to create a SIMPLE, PRACTICAL TOOL (software) TO ESTIMATE ANNUAL RISK EXPOSURE using pre-established calculation models. Once the intrinsic values of each task characterising a particular form of agriculture have been pre-calculated, the annual exposure level can be calculated immediately, simply by asking the worker which tasks are performed, month by month, over the year.

Key words: wine-growers, upper extremities musculoskeletal disorders, annual exposure, risk assessment tools

1 Introduction

Work-related musculoskeletal disorders (WMSDs) of upper limbs (UL) and spine, in the last 35 years, have become extremely widespread, reaching epidemic levels, in all advanced industrialised countries (Hagberg M e al.1995).

For the origin of UL-WMSDs it must be recalled that some organizational and biomechanical factors (frequency and repetitiveness of movements, use of force, type of posture and movements, distribution of recovery periods, duration of exposure) are worth being considered. There are other risk factors (additional factors) that might enhance the overall risk .

More recent European statistical data regarding upper limb musculoskeletal disorders (EUROSTAT 2004) show that sectors in leading position (after manufacturing) are construction, fishing and agriculture. In 2004 in the agricultural sector, 51% of all recorded work-related diseases, are upper limb musculoskeletal disorders. In Italy, in 2005, WMSDs (spine and upper limbs) recorded in agriculture, are nearly 60% of all work-related diseases. Other data. report WMSDs incidence rates exceeding 3% per year. These data confirm the need to tackle more systematically this issue in the specific sector.

2 Objectives

Traditional risk assessment methods for multiple-task involving upper limbs repetitive movements generally concentrate on typical daily exposure: however, in agriculture, exposure varies in duration and type over the period of one year.
The aim of this study is:

- to define a peculiar procedure for a preliminary analysis of all the manual tasks typical of a given job during one year by traditional risk-assessment methods by experts;
- to outline special multitask assessment models using the preliminary results to evaluate the cumulative exposure level in agricultural jobs and for all manual jobs having the common characteristic of an annual distribution, since quality and duration of work depend on month or season.

In order to validate those calculation models, they should be compared to the occurrence of UL-WMSDs traced (by an active health surveillance program) in several groups of workers in different agricultural sectors. This will help identify the best predictive model (of health effects) considering the specific combination of exposures over a year range.
Thus, the final objective of the research presented here is to create a simple, practical tool (software) devoted to OSH practitioners by which they can estimate annual risk exposure using pre-established calculation models: in fact once the intrinsic exposure values of each task characterising a particular form of agriculture have been pre-calculated, the annual exposure level can be calculated immediately, simply by asking the worker which tasks are performed, month by month, over the year.
These tools can be considered as "good practice" tools, in that they enable occupational safety and health operators, agriculture managers, ergonomists, occupational doctors but also occupational health authorities and insurance institutes to better identify exposure levels for this type of workers and address consequent prevention programs with related priorities.

3 Methods

3.1 Risk evaluation method: the OCRA checklist
The OCRA checklist (Colombini et al.1996, 2005) was used to estimate the intrinsic level of exposure imposed by each identified manual task performed during a year for a specific kind of cultivation (in this case vine–growing and peach cultivation). The OCRA checklist is one of the methods suggested for a risk simplified assessment in ISO 11228-3 standard. The OCRA checklist allows to classify the working exposure levels in different risk areas (Table 1).
For the specific kind of analysed cultivations, the study was organized in two stages: 1) analysis of work organization of the different tasks; 2) analysis of each task using the OCRA checklists.
To analyse work organization, after selecting some "sample" farms, data such as number of workers, working tasks and hours/months of performance were collected for each task. The production methods were analysed in detail and the relative working tasks were listed creating an "annual job description handbook".
All working tasks were video recorded and the risk analysis using the OCRA checklist was performed for each repetitive working task identified by classifying the task "intrinsic" risk (as if it were the only one over the year).

3.2 Hypotheses of risk exposure assessment models from biomechanical overload of upper limbs in annual exposure to several tasks.

The traditional risk assessment methods for multiple-task repetitive movements proposed by the OCRA and other methods are focused on daily exposure: however, in agriculture, exposure varies in duration and type over the year.
Starting from theoretical bases of the OCRA method, several alternative computational models could be outlined to establish the cumulative exposure level to different agricultural work tasks; they are at the moment hypothetical but may turn out to be useful for all jobs involving a task variation along a year given that the kind and duration of the work depend on month or season.

The hypothesized models for annual exposure are four: a) hyperbolic qualitative weighed method (non linear time); b) quantitative weighed method (linear time); c) multitask complex OCRA method index (non linear time); d) weighed method by the Gaussian curve (non linear time).

RISK AREA	OCRA VALUES	OCRA CHECKLIST VALUES	RISK LEVEL	CONSEQUENCES
GREEN	UP TO 2.2	UP TO 7.5	VERY LOW RISK WMSDs prediction is similar to the one for the reference group	No consequences
YELLOW/	2.3-3.5	7.6-11	LOW RISK Prediction of slight increase (up to three-fold) of WMSDs	Advisable to set up health surveillance.
RED	3.6-9	11.1-22.5	PRESENCE OF RISK The higher the index, the higher the risk.	Re-design of tasks and workplaces according to priorities. Health surveillance, training and information.
VIOLET	MORE THAN 9	MORE THAN 22.5	HIGH RISK Index values provide criteria for action priorities.	

Table 1 The OCRA method: final scores and risk areas.

a. Hyperbolic qualitative weighed calculation model (non-linear timeline)

This calculation method evaluates the presence of single tasks throughout the year using the distribution of a presence variable (value of 1 if present in the month, value of 0 if not) as shown in Table 2. This exposure data collection model is easy to fill in: the collector of work anamneses shows the worker the complete list of the various work tasks involved in the type of agriculture considered (previously analysed to establish the intrinsic risk value). The worker simply says how many times and in which month he has performed these tasks.
For each task a count is made (horizontal in the table) of how many months the operator has worked no matter for how long (all month or only part of a month). The example in Table 2 shows that the worker has worked 21 "false unit months". This is the total on which the % duration of each task is calculated over the year (see final column).
The scheme proposed here already provides a graphic image of the real distribution in the different months of the year for the various tasks. Moreover, months during which the operator has been actually employed can be clearly seen: in this case 10 (he did not work in August and December).

	TASK DISTRIBUTION BY MONTHS																
	TASKS	INTRINSEC CHECK-LIST OCRA RIGHT	INTRINSEC CHECK-LIST OCRA LEFT	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOT	% TOT
1	task a	12,0	10,0	1		1		1				1		1		5,00	24%
2	task b	8,0	6,0		1		1	1	1			1				5,00	24%
3	task c	28,0	21,0				1		1	1						3,00	14%
4	task d	18.0	11,0		1		1	1	1				1			5,00	24%

5	task e	31.0	26.0					1					1	1		3,00	14%
			10.0	1.00	2..00	1.00	3.00	4.00	3.00	1.00	0.00	2.00	2.00	2.00	0.00	**21.00**	100%

Table 2. Scheme for anamnesis collection for the hyperbolic qualitative method.

Once the % of the single tasks has been established, we can proceed to calculate the weighed average:

$$Qualitative \quad Hyperbolic \quad Index \equiv \sum_{i=1}^{n} ck\_OCRA \times P_i Qual\%$$

where "i " is the task index and "PiQual%" is the hyperbolic weighing parameter.

<u>b. "Quantitatively weighed" calculation method (linear timeline)</u>

The starting point for this model is a more precise definition of how the various work tasks are distributed, both within the month and the year .

The scheme for anamnesis collection shown in Table 3 is similar to the one shown in Table 2 but for the indication (as a percentage) of the "level of involvement" for each task, for each month of the year. For more than one task in a month, their distribution is indicated (total cannot be more than 100%).

Each line of exposure percentages for each task is then summed to provide an estimate of the real working time (for that task) expressed in months. These data can then be used to calculate annual percentage duration in relation to the "maximum months work per year" (which is a constant of 11 months).

Again the exposure index is obtained with the weighed average calculation:

$$Quantative \quad weighted \quad index \equiv \sum_{i=1}^{n} ck\_OCRA \times P_i Quant\%$$

where "*PiQuant" is the weighted multiplier for each "i" of task, given by:*

$$P_i Quant\% = \frac{\sum_{j=1}^{12} s_{ij}}{Work\_month\_cons\tan t}\% = \frac{Si}{11}\%, \quad s_{ij} \in [0,1]$$

where" s_{ij}" is the saturation of the" task i-th" in the "month j-th" (the percentage values introduced into the matrix)

As compared with the previous one, this approach is more precise in defining exposure times even if it is more difficult for the worker: the interviewer should try to explain quite clearly to the worker how to judge the monthly exposure percentages.

Again as compared with the previous one, this calculation model has the advantage to be more accurate and introduce into the index itself the variable "actual duration of months worked in the year" weighed by constant "11 months" which is the highest level of annual exposure.

TASK DISTRIBUTION BY MONTHS																
TASKS	INTRINSEC CHECK-LIST OCRA RIGHT	INTRINSEC CHECK-LIST OCRA LEFT	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUNE**	**JULY**	**AUGUST**	**SEP**	**OCT**	**NOV**	**DEC**	TOT	% TOT
task a	12.0	10.0	50%		100%		10%				10%		50%		2.20	20%
task b	8.0	6.0		50%		20%	5%	30%			90%				1.95	18%
task c	28.0	2.0				10%		30%	100%						1.40	13%
task d	18.0	11.0		50%		70%	5%	40%				25%			1.90	17%
task e	31.0	26.0					80%					25%	50%		1.55	14%
		11.0	50%	100%	100%	100%	100%	100%	100%	0%	100%	50%	100%	0%	9.00	82%

Table 3. Scheme for anamnesis collection for the "quantitatively weighed" method. Used as a basis for "multitask complex" and "Gauss curve weighed" methods.

c. Multitask Complex analysis model

Recently Occhipinti and Colombini (data not yet published) have set up a new calculation model of daily exposure index to several working tasks whose turnover extends by over one hour in the shift.
In fact when task rotation is not very frequent, the "time weighed average" traditional approach resulted into an underestimate of the exposure actual level (owing to flattening of exposure peaks). For these scenarios, an alternative approach based on "more overloading task as a minimum" appeared to be more realistic. The result of this approach will be as a minimum equivalent to the

OCRA checklist value of the more overloading tasks considered for its actual duration and, as a maximum, equal to the OCRA checklist value of the same task considered however (only theoretically) for the whole duration of all examined repetitive tasks. A special procedure allows to exactly estimate the actual index within the range of values between minimum and maximum.
The procedure is based on the following formula:

$$complex\ Checklist\ final\ score = score_{1(Dm1)} + (\Delta score_1 \ x\ K)$$

where

1,2,3,…,N = repetitive tasks ordered according to checklist score values (1= highest; N = lowest) calculated considering the actual duration respective multiplier (Dm_i)
$score_1$ = score of task $_1$ considering Dm_1
Dm_i = duration multiplier according to actual duration of task
Dm_{tot} = duration multiplier for total duration of all repetitive tasks
$\Delta\ score_1$ = highest score considering Dm_{tot} (selected among N tasks) - score of task $_1$ considering Dm_1
$K = \frac{(score_{1\,max} * FT_1) + (score_{2\,max} * FT_2) + \ldots + (score_N * FT_N)}{(score_{i\,max})}$
$score_{i\,max}$ = score of $task_i$ considering Dm_{tot}
FT_i = Time fraction (values between 0 and 1) of task, as compared with repetitive total time.

In this case we need to have duration multipliers versus total exposure of repetitive tasks no longer expressed in minutes/shift (like for daily exposure) but in exposure months/year.
Table 4 provides a rough estimate..

DAYS		MONTHS									
< 15 days	15-30 days	1 o 2	2.1-3	3.1-4	4.1-5	5.1-6	6.1-7	7.1-8	8.1-9	9.1-10	10.1-11 or more
0.300	0.400	0.500	0.600	0.700	0.800	0.850	0.900	0.950	0.975	0.990	1.000

Table 4 Hypotheses o**f** elements for calculation of duration multiplier (Du_M) referred to exposure months/year.

With this method we can use the same anamnestic scheme as reported in Table 3.

d. Gauss curve weighed method (non linear time)

This method is absolutely similar to method b) and refers to a similar starting matrix (Table 3). The difference as to the previous one is inherent in the weighing factor (multiplier) allowing to adjust the final result versus saturation and task variability (Gauss function).
In this case reference will be made to formula:

$$Gaussweigh\ edindex \equiv \sum_{i=1}^{n} ck\_OCRA \times G\, i, k$$

Where:

- Si: saturation of i-th task in the year;
- Stot: saturation of all tasks of the year in the year itself (sum of Si);
- k: rotation factor among jobs.

Then, Gi,k is expressed by:

$$G_{i,k} = \frac{1}{2 * k * \sqrt{\pi}} * e^{-\frac{\left(\frac{S_i + S_{tot}}{2} - 11\right)^2}{(k*11)^2}}$$

4 Results

4.1 Evaluation of exposure index (checklist score) in different kinds of cultivations.
Table 5 shows the results of the OCRA checklist score (and their determinants) obtained in several vine-growing tasks as recorded in a sample of farms in different Italian regions. The results show that most analyzed tasks, if individually considered as performed all the time, are included in the red/violet area of exposure. This means, in general, a high risk of biomechanical overload of the upper

extremities. On the other side, the table shows which kind of analytical output should be derived for each agricultural kind of cultivation to help practitioners fill in data on yearly exposure to the different tasks.
Table 6 shows similar data for peach cultivations: also for this kind of cultivation, most of the analyzed tasks are included in the red-violet band of OCRA check list.

4.2 Results of preliminary epidemiological studies and predictivity assessment of annual exposure complex models
This work hypothesized 4 new calculations of final exposure level (the fifth one being the traditional one used for calculating daily exposure), each leading to different final exposure results. Now the point is to define which is the best exposure estimator, that is in other terms, the best "predictor" of upper limb WMSDs reported in a population of exposed subjects. This can be checked considering the already known OCRA index association (predictivity), and also of checklist score, with the prevalence of exposed workers (% PA) affected by one or more UL-WMSDs. This association is expressed by the following linear equations

%PA (Pathological subjects Affected by UL-WMSDs) = 2.39 (± 0,14) x OCRA index
%PA=(OCRA checklist)^{1,004}

Owing to the strong association, it is also possible to identify the best OCRA checklist score, PA % being known through formula:

OCRA checklist = %PA $^{(1/1,004)}$

This methodological approach, beyond some theoretical limits, will be very useful practically speaking, as clinical data from workers exposed to different manual tasks along one-year period become available. In fact they will allow to establish with increasing certainty the mathematical models better associating with traced prevalences of pathological subjects (%PA).
This check has been possible for the time being only over a very small set of (exposure and disease) data collected in two small farms. All the calculation models presented in this study were tested with such data.
The results are reported in Table 7: column 3 reports PA% values traced in all farms. Column 4 reports the value of OCRA checklist expected starting from actually present PA% (column 3). In the subsequent columns, for each calculation model proposed, the actually calculated exposure value and corresponding error % as to expected value are expressed.. Notice that the exposure assessment traditional method for study of daily shifts tends to underestimate the risk, while the two proposed methods (columns 8 and 9) seem to provide a good predictivity of actually traced PA%. It is noteworthy that the results of such reliability checks of proposed calculation models are still hypothetical because of the small number of cases considered.

5. Conclusions

In view of upper limb biomechanical overload risk assessment in works varying in the different months of the year, typically in agriculture, a methodology is presented including:

- pre-assessment with accredited traditional methods such as OCRA method (OCRA checklist) of each manual tasks typical of a given job or cultivation.
- Set up of anamnestic schemes of more or less detailed information collection on times and ways of different task performance during the year by one or more workers.
- Use of mathematical models (still to be validated) to assess annual cumulative exposure given the type of works and related performance times.

As regards the latter, a methodology has been set up to identify the "most reliable" ones in relation to the well known trend of associations between exposure indicators and illness (collective) indicators. Completion of the first presented studies, together with the collection of more numerous clinical data

together with exposure ones, will allow to set up exposure assessment methods easily applicable not only to agriculture but also to all working activities with rather long periodicities (months), to activities with year fractions (task rotations in the year) and more generally to all situations involving cyclic rotation of workers on working tasks not only on a daily basis. As already said, the final objective of this work is to create a simple, practical tool (applicable by a simple and free software) to estimate annual risk exposure using predetermined calculation models. Once the intrinsic values of each task characterising a particular form of agriculture have been pre-calculated, the annual exposure level can be calculated immediately, simply by asking the worker which tasks are performed, month by month, over the year.

WORKING TASKS	Side	Recovery	Frequency	Force	Total of posture	Additional factors	Value of OCRA Check list
Mother vine	dx	4	9	7	9,5	2	**31,5**
Mother vine	sx	4	3	7	9,5	2	**25,5**
Vine plantation	dx	4	4,5	0	5	0	**13,5**
Vine plantation	sx	4	2	0	9	0	**15**
Manual "tirafili"	dx	4	8	11	10	2	**35**
Manual "tirafili"	sx	4	6	11	10	2	**33**
"Tirafili" with tool	dx	4	5	2	7	2	**20**
"Tirafili" with tool	sx	4	5	2	7	2	**20**
Pruning (dry part) - Tuscany	dx	4	7	2	7	2	**22**
Pruning (dry part) - Tuscany	sx	4	1	1	5,5	2	**13,5**
Pruning (dry part) - Piedmont	dx	4	7	2	13	2	**28**
Pruning (dry part) - Piedmont	sx	4	1	1	13	2	**21**
Pruning (dry part) - Marches	dx	4	7	3	17	2	**33**
Pruning (dry part) - Marches	sx	4	7	1	17	2	**31**
Green pruning - polling	dx	4	1	1	3,5	0	**9,5**
Green pruning - polling	sx	4	8	2	5,5	0	**19,5**
Green pruning – pinching out	dx	4	8	6	9	0	**27**
Green pruning – pinching out	sx	4	0	0	1	0	**5**
Green pruning – stripping of leaves	dx	4	5	2	3,5	0	**14,5**
Green pruning – stripping of leaves	sx	4	2	2	3	0	**11**
Grape harvest - Tuscany	dx	4	3	1	6	0	**14**
Grape harvest - Tuscany	sx	4	6	1	6	0	**17**
Grape harvest - Piedmont	dx	4	3	1	6	0	**14**
Grape harvest - Piedmont	sx	4	6	1	6	0	**17**
Grape harvest - Marches	dx	4	3	1	9	0	**17**
Grape harvest - Marches	sx	4	6	1	9	0	**20**

Table 5: Results of OCRA Checklist for each working task analysed in grape growing

	WORKING TASKSI Agricultural Cooperative – women –right arm	CHECKLIST OCRA intrinsic value (CK)
a	pruning	37.1
b	Fruit thining	26.6
c	Harvest (women)	12.8

	WORKING TASKSI Agricultural Cooperative – women –right arm	CHECKLIST OCRA intrinsic value (CK)
d	Emptying of bins	16.6
e	Fruit selection	21.9
f	Grape harvest	23.0

Table 6: Results of OCRA Checklist for each working task analysed in peach cultivations (right arm)

n°	1.Farm	2.SIDE	3%PA	4. EXPECTED OCRA CHECKLIST INDEX	5. (AVERAGE CLASSICAL DAILY EVALUATION)		6. HYPERBOLIC QUALITATIVE AVERAGE WEIGHED INDEX		7. QUANTITATIVE WIEIGHED AVERAGE INDEX		8. MULTITASK COMPLEX MODEL		9 GAUSSIAN WEIGHED AEVERAGE IONDEX	
					value	Error%	Value	Error%	value	Error%	value	Error%	value	Error%
1	Global Agric. Cooper. (TOT=13, PA=4)	R	30.8%	30.4	24.1	20.6%	23.8	21.7%	23.0	24.3%	31.7	-4.4%	31.4	-3.5%
2	Agricu. Enter. -men - (TOT=6, PA=1)	R	16.7%	16.5	12.5	24.2%	17.0	-3.1%	12.4	24.9%	17.5	-6.2%	15.2	7.5%

Table 7: Comparison of results of the calculation models and their predictive errors in two farms. .

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