ACTA SCIENTIFIC AGRICULTURE (ISSN: 2581-365X)

Volume 3 Issue 2 February 2019

Review Article

Application Study: Biomechanical Overload in Agriculture

Daniela Colombini*

EPM International Ergonomics School, Milano, Italy

***Corresponding Author:** Daniela Colombini, EPM International Ergonomics School, Milano, Italy.

Received: December 03, 2018; **Published:** January 03, 2019

Abstract

This project has the goal of defining the basic criteria for producing a guide (Technical Report-TR) for the specific use of the ISO 11228 series, of ISO 11226 and of ISO TR 12295 [4-8] in the agricultural sector. Specifically, the project is aimed at providing the potential users with additional information on how to use existing standards in a world widespread working sector as agriculture where, also if with different characteristics, biomechanical overload is a relevant aspect, WMSDs occurrence is very high and where specific preventive actions are needed.

One of the main goals is therefore to provide all users, and particularly those who are not experts in ergonomics, with criteria and practical procedures for a correct risk analysis. Method as checklist OCRA, NIOSH, carrying, push and pull evaluation are used, applied to annual multitask analysis, through the use of original software by EPM IES, free download from www.epmresearch.org

Keywords: Agriculture; Biomechanical Overload; Multitask Analysis; Repetitive Movements; Manual Lifting; OCRA Method; TACOs Method; Pushing -Pulling

Purpose and justification

Agriculture is by far the biggest working sector in the world. It is estimated that 2.6 billion people or 40 percent of the world's population are farmers. Agriculture is one of the most hazardous sectors in both the developing and the developed worlds. WMSDs are caused mainly by manual handling, heavy physical work, awkward postures and repetitive movements. Increasing attention is being drawn to the application of practical actions in agricultural settings to help reduce work-related accidents and illness and WMSDs in particular. ISO 11226, ISO 11228 series and, more recently, ISO TR 12295 could be useful for this specific scope: experiences of application of these standards have been performed in different parts of the world, but rarely in agriculture.

Scope of proposed project and normative references

This project has the goal of defining the basic criteria for producing a guide (Technical Report-TR) for the specific use of the ISO 11228 series, of ISO 11226 and of ISO TR 12295 [4-8] in agricultural sector. Specifically, the project is aimed at providing the potential users with additional information on how to use existing standards in a world widespread working sector as agriculture where, also if with different characteristics, biomechanical overload is a relevant aspect and where preventive actions are needed.

One of the main goals is therefore to provide all users, and particularly those who are not experts in ergonomics, with criteria and procedures:

- To identify the situations in which they can apply the standards of the ISO 11228 series and/or ISO 11226 and ISO TR 12295 in different agricultural contexts (key-enter level).
- To provide a quick assessment method (according to the criteria given in the relative standard) to easily recognize activities that are “certainly acceptable” or “certainly critical”.

If an activity is "not acceptable because critical" it is necessary to proceed as soon as possible with the subsequent improvement actions. Where the quick assessment method shows that the activity risk falls between the two exposure conditions, then it is necessary to refer to the detailed methods for risk assessment set out in the relevant standard. This scope and approach is illustrated in the flowchart in figure 1.

Figure 1: The different risk assessment levels approach, present in ISO 11226 series for the part regarding biomechanical overload estimation [4-8].

General outline of the working process in annual multi-task analysis in agriculture: qualitative tasks distribution over the year and research of the homogeneous groups of workers.

Introduction and general structure of a multi-task analysis

Task rotation is when a worker alternates between two or more tasks during a certain period of time. In special situations, such as in agriculture, where the worker has to perform a large number of tasks and the tasks are distributed "asymmetrically" throughout the shift, risk assessments can become extremely complex. This is why it is necessary to carry out a thorough preliminary study of how the work is organized. At any rate, the risk analysis process involves a number of steps, listed further on.

The first step consists in defining the time required to complete the task rotation schedule. This is the macro-cycle time, which may be: daily, weekly, monthly, yearly. In agriculture, the cycle of alternating the tasks, it is most often an annual cycle, or depending on the weather, multi-annual (2 or 3 yearly harvests).

The annual multi-task analysis in agriculture: qualitative tasks distribution over the year and research of the homogeneous groups of workers.

In this contest, such as agriculture, it is necessary, for starting the risk process analysis, to define a set of procedures and criteria for estimating risk in more complex situations, where workers perform multiple tasks variously distributed in qualitative and quantitative terms over the year (annual cycle). The general risk evaluation process entails steps, where the two preliminary of them are listed here: a) analysis of work on a farm, in order to identify tasks performed in the period for obtaining a qualitative definition of work during each month of the year;b) identification of homogeneous group/s.

It is an anything but simple matter to identify farming tasks, which may be very numerous and performed by different workers or groups of workers. At the outset, therefore, it is necessary (as shown in Figure 2) to:

MACRO PHASES	PHASES	TASKS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
SOIL PREPARATION	SOIL PREPARATION	Plowing (tractor)												
		Installing irrigation system												
	SOW SEEDS/PLANT SEEDLINGS	Planting (manual)											40%	10%
		Planting (mechanical)											20%	90%
PRUNING	DRY PRUNING	Pruning large branches with chainsaws												
		Pruning wth manual shears										50%	5%	
		MMH of large branches										40%	30%	
	GREEN PRUNING	Pruning wth manual shears		70%	70%	60%	60%	60%						
		MMH of small branches		20%	20%	30%	30%	30%						
HARVESTING	HARVESTING	Manual harvesting on ground							45%	45%	45%			
		Manual harvesting on ladder							35%	35%	35%			
		MMH of ladder							10%	10%	10%			
TREATMENTS	SOIL FERTILIZING	Preparing machine to apply fertilizer												
		Driving tractor												
		Composting (manual)												
	CROP TREATMENT	Disinfection (manual)												
		Disinfection (tractor)												
OTHER TASKS	PUSH PULL	Push/pull trolley with large branches		5%	5%	5%	5%	5%				5%	5%	
		Push/pull trolley with small branches		5%	5%	5%	5%	5%				5%		
		Push/pull trolley with large branches							10%	10%	10%			

Figure 2: Example of semi-quantitative description of tasks (pruning and harvesting tasks) per month among homogeneous group of workers NO.1.

- Identify a specific farming;
- Break down the growing activities work into MACRO-PHASES and PHASES: all of the relevant tasks must be identified;
- List all the tasks required annually to grow and harvest the crop, regardless of who performs them: the allocation of tasks to workers (either on an individual basis or as a homogeneous group for risk exposure).

The same operation obviously can be carried out in several different ways; each method should be viewed as a separate task and listed accordingly. It is important to note that all the tasks performed on the farm over the year must be evidenced, including preparing the soil, applying fertilizers and disinfectants and other seemingly ancillary activities, regardless of who performs them.

The next step is to assign tasks to an individual worker or group of workers exposed to the same risk, to identify homogeneous groups. For each type of growing, tasks will be assigned to different groups of workers. When tasks of the same nature, duration and side are assigned to the same group of workers, we may speak of a homogeneous group in terms of risk exposure. A homogeneous group may sometimes be made up of just one person, if no other workers perform the same tasks qualitatively and quantitatively. For instance, typically (as presented in Figure 2), a single group of workers may be assigned the job of actually growing a crop (tasks may include pruning, harvesting, etc.: homogeneous group NO.1), whilst other workers prepare and disinfect the soil, apply fertilizers and so on (homogeneous group NO.2).The assignment of the tasks to a homogeneous group (or individual worker) even just qualitatively (or semi-quantitative as here), is absolutely necessary before proceeding with any level of risk evaluation. The Figure 2 shows (as example) all the tasks, subdivided by macro phases and phases that characterize the whole crop, highlighting the tasks actually performed by homogeneous group NO.1 during the entire year, broken down into each month.

Pre-mapping of danger and discomfort

Foreword

One of the latest developments being pursued by the World Health Organization (WHO) and other international organizations (ILO, ISO), in relation to preventing work-related diseases and disorders, concerns the creation of toolkits.

The main aim is to rapidly but accurately identify the presence of possible sources of risk, using instruments that can easily be used by accident prevention officers, occupational physicians, business owners, workers, trade union representatives and security services. However, this objective also reflects the criteria set forth in ISO/TR 12295 with respect to the risk of biomechanical overload.

Against this backdrop, the "problem" of WMSDs must be considered together with other occupational "hazards" (be they physical, chemical, or other), for the more general purposes of prevention. Aim here is to suggest a methodology and some simple tools for bringing together various parties to undertake a preliminary mapping of discomfort/danger (i.e. to identify risk sources in the work cycle) in the work place.

The tool does not pretend to replace the standard risk evaluation process, but to support such a process in order to identify hazardous situations in the work place, based on which to single out emerging problems that need to be submitted to a full risk assessment (in the appropriate order of priority). The procedure presented here demands a cooperative approach towards assessing and managing risk, as it also entails interviews with workers.

In accordance with the recommendations of the WHO three main criteria underpin the methodology:

- Globality: a global approach towards assessing the worker's discomfort, due to either the task or the work place;
- Simplicity: the methodology consists in an easy to use model for collecting data;
- Priority-Setting: the results obtained automatically via dedicated software and depicted clearly in bar graphs will not only help to identify problems but also offer a scale of priorities for conducting subsequent assessments (Figure 3).

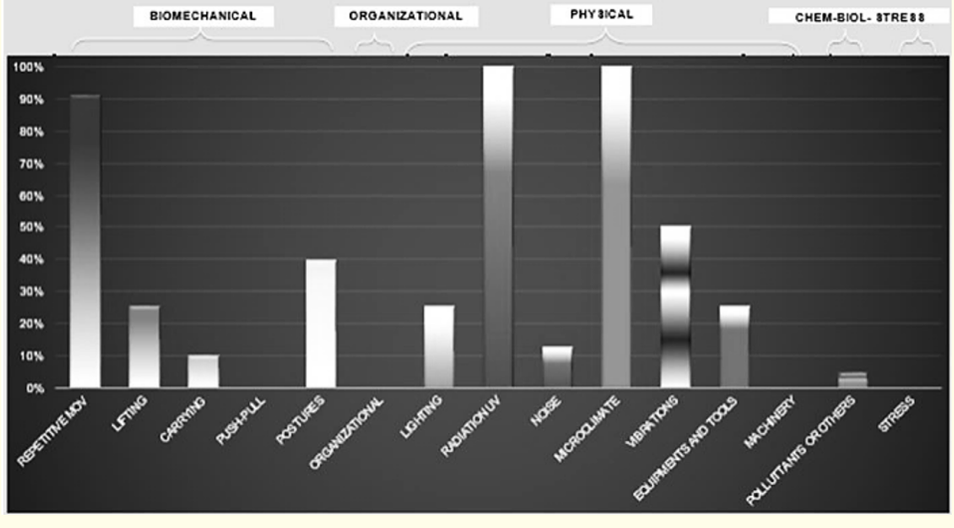


Figure 3: Final summary results generated automatically by the software, depicting histograms for all possible risks presented by homogeneous group NO.1 full time (example in Figure 2).

The pre-mapping models

Please note that the pre-mapping model should be given to interview for homogeneous groups of workers. The operation involves two levels of intervention before presented in Figure 1. The methodology consists in an easy to use computer-based model for collecting data (Excel spreadsheet): the EPMIES- ERGOCHECK premapEN () MULTIYEAR software can be free downloaded in Italian or English from www.epmresearch.org.

The model provides a general preliminary overview of all the main risk factors that may be present, regardless of the size of the manufacturing facility, and is underpinned by the basic tenets of ergonomics, entailing a global interpretation of the worker's discomfort deriving from the task or the work place [2]. The results of the pre-mapping exercises carried out via key enters and quick assessments can also be summarized graphically to more comprehensively define the "PRE-MAP" and corrective action priorities. Figure 3 shows an example of a summary of the results obtained from "pre-mapping" of the homogeneous group NO.1 full time: the figure shows the final summary results generated automatically by the software, depicting histograms for all possible risks. These histograms are merely descriptive scores, to be used to "rank" events from the best to the worst. The scores do not reflect an analysis or assessment of risk: they are simply descriptive scales designed to help not only to identify problems but also to set priorities for the analyses and evaluations that will have to be undertaken to adopt immediate measures to reduce risk, especially for conditions defined as "critical".

Analytical study of working process in annual multi-task analysis: the typical working day and the quantitative tasks distribution.

To switch from pre-mapping of discomfort and dangers (level 1 and 2), the actual assessment phase of the risk (Level 3), whatever the risk to be analyzed, it is necessary to deepen the organizational studies with data no longer just only qualitative but also quantitative. Three phases are necessary.

- Phase a – Description of a typical working day
- Phase b – Estimation of the total number of hours worked every month of the year
- Phase c – Assignment of tasks to a homogeneous group (or individual worker) and calculation of their proportional duration in each individual month.

Before going on to complete the organizational analysis of the risk-exposed worker or homogeneous group of workers, listed below are the exposure constants (Table 1) to which reference is made for calculating exposure time prevalence to various tasks and also for reconstructing the fictitious working day [2]. that will be representative of the whole year (see below). It has been found to be useful to adopt several exposure constants representing the typical exposure level for the industry.

Hours/day constant	**8**	Hours/month constant	**160**
Minutes/ day constant	**440**	Days! Month constant	**2**
Days week constant	**5**	Months / year constant	**11**
Minutes/week (440 min' 5 days) constant	**2200**	Days! Year constant	**220**
Weeks/month constant	**4**	Hours! Year constant	**1760**

Table 1: Exposure time constants essential to build the fictitious working day, representative of the work actually carried out during the year.

Obtained the duration of tasks in each month, we obtain the critical figure enabling the final risk to be evaluated: the total number of hours worked per year on each task by each member of the homogeneous group and the proportion of these hours to both the total number of hours worked and to the constant 1,760 hours/year.

Annual multitask risk assessment of biomechanical overload for upper limbs

To arrive at a final risk index with use of the OCRA method for multi-analysis tasks, it is necessary to proceed by the following successive steps:

- Phase a – Analysis of each individual task using the OCRA checklist to calculate the intrinsic score and prepare the "basic tasks risk evaluation" for each crop.
- Phase b - Application of mathematical models: preliminary preparation of "fictitious working day" representative of the whole year and of every month of the same year.

Two models are proposal for calculating the final exposure risk index: one based on the Time-Weighted Average and the other on the Multitask Complex, which has based on the most overloading task (calculated with respect to its actual duration), as the minimum exposure score that must be increased versus the score of the other tasks, taking their relative durations into account.

In order to apply them to annual and monthly exposure, as mentioned before, it has been necessary to convert the data relative both to the individual months and to the year into a fictitious working day, representative first of each month of the year and then of the full year [2].

Figure 4 compares, month-by-month, the checklist OCRA risk index obtained in two homogeneous groups (4a-homogeneous group working full time, eleven months; 4b-homogeneous group working on a crop for half of the year, but with very low risk for three out of the six months), using Multitask Complex model, as obtained automatically using the Excel template. Discrepancy between the scores obtained is quite remarkable. The interpretation of the results for the attribution of risk could be, in some case, problematic. It goes without saying that health surveillance findings proving the exposure risk index scores would be most welcome but, in these cases, with workers exposed to risk for only half of the year, it might be difficult to attribute a disease or disorder to occupational factors when the worker's activities in the other half of the year are unknown.

The TACOS method: contents and criteria for back and lower limbs posture analysis

As a general approach towards identifying and describing postures and posture duration, the following general rules were followed:

- Postures should not be identified and described for each part of the body and subsequently aggregated using ergonomic evaluation tools (RULA; REBA; OWAS);
- Overall postures for different body segments (various standing, sitting, squatting postures, etc.) have been defined using sketches and simple descriptions (Figure 5);

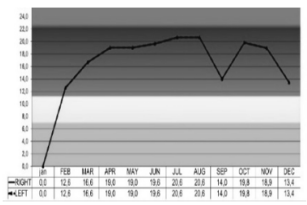
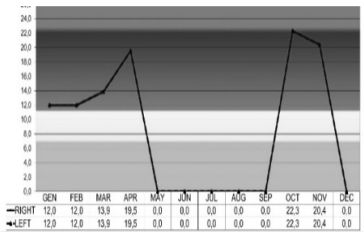
Multitask complex: Checklist OCRA right 15.8	Multitask complex: Checklist OCRA right 13,1
	
4a - Homogeneous Group A: 11 months working full time (7 hours a shift)	4b - Homogeneous group B: 6 months working, full time (7 hours a shift)

Figure 4: Risk index scores (for homogeneous group A, full time but working eleven months/year and B, full time but working seven months/year) plotted by month over the whole year using Multitask Complex formula.

- Postures must be identified by task, and each task will thus be defined by the posture(s) characterizing it.
- The duration of postures in each task can be readily measured with the help of pie charts depicting different risk scores; stopwatches are seldom required.

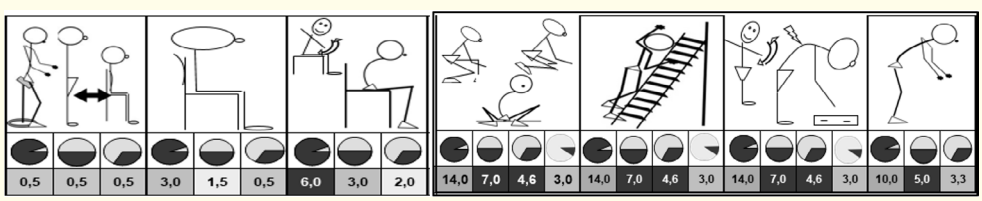


Figure 5: Some examples of the analysed postures, proposed by TACOs method, divided for body areas and their specific scores defined on the basis of the incongruity of the posture and its duration.

The figures help to group postures into 5 main categories: standing postures, sitting postures, postures primarily involving the lower limbs, complex (mixed) postures involving many parts of the body, and postures involving the cervical spine (Figure 5). Since the maximum score is 14, a series of 5 categories has been arbitrarily defined, each with a different colour, indicating the different degrees of awkwardness, also as a function of the duration of the posture [3]. The approach is adopted intrinsically for each posture and for the final outcome of the total task analysis.

The OCRA system analyses upper limbs awkward postures as one of a range of risk factors. It looks at the main joint segments of both the left and the right arm, defines at-risk postures and assigns different scores based on the region of the limb involved and the duration of the posture. In this method, considering the individual risk scores of the individual risk factors, it is clear that the contribution of the upper limbs posture factor to the final task score is about 50%.

As always, to start these studies with multitask exposure, you must have the intrinsic risk assessments of each of them (as if each task only lasted a standard shift). This is present both for the OCRA checklist, as well as for intrinsic postural risk, relative to the spine and lower limbs, obtained by the TACOs method.

Having the intrinsic risk scores and the duration of each task available for each task in the year, it becomes possible, with the same calculation models used for the OCRA checklist, to estimate the risk indexes for spine and lower limbs, both the Time-Weighted average and the Multitask Complex. The global result is presented also divided into four major areas) standing rachis, spine in sitting posture, lower limbs, head-neck. The final result illustrates also the proportional distributions of the different postures of the spine and lower limbs in their entirety [3].

Annual multitask risk assessment of manual material handling

In order to study the annual exposure risk for manual lifting of loads, it is necessary, as for other factors, to start from the quantitative organisational studies already set out before. Starting from Figure 1, as a starting point, dedicated to identifying the tasks performed during the year involving upper limbs repetitive tasks, we now have to activated only tasks where the MMC is present [8]. Tasks, with MMH present but without risk, are to be included, assigning them a standard risk value equal or less than 1 (acceptable risk, green band). Figure 1 shows the tasks in which MMC is present, their duration in hours, for each month of the year. Always following the same criteria used for other hazards that may cause biomechanical overload, we will calculate for each task, intrinsic risk, with the calculation techniques defined in ISO standards [5, 8]: for the analysis a day, defined as representative of the annual modal working days has to be used The tasks performed may be characterized by manual lifting of loads of type mono task, or composite task or variable task. There are no rotations between tasks of sequential task type (typical of work done on assembly lines or workbenches, with turn-over every few hours on 2-3, maximum 4 tasks in a shift) since, in general in agriculture, the operators perform the same tasks for several days, alternating their tasks mainly with the change of season. For this reason, when calculating the intrinsic indexes for MMH in agriculture, always use the frequency/duration multiplier for long duration [1,5]. The intrinsic values are calculated separately for adult male, adult female, younger/older male, younger/older female [1,5]. Now having the intrinsic risk indices and the proportional duration of each task, both within each month of the year and throughout the year, becomes possible calculate risk indices through the reconstruction of fictitious working days, representative of each month and of the year.

This procedure is the same as used for calculating exposure to repetitive movements with OCRA method and awkward postures of the spine (without load lifting) and lower limbs with TACOS method.

One examples of application are proposed in Figure 6, concerning MMH risk assessment in the homogeneous NO.1 group, full time contract (7 hours per shift), where the manual handling, when present, is less then all shift period: here only the Multitask Complex has to be used, the only suggested in NIOSH method.

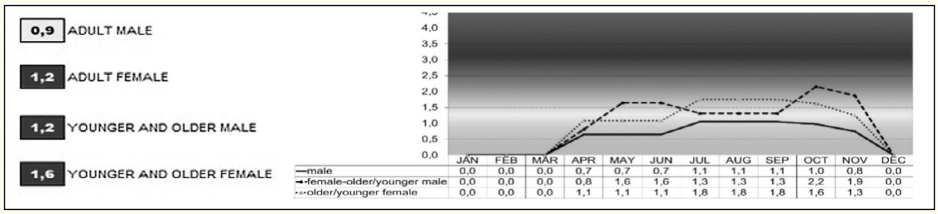


Figure 6: The MMH risk indices (homogeneous NO.1 full-time) calculated using the Multitask Complex model for each month of the year and the year after.

Annual multitask risk assessment of pushing and pulling

In order to study the annual exposure risk for manual pushing and pulling it is necessary, as for other factors, to start again from the quantitative organisational studies already set out.

Starting from Figure 1, as a starting point, dedicated to identifying the tasks performed during the year, we now have to activated only tasks where the PUSHING and/or PULLING are present [6]. Always following the same criteria used for other hazards that may cause biomechanical overload, we will calculate for each task, intrinsic risk [8]. Now having the intrinsic risk indices, hours and percentages of the duration of each task, both within each month of the year and throughout the year, becomes possible through reconstruction of fictitious working days, representative of each month and year, calculate risk indices. The procedure is the same as used for calculating exposure to repetitive movements and awkward postures of the spine (without load lifting) and lower limbs and MMH.

An example of application is proposed in Figure 7 concerning PUSHING and/or PULLING risk assessment in the homogeneous NO.1 group, full time contract (7 hours per shift), The calculation model, is only the Multitask Complex. as for MMH.

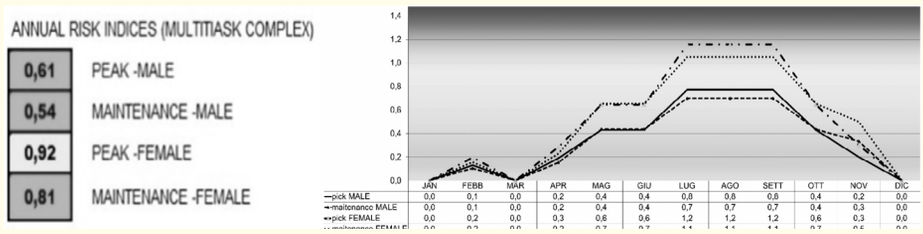


Figure 7: The PUSHING/PULLING risk indices (relative to the homogeneous group NO.1 full-time) calculated using the Multitask Complex model for each month of the year and the year after.

Annual multitask risk assessment of pushing and pulling

In order to study the annual exposure risk for manual pushing and pulling it is necessary, as for other factors, to start again from the quantitative organisational studies already set out.

Risk assessment of carrying

For this risk factor, as there are no computational models that can face multi-tasking at a cycle different from the daily one, you can limit the search for the homogeneous group and then evaluate for it the risk for: a) the most representative modal day of the year and its percentage of appearance in the year; b) the heaviest day of the year and its percentage of appearance in the year; c) the lightest day of the year and its percentage of appearance in the year. To address this analysis, we will use the relevant ISO standard [5,8].

Conclusion

This document discusses the complex procedures for addressing the biomechanical overload in agriculture, which includes the study of the risk of repetitive upper limb movements, manual lifting and awkward postures including lower limb and spine studies. Criteria and measurement methods already present in the ISO standards dedicated to biomechanical [4-8] have been proposed and adapted to the characteristics of agricultural work that involves a more frequent annual cycle organization, with exposure to more work tasks, which diversify qualitatively and quantitatively over the course of the year. Given the clear complexity of the risk assessment, it is suggested to start with a first qualitative and simple analysis (using the key questions and quick assessment) but extended not only to biomechanical risk factors but to all risks, so as to obtain a sort of global risk pre-mapping, which points out the presence of discomforts and dangers and with what priorities should be addressed the future more precise risk assessments. A simple tool to deal with this first phase of analysis is available. In all situations where the staff is unable to complete the evaluation phase of the real risk (small companies, etc.), they will obtain, by pre-mapping, at least one document that indicates the potential risk factors present and priority. This paper also discusses how to conduct the real risk assessment level, illustrating strategies for applying risk calculation methods (OCRA, NIOSH, TACOs, PUSHING and/or PULLING) adapted to analysis in agriculture, all published in specific manuals produced by the author [1-3]. Here too, a simple tool in available.

Bibliography

1. Colombini D., *et al*. "Manual lifting, a guide to study of simple and complex lifting tasks". CRC Press by Taylor and Francis, New York (2012).

2. Colombini D and Occhipinti E. "Risk analysis and management of repetitive actions: a guide for applying the OCRA system (Occupational repetitive actions)". CRC press by Taylor and Francis, New York (2016).

3. Colombini D and Occhipinti E. "Working Posture Assessment, The TACOs Method, Time-Based Assessment Computerized Strategy". In press by CRC Taylor and Francis, (2018).

4. ISO 11226, Ergonomics - Evaluation of static working postures.

5. ISO 11228-1, Ergonomics - Manual handling - Part 1: Lifting and carrying.

6. ISO 11228-2, Ergonomics - Manual handling - Part 2: Pushing and pulling.

7. ISO 11228-3, Ergonomics - Manual handling - Part 3: Handling of low loads at high frequency.

8. 8 ISO/TR 12295, Ergonomics - Application document for International Standards on manual handling (ISO 11228-1, ISO 11228-2 and ISO 11228-3) and evaluation of static working postures (ISO 11226).ISO 12100, Safety of machinery - General principles for design.

Volume 3 Issue 2 February 2019