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Ergonomics — The application of ISO/TR 12295, ISO 11226, the ISO 11228 series and ISO/TR 23476 in the construction sector (civil construction)

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National foreword

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Ergonomics — The application of ISO/TR 12295, ISO 11226, the ISO 11228 series and ISO/TR 23476 in the construction sector (civil construction)

Ergonomie — Application de l'ISO/TR 12295, de l'ISO 11226, de la série ISO 11228 et de l'ISO/TR 23476 dans le secteur de la construction (construction civile)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 3, *Anthropometry and biomechanics*.

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Introduction

Construction is one of the biggest working sectors in the world. The sector includes an immense diversity of skill sets and categories of workers. In addition, the size, structure and market of construction companies can also be extremely variable. The sector employs on average between 5 % to 10 % of the workforce in most countries, indicating that construction is a significant component of the global economy and is one of the largest employers in the world. Globally, musculoskeletal disorders are the major cause of work-related illnesses, accounting for more than 33 % of all occupational diseases, with the prevalence becoming 65 % for construction workers.[49] There are also indirect socio-economic implications due to job loss, absenteeism, health costs and even worker hospitalization.[29] There is no doubt that the prevention of work-related musculoskeletal disorders (WMSDs) can significantly contribute to reduce economic and social impact. Increasing attention is being drawn to the application of practical actions in construction settings to help reduce work-related accidents and illness and WMSDs in particular. ISO 11226, the ISO 11228 series and, more recently, ISO/TR 12295 and ISO/TR 23476 are useful for this specific scope.

Experiences in the application of these documents have been acquired in different parts of the world, but rarely in construction. This document extends the scope and methods included in existing standards to all the different construction, although the application experiences presented in this document are mainly based on the civil construction sector. Special attention is devoted to rendering this document accessible also to non-experts. Reference is made to easily applicable, non-commercial online tools (simple tools in spreadsheets) that can be useful for the purposes of this document, making possible the application of the criteria provided here and therefore the real numerical estimate of the biomechanical overload risks.

The ISO 11228 series, ISO 11226, ISO/TR 12295 and ISO/TR 23476 establish ergonomic recommendations for different manual handling tasks, repetitive movements and working postures. All their parts apply to occupational and non-occupational activities. The documents provide information for designers, employers, employees and others involved in work, job and product design, such as occupational health and safety professionals.

The ISO 11228 series consists of the following parts, under the general title *Ergonomics — Manual handling*:

— *Part 1: Lifting, lowering and carrying;*

— *Part 2: Pushing and pulling;*

— *Part 3: Handling of low loads at high frequency.*

ISO 11226 provides recommended limits for static working postures with no or minimal external force exertion, while taking into account body angles and duration.

ISO/TR 12295 serves as an application guide of the ISO 11228 series and ISO 11226. It offers a simple risk assessment methodology for small and medium enterprises and for non-professional active.

This document is intended to be used alongside ISO/TR 12295, ISO 11226, the ISO 11228 series and ISO/TR 23476, also in the construction sector, where the risk from biomechanical work overload from repetitive movements, from manual handling of loads, from towing and pushing carts and awkward postures is universally present.

The OCRA checklist method, in its multi-day cycle risk assessment version,[22] is currently the only risk assessment method available in literature capable of offering criteria and application experiences to address multitask analysis (supported by a specific simple tool in the form of free download spreadsheets for final risk calculation).

ISO/TR 12295 had already adopted this multitask method of exposure analysis.

After all, the development of a method capable of predicting the appearance of pathologies (real risk assessment method) can be optimized only after years of use and improvement. The development of

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a new TR which, offering evaluation solutions for biomechanical overload study in construction, can stimulate many more valid epidemiological studies in the future, is therefore desirable. The concept of doing nothing, while waiting for sufficient and perfect published methods, means not doing prevention.

The National Institute for Occupational Safety and Health (NIOSH) itself, due to the formula for calculating the lifting index (LI), changed the maximum limit value of its first formula several times over the years, through years of application experience. Recently the NIOSH added the formula for calculating the variable lifting index (VLI) for the evaluation of manual lifting tasks of complex loads, with many different weights and geometries.[21],[67] The gained experience in this type of analysis was introduced in ISO/TR 12295 and ISO 11228-1.

For the study of working postures it is important to point out the new time-based assessment computerized strategy (TACOS)[25] for posture, which adds to all the experience gained from the RULA and REBA methods and from ISO 11226, a more adequate timing assessment (therefore not only qualitative studies of work postures, but also studies of their real duration).

The mathematical criterion for the extension of the calculation of any risk factors for the study of biomechanical overload, not only for the working day cycle but also for cycles different in duration (e.g. annual cultivation cycles), was also discussed within a specifically activated writing group of experts for the preparation of this document. The transition is indispensable for the extension of the evaluation models already present in the specific International Standards (all used in this document) to the risk evaluation in multitask exposition with annual turnover needed for risk studies in construction (see Annex B).

Any other risk assessment methods that include a multitask analysis procedure can adopt the criteria here proposed, extending multitask annual exposure risk study, for instance to:

— repetitive movements (e.g. strain index, method present in ISO 11228-3);

— manual handling of loads (NIOSH formula in ISO 11228-1);

— application of ISO 11226, the ISO 11228 series and ISO/TR 12295 in the agricultural sector (ISO/TR 23476).

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Ergonomics — The application of ISO/TR 12295, ISO 11226, the ISO 11228 series and ISO/TR 23476 in the construction sector (civil construction)

1 Scope

This document is intended to be used alongside ISO/TR 12295, ISO 11226, the ISO 11228 series and ISO/TR 23476 in the construction sector.

This document (although the examples shown refer only to the civil construction sector) gives information on how existing standards can be used in a global sector, such as construction. Where biomechanical overload is a relevant aspect, albeit with different characteristics, work-related musculoskeletal disorders (WMSDs) are common and specific preventive actions are needed.

This document is intended to:

1) define the user(s) and fields for its application (including non-experts in ergonomics);

2) provide examples of procedures for hazard identification, risk estimation or evaluation and risk reduction in different agricultural settings, through:

   — more synthetic procedural schemes (main test);

   — more analytical explanations of the procedures, through mathematical models and application examples, and with the use of specific free simple tools in Annexes A, B and C.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 General outline of work processes in an annual multi-task analysis in civil construction

4.1 General structure of a multi-task analysis

Specifically, this document provides additional information to aid the user in the selection and use of the appropriate standards. Depending upon whether specific risks are present, it is intended to help the user to decide which standards to apply. It will include three levels of approach (Figure 1):

— First level: the participatory approach for pre-mapping of danger and discomfort provides all users, particularly those who are not experts in ergonomics, with criteria and procedures to identify situations in which they can apply the ISO 11228 series, ISO 11226 and ISO/TR 12295 as well as in agricultural settings (ISO/TR 23476): key-enter and key-questions level. Only in the early analytical

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stage is the opportunity offered to map, even if only using subjective data obtained by interviewing the workers (through the identification of groups of workers, homogeneous for exposure to occupational risks), all the occupational hazards and not just the risk of biomechanical overload.

— Second level: provides a quick assessment method (according to the criteria provided in ISO/TR 12295 and in ISO/TR 23476) for easily recognizing activities that are definitely acceptable or definitely critical. If an activity is neither definitely acceptable nor definitely critical, it is necessary to complete a detailed risk-assessment as set out in the standards, continuing with the necessary subsequent preventive actions.

— Third level: refer to detailed methods for risk assessment set out in the relevant standards when the quick assessment method shows that the activity risk falls between the two exposure conditions (definitely acceptable or definitely critical).

These approaches and scopes are illustrated in the flowchart in Figure 1 and are described in the main text of ISO/TR 12295.

At first the user is required to answer a short series of practical questions present in the first and second level. It is emphasized that the quick-assessment method is best implemented using a participatory approach involving workers in the enterprise (homogeneous groups of workers).

This involvement is deemed to be essential for effectively setting priorities for dealing with the different hazard and risk conditions and, where necessary, identifying effective risk reduction measures.

In construction, as well as in agriculture evaluation, it can be possible to limit the study to the first and second levels, obtaining sufficient data about occupational risk priorities.

The analytical risk assessment approach (third level) provides all users, especially those experienced in ergonomics, or familiar with the ISO 11228 series, with details and criteria for applying the risk assessment methods proposed in the original standards also to construction.

This analytical risk assessment approach is fully consistent with the methods proposed in the standards and does not introduce any changes in the criteria (mathematical model) for risk calculations, defined in the existing standards (as well expressed in ISO/TR 12295) but only adapts the proposed methodology to the risk assessment in construction

The proposed additional analyses aim to facilitate the use of the actual standards, making it possible to extend them to risk assessment in agriculture (ISO/TR 23476) and now, with many methodological analogies, also to construction (Annexes A, B and C present application examples in civil construction).

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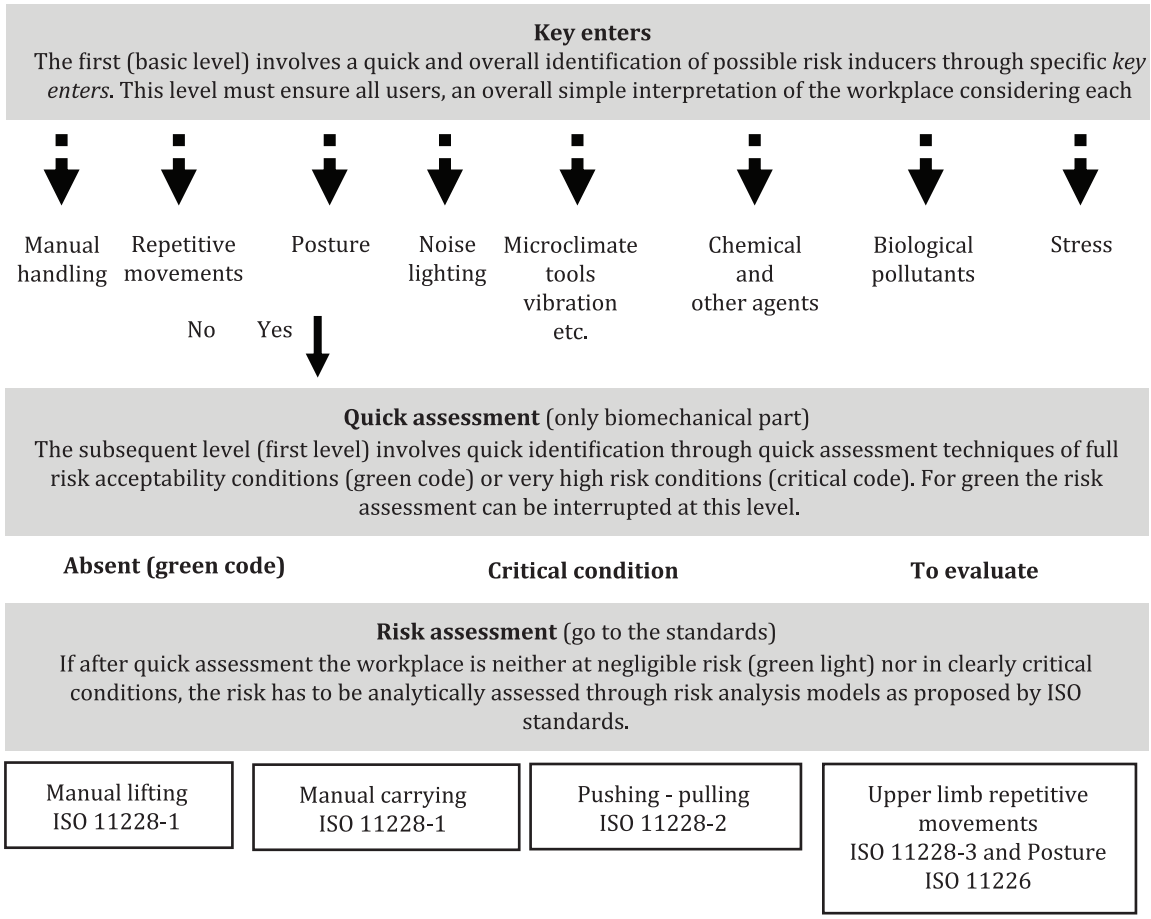

Figure 1 — Different risk assessment levels according to ISO/TR 12295 for biomechanical overload estimation

4.2 Study of tasks distribution over the year on groups of workers who are homogeneous in terms of risk exposure

4.2.1 General

Studying the organization of work in the construction sector, the basis for comprehensively addressing the study of exposure risk is certainly very complex. In this work, while evaluation criteria and techniques can be extended to all sectors that characterize construction, the application examples presented here refer to the civil construction sector.

Table 1 summarizes the main macro-phases that characterize the civil construction sector, which can be summarized even more briefly in eight main construction phases: ground preparation, excavation of foundations and their reinforcement; construction of vertical and horizontal support structures (pillars and support beams); flooring construction; construction of internal and external walls; re-embossing and finishing of internal and external walls and floors with mortar; external coatings and internal whitewashing; laying pipes for electrical systems; roof construction.

The study of the finishes of civil constructions with the installation of all the necessary systems, such as plumbing, electrical, heating or the laying of interior coverings (wood tiles), has been deliberately neglected, since each of these works presents its own specific risk professional.

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Table 1 — Main macro-phases and work phases present in the civil construction sector

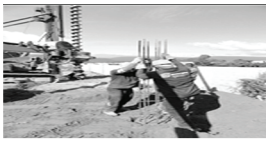
Macro-phases	Phases	
supplies	cranes — pallets trucks — wheelbarrows	
work tools	— jack hammer — planer — drill — float — hammer — trowel — screwdriver — crowbar — line level — spade	
foundation excavation and armour	— initial preparation of the soil — delimitation of building site -excavation and drilling — land compaction-positioning foundation armour, beams, pipes	
building vertical support supplies	— preparation of wooden panels construction and assembly shapes and frames in wood for pillars and beams	
building horizontal supports: floors/ceiling	— laying support material floor/ceiling assembly piping installation — concrete distribution-disassembly of wooden structure	
wall construction with bricks; electrical installations	external and internal wall construction with bricks — electrical installations	

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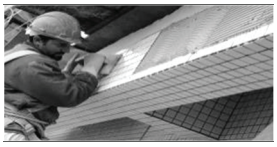
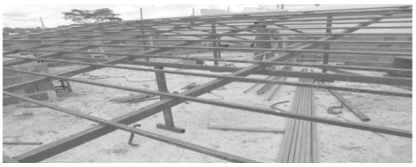
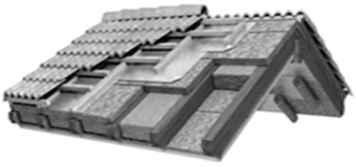
Table 1 *(continued)*

Macro-phases	Phases	
mortar application and finishing	facade coating – external and internal wall, beams and pillar, window, doors, ceiling with mortar — finishing; floor levelling mortar -waterproofing	
external and internal coating (painting or other)	— different external coating — internal coating (painting or other	
roof assembly	roof assembly -structure	 

In a setting such as construction, before starting a risk analysis it is necessary to define a set of procedures and criteria for estimating risk in 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 a certain number of steps, beginning with:

a) identification of the macrocycle of the many different tasks;

b) analysis of construction site to identify tasks performed within the period and obtain a qualitative definition of the work during each month of the year;

c) identification of one or more homogeneous groups.

4.2.2 Macrocycle duration

Task rotation is when a worker alternates between two or more tasks during a certain period of time; this situation occurs quite often in modern work organizations and, if properly designed, can represent one of the most effective strategies for reducing the risk of biomechanical overload.

In situations, such as in construction, where the worker has to perform a large number of tasks and the tasks can be distributed asymmetrically over 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 different 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 can be daily, weekly, monthly or yearly.

The types of macrocycles durations are infinite, but if there are no simplification criteria that allow the risk to be estimated, every risk assessment stops and nothing is done (the excuse being that the mission is impossible).

The modal macro-cycle periods appear to be, at least in the sectors of agriculture, building construction and services, accurately representative of job cycles. In civil construction, task rotations are typically annual, but one can use annual cycles even when multiple cycles of fewer months in each year are repeated identically. In the construction sector there is generally a yearly cycle for large construction sites, but a monthly cycle (modal) is more frequent in smaller-scale constructions and civil engineering

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projects. In other sectors (e.g. logistics for retail chains, cleaning services, food preparation facilities), the most common rotation scenario is monthly, while in yet other situations (e.g. supermarkets) tasks can be rotated on a weekly or, occasionally, a monthly basis.

In summary, some practical options are provided here for using the predefined macro-cycle (weekly, monthly, yearly), thus certainly simplifying subsequent evaluations:

— If several identical sub-macro-cycles are repeated over the year, the annual macro-cycle can be used.

— If several identical sub-macro-cycles (e.g. week, fortnight) are repeated within the month and if the following months are similarly repeated, the monthly macro-cycle can be used.

Whichever macro-cycle duration is chosen, the criteria and procedures for dealing with the biomechanical overload risk analysis are the same. Given the extreme activity variability, the procedure is, however, to identify and evaluate representative modal scenarios.

4.2.3 Phase and task identification

It is not simple to identify farming tasks, which can be very numerous and performed by different workers or groups of workers. At the outset, therefore, it is necessary to:

a) identify the specific worksite (e.g. civil and road construction sites, demolitions, renovations);

b) break down the worksite activities into phases; all relevant tasks must be identified inside each phase.

The same activity can be carried out in several different ways; each operating method is intended to be viewed as a separate task and listed accordingly (e.g. plastering with short trowel, with spoon, with projector, with long level).

It is important to note that all the tasks performed at the farm over the year have to be evidenced, including preparing the soil, applying fertilizers and pesticides and other seemingly ancillary activities, regardless of who performs them.

As it is so inherently difficult to identify phases and tasks in the construction sector, a kind of universal civil construction system has been developed that will enable even beginners to conduct a preliminary organizational analysis. This universal structure could also be extended to the study of other construction sectors, but additions will certainly be necessary to make it more specific.

It consists of a list of phases, including those ancillary to the actual construction of the building, for example all material transportation mechanized or not, demarcation of the construction in the site, excavation with drilling equipment preparation of wooden panels or removal of wood shapes from the foundation, see Table 2.

Table 2 — Principal tasks characterizing a universal civil construction system

Macro-phases	Phases	Tasks
common tasks at all stages	mechanized	crane operation - street level
	material transportation (aa)	operation with high cab crane
		transport with electric pallet
		transport with manual pallet
		transport with 4-wheel cart
		transport with 2-wheel cart
		transport with mason wheelbarrow

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Table 2 *(continued)*

Macro-phases	Phases	Tasks
	manual transportation: weight per person. (ag)	manual transportation weight kg = inf. 3 manual transport weight kg = 4 to 7 manual transportation weight kg = 8 to11 manual transportation weight kg = 12 to15 manual transportation weight kg = 16 to 25 manual transportation weight kg = 26 to40 manual transport weight kg = 4 to7 (head or shoulder) manual transport weight kg = 8 to11 (head or shoulder) manual transport weight kg = 12to 15 (head or shoulder) manual transport weight kg = 16 to25 (head or shoulder) manual transportation weight kg = 26 to40 (head or shoulder) manual transport weight kg = sup 40 (head or shoulder)
work tool	working tools	drill pneumatic hammer electric screwdriver electric cutter milling machine hammer cutter circular saws hand cutting saw alternative saws screwdriver manual pliers and other like it
foundation excavation	delimitation of building site (plant) with reference points	marking of reference points manual fixing of the wooden props to the ground fixing side boards in the jig with nails plumb line positioning to delimit the foundations
	initial preparation of the soil	excavation of land with tractors levelling/ backfilling ground with tractors
	excavation with drilling equipment	positioning drilling equipment check excavation with rotary drilling tool manual removal of land near the machine drilling
	positioning foundation armour positioning of foundation beams	positioning of the armour irons inside the holes of the foundation construction of connection beams with wood and concrete castings homogenization of concrete with vibration equipment
	removal of wood	manual removal of wood shapes from foundation beams
	manual excavation for pipes	manual excavation for passage of underground pipe
	land compaction	land compaction with specific vibrating tool

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Table 2 *(continued)*

Macro-phases	Phases	Tasks
support supplies	preparation of wooden panels (shapes)	receiving and sending spare parts for storage and cutting areas
		align, cut, adjust parts
		cut panels according to the project
		number of panels according to the project
		storage of panels in a clean area
		preparation of the pillar forms
		preparation of beam shapes
		prep. external wooden panels with cutter
		waterproofing wood shapes
	wood panel (shape) installation	angular anchorage support for wooden pillars
		waterproofing application in pillar forms
		installation of wood shapes on the floor
		installation of internal forms
		installation of external security armour
	construction wood shapes for pillars (formwork)	placement of armour in the pillar
		assembly of the pillars wooden form
		pillar filling with concrete
		homogenization of concrete with vibrator
		removal of wood forms of pillar
	beam assembly	placement of armour within the shape of beams
		assembly of beam shapes with wooden form
		pillar filling with concrete
		homogenization of concrete with vibrator
		removal of wooden beam shapes
building floors/ ceiling	laying support material	placement of punches
		placement of cross beams
		placement of panels, prefabricated beams and special bricks
	floor/ceiling assembly (pre-manufactured)	prefabricated slab positioning
		transport and positioning of the electro-welded network
		fixing of the electro-welded network
	piping installation	preparation of cable and tube passage - (electric)
		transportation of pipes and cables
		pipe cutting and insertion
		fixing the tube in the electric passage box
	concrete distribution	automatic pump driver operator of concrete launch
		filling slab with concrete using bucket
		filling slab with concrete using pump
		homogenization with vibrator
		wet concrete with water barrel
		spreading concrete with shovel
		concrete levelling with metallic ruler
		concrete levelling with laser level

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Table 2 *(continued)*

Macro-phases	Phases	Tasks
	disassembly of the structure	shoring removal
		formwork removal with crowbar
wall construction with bricks	external and internal wall construction with bricks	preparation of cement mortar
		lift brick wall 0 kg to 3 kg (low-medium-high)
		lift brick wall 4 kg to7 kg (low-medium-high)
		lift brick wall 8 kg to11 kg (low-medium-high)
		lift brick wall 12 kg to 15 kg (low-medium-high)
		lift brick wall 16 kg to 25 kg (low-medium-high)
		lift brick wall sup 25 kg (low-medium-high)
		using plumb-line in the construction of wall
		using bubble level tool
		side jamb installation
		installation jamb to window
mortar application and finishing	facade coating - external	cement mortar application with projector
		external coating and finishing with trowels and floats
		smoothing with rod
		cement mortar application - external - with scaffolding
	internal wall, beams and pillar, window, doors, ceiling mortar	internal wall covering with projector
		external coating and finishing with trowels and floats
		smoothing with rod
		spreading running pasta (thin) with roller
	finishing	smoothing with spoon
		smoothing with rod
		small defects closure with trowel
	floor levelling mortar	spreading and flattening cement mortar with hand tool
		spreading adhesive mortar with toothed spatula
		placement of ceramic on floor
		performing joint
waterproofing	waterproofing	waterproofing with liquid blanket
electrical installations	electrical installations -	electrical installation: piping
		electrical cable installations in the slab
external coating	external coating	adhesive application (special mortar)
		laying the coating on the adhesive
	other	other external coating application
internal coating (painting)	internal painting	application of the wall putty
		drywall sanding wall putty
		application of the sealant or preparatory base
		roller paint application
		brush paint application
roof assembly	roof assembly -structure	structure assembly
		manual parts handling (see manual transportation)
		cover assembly (electric screwdriver)

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4.2.4 Identification of the different homogeneous groups

The next step is to assign tasks to an individual worker or group of workers exposed to the same risk, to identify homogeneous groups. Since the focus of the analysis is the exposure of workers to a set of conditions determined by the tasks they are assigned to perform, it is first necessary to identify which homogeneous group of workers are present that need to be examined.

The homogeneous group of workers for risk exposure (as groups of workers homogeneous for working risks are being defined, not groups of people homogeneous for other factors, such as weight, age, culture or gender) is the group of workers that performs the same tasks, in the same workplace and with similar durations (or time patterns) during the selected period (macro-cycle).

Note that a homogeneous group can sometimes be made up of just one person, if no other workers perform the same tasks qualitatively and quantitatively.

Moreover, if two groups of workers perform the same tasks in the same workplaces but with different durations or time patterns (e.g. one group works full-time and the other works part-time) the two groups must be analysed separately.

The homogeneous groups that can be identified in a construction site can be very numerous: by way of example, in Tables 3 and Figure 2, three groups are presented, different in terms of tasks performed and duration. Table 3 reports the distribution in % of tasks duration in different months of the year in different homogeneous groups; Table 4 describes the representation of task duration in % in different months of the year where grey area indicates when 100 % of the constant is exceeded.

The assignment of the tasks to a homogeneous group (or individual worker) even just from the qualitative standpoint (or semi-quantitative as here), is not difficult but it is absolutely essential before conducting the first levels of risk evaluation (key questions and quick assessment level).

To determine the real risk exposure (risk assessment level) it is necessary to study a quantitative description of all active tasks.

Only after this organizational analysis can the different risk levels be assessed in terms of repetitive movements, manual load handling, awkward postures and pushing-pulling.

Table 3 — Distribution in % of task duration in different months of the year in different homogeneous groups

All the repetitive tasks	Breakdown of the task duration for each month of the year											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Homogeneous group no.1: distribution of concrete (floors, columns, beams)												
hours worked per month		220		200		220	220	200		195		220
floor filling with concrete		15 %		15 %		15 %	15 %	15 %		15 %		15 %
concrete vibrator homogenization		5 %		5 %		5 %	5 %	5 %		5 %		5 %
filling with concrete		15 %		15 %		15 %	15 %	15 %		15 %		15 %
homogenization with vibrator 20 mm - 40 mm		5 %		5 %		5 %	5 %	5 %		5 %		5 %
pump operator guide launches concrete		10 %		10 %		10 %	10 %	10 %		10 %		10 %
emptying concrete with cement mixer		10 %		10 %		10 %	10 %	10 %		10 %		10 %
spreading concrete with shovel		10 %		10 %		10 %	10 %	10 %		10 %		10 %
homogenization		3 %		3 %		3 %	3 %	3 %		3 %		3 %
insured vibrator extension		1 %		1 %		1 %	1 %	1 %		1 %		1 %

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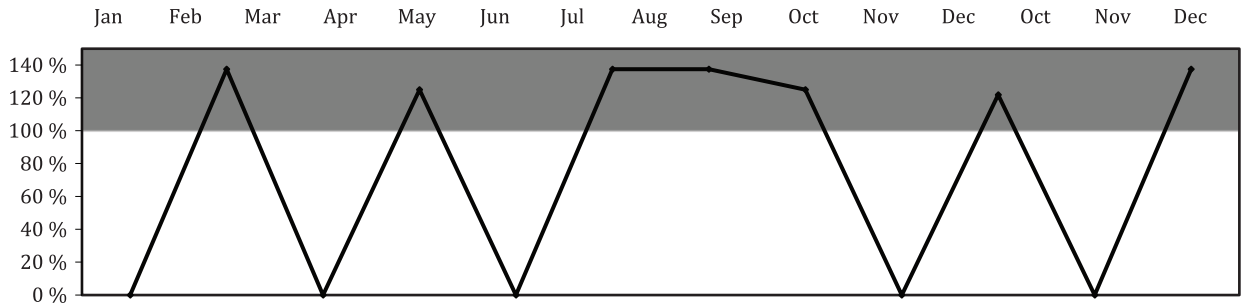
Table 3 *(continued)*

filling slab with pumped concrete		10 %		10 %		10 %	10 %	10 %		10 %		10 %
concrete spreading with hoe		10 %		10 %		10 %	10 %	10 %		10 %		10 %
concrete level with metal ruler		5 %		5 %		5 %	5 %	5 %		5 %		5 %
levelling with laser (reinforced concrete)		1 %		1 %		1 %	1 %	1 %		1 %		1 %
		100 %		100 %		100 %	100 %	100 %		100 %		100 %
Homogeneous group no.2: walls construction												
hours worked per month			220	200	200	190	195	200	200	200	200	200
control crane			5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %
manual pallet transport (strong force)			5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %
transport with wheelbarrow (moderate force)			5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %
transport with wheelbarrow (strong force)			5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %
preparation to block discharge			10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %
mortar preparation			10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %
lift wall brick inf 3 kg			10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %
lift wall 4 kg to 7 kg (low - medium - high)			15 %	15 %	15 %	15 %	15 %	15 %	15 %	15 %	15 %	15 %
lift wall brick 8 kg to 11 kg (low-medium-high)			15 %	15 %	15 %	15 %	15 %	15 %	15 %	15 %	15 %	15 %
use plumb			10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %
level use			10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %
			100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
Homogeneous group no.3: preparation internal wall for painting												
hours worked per month							220	220	220	220	200	200
transport weight 16 kg to 25 kg							5 %	5 %	5 %	5 %	5 %	5 %
spread fine mortar with a roller							10 %	10 %	10 %	10 %	10 %	10 %
fine mortar sanding							10 %	10 %	10 %	10 %	10 %	10 %
finishing with floats (in instable position)							15 %	15 %	15 %	15 %	15 %	15 %
coating with fine mortar with floats (in instable position) -							15 %	15 %	15 %	15 %	15 %	15 %
fine mortar coating with projector							15 %	15 %	15 %	15 %	15 %	15 %
coating with fine mortar with floats							15 %	15 %	15 %	15 %	15 %	15 %
finishing fine mortar with floats							15 %	15 %	15 %	15 %	15 %	15 %
	0 %	0 %	0 %	0 %	0 %	0 %	100 %	100 %	100 %	100 %	100 %	100 %



a) Homogeneous group no.1: distribution of concrete (floors, columns, beams)

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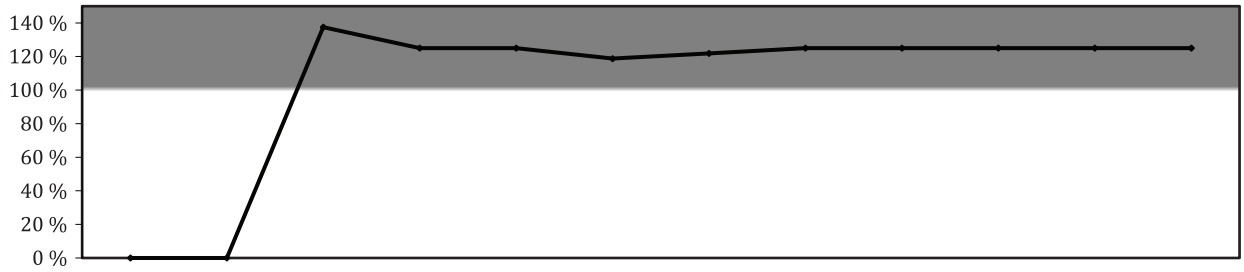
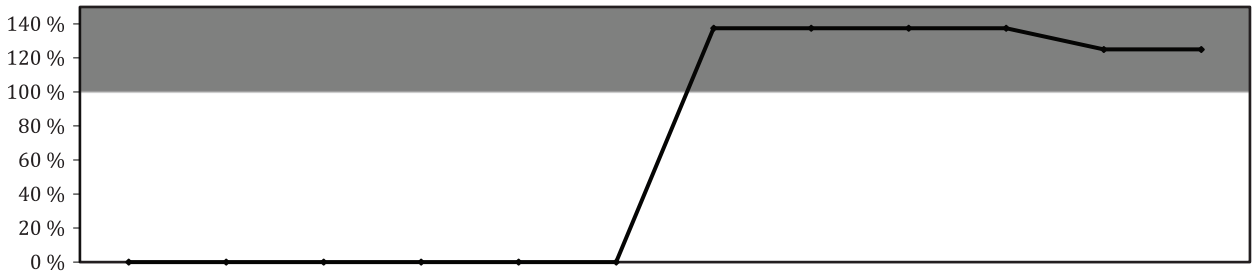


b) Homogeneous group no.2: walls construction



c) Homogeneous group no.3: preparation internal wall for painting

NOTE Grey area indicates when 100 % of the constant is exceeded.

Figure 2 — Representation of task duration in % in different months of the year where grey area indicates when 100 % of the constant is exceeded

5 First levels: pre-mapping of danger and discomfort through key questions and quick assessment

5.1 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.[9],[10],[18],[20],[27],[28]

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, as mentioned in Annex A. In Annex A, all the criteria and methods used for the pre-mapping are presented again but in greater detail and through real examples. The presented results have been obtained with specifically prepared simple tools. Against this backdrop, the problem of WMSDs can be considered together with other occupational hazards (e.g. physical, chemical), for the more general purposes of prevention.

The aim here is to suggest a methodology and some simple tools (free downloadable calculation sheets[64]) to undertake a preliminary mapping of discomfort or danger (i.e. to identify risk sources in the work cycle), especially in small and very small businesses. The simple tool is not designed to replace the standard risk evaluation process, but to support such a process in order to identify hazardous situations in the workplace, to single out emerging problems that need to be submitted to a full risk assessment, in the appropriate order of priority. The simple tool is primarily designed to be used by employers and work safety officers, but it can also be useful for:

— medical staff conducting periodical inspections and drafting health surveillance protocols;

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— work safety officers periodically monitoring hazardous situations in the workplace;

— supervisory bodies (labour inspectors) conducting inspections in the workplace, needing to rapidly detect potentially dangerous situations requiring specific preventive interventions;

— trade union representatives.

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 workplace;

— 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 and ergonomic redesign.

5.2 The pre-mapping model

Please note that the pre-mapping model (presented in greater detail in Annex A) must be used through the interview of workers of each homogeneous group (i.e. groups of workers exposed to the same occupational hazards).

This step entails two levels of intervention (Figure 1):

— level one: a rapid and general identification of possible risk inducers via the use of specific key-enters and key questions.

The first level is broken down into several boxes relating to the main types of risks, for example handling loads, repetitive movements of the upper limbs, postures, noise, microclimate, chemicals, organization of work and stress. This preliminary level ensures that anyone can simply and generally observe the workplace and respond to the expected closed-ended questions by interviewing the workers. The main highlights of the model are described in Annex A.

— level two: quick assessment (only for studying biomechanical overload).

Quick assessment consists in a rapid identification of acceptable risk (using the traffic light colours), indicated as green when risk is absent, red when very high and purple when critical. Quick assessment procedure produce the following information:

a) if the situation is code green (green light) the quick risk assessment process can stop here because it means that there is no meaningful occupational risk;

b) if a critical code (purple light) is detected, then there is definitely a significant occupational risk and immediate corrective action is required;

c) if the quick assessment finds that the risk level at the work station is neither acceptable (green light) nor critical (purple light), and therefore the situation is intermediate (potentially code yellow or red), then the risk assessment has to be carried out, using the analytical methods suggested by International Standards or the accredited literature (third level).

To simplify as far as possible this kind of approach, the criteria and methodology were included in an easy-to-use computer-based model (the first specific simple tool) for allowing users to collect data in the correct way through close questions and to obtain an automatic evaluation of them.

The first specific simple tool for pre-mapping construction with ERGOCHECK can be downloaded free of charge.[68]

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The compilation has to be done through the answers provided by the workers involved in each homogeneous group, homogeneous by occupational exposure (one spreadsheet, one homogeneous group). It is a matter of drawing information on work-related distress through their collective subjectivity. The study of the results of the collective hardships provides the priorities, emerging from the level with which the various problems were indicated, useful for the subsequent real evaluative interventions.

Compared to the concern of not taking into account the different anthropometric parameters[35] that characterize the different construction populations of the world (e.g. body weights, heights, body structures from thin to muscular), at this stage of pre-mapping, the reported discomfort for exposure to the various risk factors is estimated through the study of the collective subjectivity of the homogeneous working group.

As an example, in a group of workers (homogeneous for risk exposure), both people with small and lean anthropometric parameters and more robust workers can be present. Only the smaller and leaner workers report greater discomfort during the lifting of the same load, but not the more robust workers. The result of the collective subjective study will confirm manual material handling (MMH) as a priority risk factor, based on the smaller and leaner worker.

In this way, through the subjective verification of collective distress, the effect of anthropometric parameters on the work performed is taken into great consideration in determining the priorities for subsequent improvement interventions.

The results of the pre-mapping exercises carried out via key-enters, key questions and quick assessments is also summarized graphically to more comprehensively define the pre-mapping and corrective action priorities. The programmed spreadsheet, described previously, generates this summary automatically.

Figure 2 shows an example of a summary of the results obtained from the pre-mapping of homogeneous group 1 (a: full-time and b: part-time 4 hours a day) and Figure 3 shows the results for homogeneous group 2 (full-time), whose job organizations are described in Table 3 and Table 4, respectively. Figures 2 and 3 show the final summary generated automatically by the software, depicting histograms for all possible risks. The height of each histogram corresponds to the percentages resulting from Formula (1).

$$(P_{Li}/P_{Mi} \times 100 \times W) \quad (1)$$

where

P_{Li} is the score for each risk inducer;

P_{Mi} is the predefined maximum inducer score;

W is the time-weighted percentage as a proportional time length to estimate the real risk factor duration in the year compared to a predefined constant. (W = 100 % when the risk factor is present for 11 months per year, 7 h to 8 h per day, 5 or 6 working days per week).

These are merely descriptive scores, to be used to rank events from the best to the worst. The scores do not define the 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 have to be undertaken to adopt immediate measures to reduce risk, especially for conditions defined as critical.

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6 Analytical study of work processes in annual multi-task analysis: description of a typical working day for each month and quantitative task distribution over the year

6.1 General

To switch from the pre-mapping of discomfort and dangers (first and second levels) to the actual risk assessment phase (third level) for all risks, it is necessary to undertake in-depth organizational studies, utilizing not only qualitative data but also quantitative data.

In this clause all the procedures necessary for the evaluation of the most typical biomechanical overload risks (repetitive movements and manual lifting) are explained through the use a real representative example of wall in civil construction, made up of few tasks (the same homogeneous group 2 presented in Table 3). In Annex B, all the criteria and methods, mathematical formulae used for the risk assessment of repetitive movements and manual lifting are presented in greater detail,[21],[23],[30],[34],[35],[36],[37],[50],[51] [63],[64],[65],[66],[67] also through real examples derived from a big civil construction worksite.

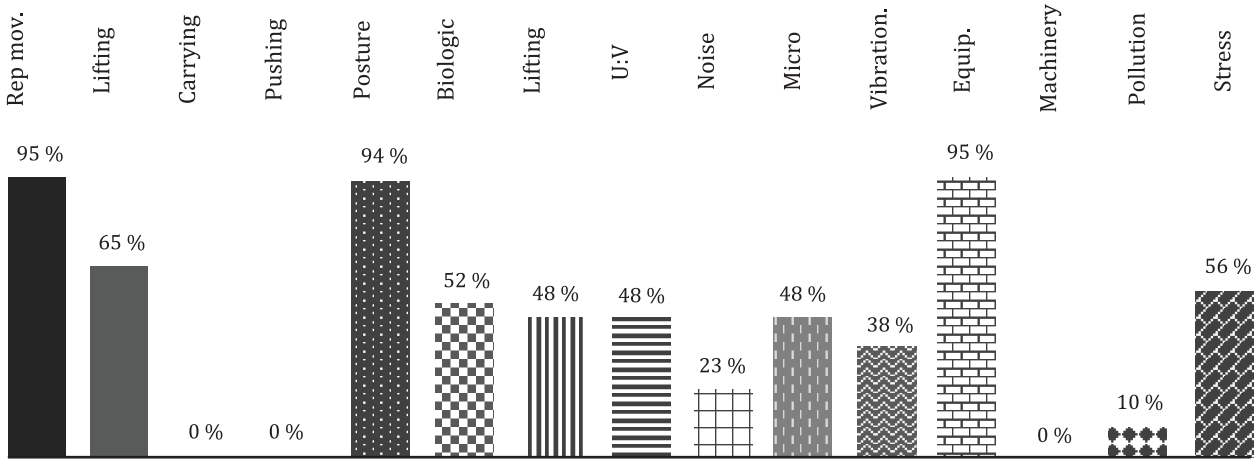
The results presented have been obtained with specifically prepared simple tool, which is discussed in this clause. In fact, considering the amount of data to be collected and written in an orderly manner and the number of calculations to be done with the use of complex formulae, another specific simple tool was built to make reliably easy and possible such risk assessments and overcome the inherent difficulties mentioned,[69] available as a free download.

After all, IEA and WHO have been recommending for years to offer those who do prevention, not only evaluation criteria but also simple tools to simplify the final risk evaluation.

To complete the risk assessment as level third, three phases are necessary.

6.2 Phase A – Description of a typical working day

The description of a representative typical or modal working day, representative of each month, is required to start the analysis (Table 4). It is obvious that in construction, the net duration of a shift can vary depending on the weather. This is why the organizational structure of a modal day (i.e. the one that appears most frequently during each month of the year) has to be described. The analysis records, for example, the duration of shifts and the number and duration of pauses in order to obtain the net duration of work (net duration of work in the shift).



a) Homogeneous group 1 — full-time (data from Table 3)

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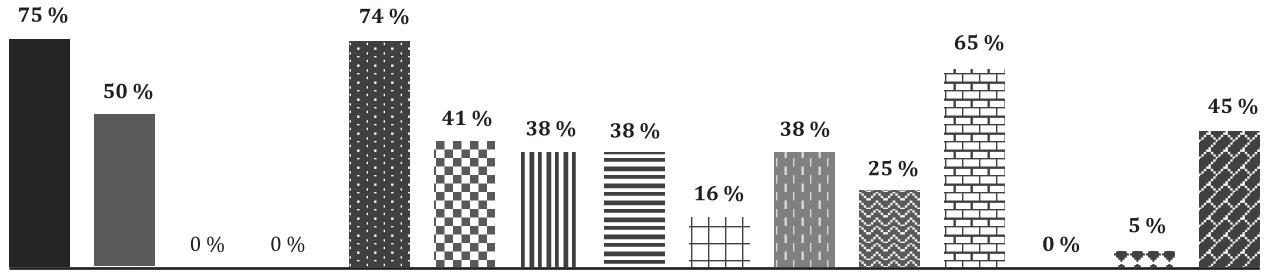
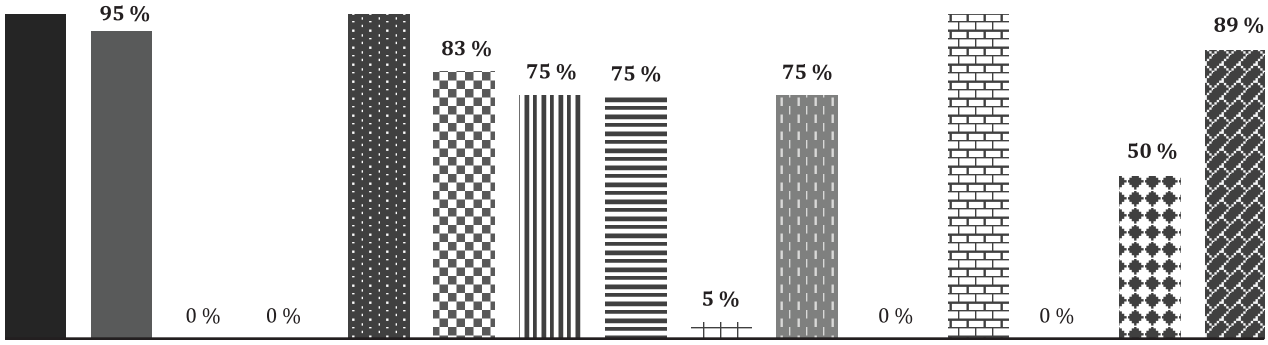


b) Homogeneous group no.1 — part-time only (4 h a day)



c) Homogeneous group no.2 (data from Table 3)

Figure 3 — Final summary of results, depicting histograms for all possible risks for homogeneous group no.1: distribution of concrete and homogeneous group no.2: wall construction (see example in Table 3)

Table 4 — Description of a typical working day representative of each month to study the modal net duration of repetitive movements (homogeneous group no.2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shift duration	-	-	480	480	480	480	480	480	480	480	480	480
No. actual breaks duration of more than 8 min (excluding lunch break)	-	-	2	2	2	2	2	2	2	2	2	2
Actual duration of the pause (excluding lunch break)	-	-	30	30	30	30	30	30	30	30	30	30
Duration lunch break if this is inside the shift (the technical name is "paid lunch".	-	-	60	60	60	60	60	60	60	60	60	60
Shift is held consecutively (i.e. without interruptions, for example due to a change of workplace)	-	-	X	X	X	X	X	X	X	X	X	X
Number of interruptions only if the duration is equal to or higher than half an hour (e.g.: not paid lunch break)	-	-	-	-	-	-	-	-	-	-	-	-
Total actual pause duration present in working time			90	90	90	90	90	90	90	90	90	90
Putting on or taking off work clothes	-	-	5	5	5	5	5	5	5	5	5	5
Cleaning	-	-	10	10	10	10	10	10	10	10	10	10
Other: time to reach workstation	-	-	10	10	10	10	10	10	10	10	10	10
Other:	-	-	20	20	20	20	20	20	20	20	20	20
Total minutes of non-repetitive tasks in shift	-	-	45	45	45	45	45	45	45	45	45	45
Net repetitive working time (minutes)	-	-	**345**	**345**	**345**	**345**	**345**	**345**	**345**	**345**	**345**	**345**

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6.3 Phase B – Estimation of total number of hours worked every month of the year

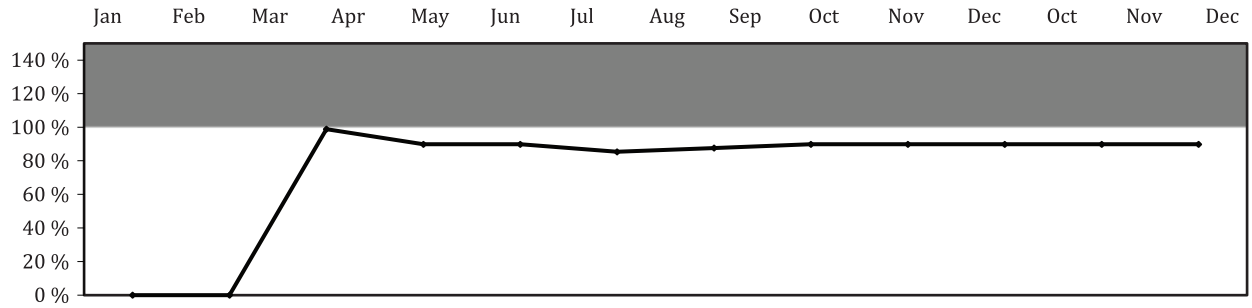
In order to make this estimation, the following information is necessary (Table 5): the number of hours worked every month by the entire homogeneous group for the total number of tasks. This information is readily available on the farm as it is required to calculate the cost of the active workforce.

Since the aim is to obtain the number of hours worked by each member of the homogeneous group, the number of workers present in the whole homogeneous group has to be described. Figure 4 provides a graphic depiction of the hourly distribution of work over the various months of the year.

In the graph (Figure 4), when the threshold of 160 h/month/worker (defined month constant) is passed, the ratios enter the critical zone (100 % of the constant is exceeded: grey colour). The example shows an uneven distribution of working hours over the various months of the year, with some months where the hours are below the constant and others where they are above (these months often correspond to the harvest). Harvesting requires speed and also the addition of seasonal workers is often required.

Table 5 — Estimation of number of hours worked per month and per worker in homogeneous group 2

Total working hours per year/worker	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
No. of hours worked per month (by the whole group or individual worker) including any seasonal or casual workers	-	-	1 100	1 000	1 000	950	975	1 000	1 000	1 000	1 000	1 000
% reduction, considering the real shift duration and the net duration	-	-	**72 %**	**72 %**	**72 %**	**72 %**	**72 %**	**72 %**	**72 %**	**72 %**	**72 %**	**72 %**
No. of hours spent per month/worker performing repetitive tasks	**-**	**-**	**143,8**	**143,8**	**158,1**	**143,8**	**143,8**	**136,6**	**140,2**	**143,8**	**143,8**	**143,8**
No. of hours worked per month/worker	-	**-**	**220**	**200**	**200**	**190**	**195**	**200**	**200**	**200**	**200**	**200**
Net duration % based on a constant of 40 h/week, 160 h/month, 20 days/month	-	-	99 %	90 %	99 %	85 %	88 %	90 %	90 %	90 %	90 %	90 %
No. of workers versus total workers	-	-	5	5	5	5	5	5	5	5	5	5
No. of seasonal or casual workers	-	-	-	2	2	4	8	6	3	-	-	-
Total working hours/worker	**2 005**											
Constant working hours/worker	**1 760**											



NOTE Grey area indicates when 100 % of the constant is exceeded.

Figure 4 — Number of hours worked per month (as net duration of repetitive tasks) and per worker as a percentage of 160 h/month constant, for homogeneous group no.2

6.4 Phase C – Assignment of tasks to a homogeneous group (or individual worker) and calculation of proportional tasks duration in each individual month

Before going on to complete the organizational analysis of the risk-exposed worker or homogeneous group of workers, Table 6 lists the exposure constants to which reference is made for calculating exposure time prevalence to various tasks and also for reconstructing an artificial working day representative of the whole year (see Annex B). In construction (as in agriculture), it is quite common

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for work schedules to be irregular, depending on the season. It has been found useful to adopt several exposure constants representing the typical exposure level for the industry (see Annex B).

Table 6 lists all the constants used. Although expressed in different ways, (e.g. hours, days), they all reflect the aforementioned criteria.

Table 6 — Predefined exposure time constants

Constant hours/day	8	Constant hours/month	160
Constant minutes/day	440	Constant days/month	20
Constant days/week	5	Constant months/year	11
Constant minutes/week (440 min * 5 days)	2 200	Constant days/year	220
Constant weeks/month	4	Constant hours/year	1 760

To obtain a quantitative description of the active tasks it is necessary to insert the following in the specific simple tool previously mentioned:

a) The percentage duration per month of each task worked by the homogeneous group. The sum of the percentages per month in the column has always to add up to 100 % (Table 3). The proportional description of the tasks does not require extreme precision. The employer, or the members of the homogeneous group, can usually provide the information quite easily.

b) The number of hours worked each month of the year by each worker (for homogeneous group n.2 see Table 5).

Once percentage duration per month of each task has been provided, it is possible to estimate the number of hours worked on each task every month (Table 7) by matching the proportional task descriptions shown in Table 3 to the total number of hours worked per month/worker (Table 5). The free spreadsheet automatically estimates this distribution, as shown in the example in Table 7.

After obtaining the duration in hours of the various tasks performed each month, the next step is to 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 versus both the total number of hours worked and the constant 1 760 h/year (Table 8).

Table 7 — Calculation of total hours worked, per task, in each month and per year, for homogeneous group 2 (full-time) and prevalence of worked annual hours in each task versus both the total hours worked in a year and constant 1 760 h/year

All the repetitive tasks	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	% of total hours worked per year	Hours worked per year/ task	% on a year constant (1 760 h/ year)
control crane	11	10	10	10	10	10	10	10	10	10	5,0 %	100	5,7 %
manual pallet transport (strong force)	11	10	10	10	10	10	10	10	10	10	5,0 %	100	5,7 %
transport with wheelbarrow (moderate force)	11	10	10	10	10	10	10	10	10	10	5,0 %	100	5,7 %
transport with wheelbarrow (strong force)	11	10	10	10	10	10	10	10	10	10	5,0 %	100	5,7 %
preparation to block discharge	22	20	20	19	20	20	20	20	20	20	10,0 %	201	11,4 %

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Table 7 *(continued)*

All the repetitive tasks	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	% of total hours worked per year	Hours worked per year/ task	% on a year constant (1 760 h/ year)
mortar preparation	22	20	20	19	20	20	20	20	20	20	10,0 %	201	11,4 %
lift wall brick inf 3 kg	22	20	20	19	20	20	20	20	20	20	10,0 %	201	11,4 %
lift wall 4 kg to 7 kg (low - medium - high)	33	30	30	29	29	30	30	30	30	30	15,0 %	301	17,1 %
lift wall brick 8 kg to 11 kg (low-medium-high)	33	30	30	29	29	30	30	30	30	30	15,0 %	301	17,1 %
use plumb	22	20	20	19	20	20	20	20	20	20	10,0 %	201	11,4 %
level use	22	20	20	19	20	20	20	20	20	20	10,0 %	201	11,4 %
Total	**220**	**200**	**200**	**190**	**195**	**200**	**200**	**200**	**200**	**200**	100 %	2 005	114 %

Table 8 — Calculation of intrinsic risk indexes for all the tasks present in farming activities, regardless of who performs them

Tasks	Recovery multiplier,	Hours without recovery	Frequency	Force	Side	Shoulder	Elbow	Wrist	Hand	Stereotypy	Posture total	Additional	OCRA checklist intrinsic value (right side only)
control crane	**1,33**	**4**	3	0	Right	1	1	3,5	4	1,5	5,5		**10,64**
manual pallet transport (strong force)	**1,33**	**4**	4,5	24	Right	0	0	0	0	3	3		**41,90**
transport with wheelbarrow (moderate force)	**1,33**	**4**	4,5	8	Right	1	0	0	0	3	4		**21,95**
transport with wheelbarrow (strong force)	**1,33**	**4**	4,5	24	Right	1	0	0	0	3	4		**43,23**
preparation to block discharge	**1,33**	**4**	1	4	Right	6	3,5	0	3,5	0	6		**14,63**
mortar preparation	**1,33**	**4**	7	2	Right	1	1	3		1,5	4,5		**17,96**
lift wall brick inf 3 kg	**1,33**	**4**	2,5	1	Right	6	0	0	4	0	6		**12,64**
lift wall 4 to 7 kg (low - medium - high)	**1,33**	**4**	2,5	6	Right	6	1	2	2	0	6		**19,29**
lift wall brick 8 to 11 kg (low-medium-high)	**1,33**	**4**	2,5	8	Right	6	1	2	2	0	6		**21,95**
use plumb	**1,33**	**4**	0	0	Right	1	0	0	4	0	4		**5,32**
level use	**1,33**	**4**	4,5	0	Right	8	0	0	3,5	0	8		**16,63**

NOTE Considering the result of the intrinsic values of the OCRA checklist, the colours used for the OCRA checklist results mean: white = no risk; light grey: borderline risk; medium grey: risk present; dark grey = high risk.

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7 Annual multi-task risk assessment of biomechanical overload for the upper limbs

7.1 General

To obtain the final risk index using the OCRA checklist method (see References [22] and [23] and ISO/TR 12295:2014, Annex B) for multi-task analysis, the following steps are necessary (the example refers to homogeneous group no.2).

7.2 Phase A – Analysis of each individual task using the OCRA checklist to calculate the intrinsic risk score and prepare the tasks basic risk evaluation for each crop

To prepare the tasks basic risk evaluation for each crop, it is necessary to calculate the intrinsic risk score for all the tasks present in the crop, that means evaluating each task as if it were the only one performed by a worker all the time (i.e. for the whole shift and the whole year). To estimate the intrinsic risk index of each task, reference is made to a shift constant featuring:

— 430/460 net minutes of repetitive work (modal value = 440, duration multiplier = 1);

— one 30 min meal break and two 8 min to 10 min breaks (recovery multiplier = 1,33).

The intrinsic risk index of each task is calculated by applying the OCRA checklist to all the tasks performed in the specific crop, for both the right arm and the left arm. The final indexes are entered into the appropriate areas of the specific simple tool, along with all the scores for the various risk factors (e.g. frequency, force, awkward posture of upper limbs, additional) required by the OCRA checklist (Table 8)

7.3 Phase B – Application of mathematical models and preliminary preparation of artificial working day representative of the whole year and of every month of the same year

Two models are proposed for calculating the final exposure risk index for the whole year and for each month of the same year [30]:

a) One based on the time-weighted average, calculation of the average value among the different tasks, weighted by their duration.

b) The other based on the MultiGEI based on the most overloading task (calculated with respect to its actual duration), as the minimum exposure score that can be increased versus the score of the other tasks, taking their relative durations into account. The new MultiGEI formula derived directly from multitask complex formula, used for daily turnover (see Annex B).

These two models have already been used for calculating the daily turnover, i.e. when the task rotation occurs within (time-weighted average) or outside (multitask complex) the 90-min timeframe. Both the mathematical models have been used and adjusted for calculating annual and monthly multi-task exposure risk.

In order to apply the models to annual and monthly exposure, it has been necessary to convert the data relative both to the individual months and to the year into an artificial working day representative of each month of the year first and then of the full year, respectively.

The steps necessary for performing this conversion, staring from data presented in Table 7 for homogeneous group no.2 (detail in Annex B, also through calculation examples), are summarized as follows:

— active tasks assessment (tasks actually performed by the homogeneous group) in each month and over the entire year;

— task duration estimates in hours relative (net duration) to each month and over the entire year;

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— estimate of proportional duration of each task versus the total net number of hours worked each month and over the entire year;

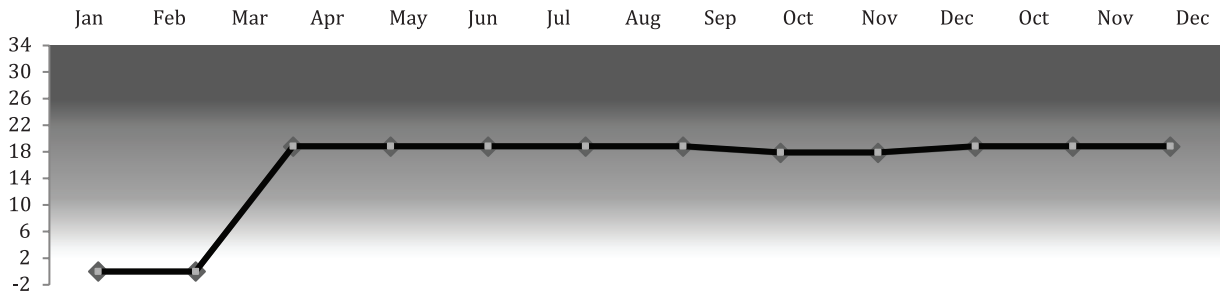
— evaluation of artificial day, or fictitious working day, representative of the year, by dividing the net hours worked/year ("net" means having excluded pauses, non-repetitive accessory works) for 220 (predefined constant number of working days per year) and multiplying the result by 60, thus obtaining the new duration in minutes, to proportionally represent the year. 1 790 h/year (default constant of working days per year) corresponds to an artificial day of 480 minutes, with a multiplier duration equal to 1. Reducing the duration of the artificial day, the duration multiplier (Annex B) becomes proportionally less than 1. Applied then to the result of the final risk index, it will reduce it, always in proportion to the actual duration. In this way the risk can be reduced, reducing or increasing the number of hours worked in the year compared to the default constant.

Figure 5 compares the month-by-month results (for the right limb) using the two formulae, i.e. time-weighted average and MultiGEI, as obtained automatically using the specific simple tools. In order to better interpret the results, the two formulae have been used also to calculate the final risk index for each month of the year, thus displaying the final risk index trends for each month of the year.

With final risk index trends shown on a monthly basis, it is easier to comprehend the differences between the two final risk indexes formulae obtained with time-weighted average and MultiGEI. Since the work is distributed differently over the various months of the year, the time-weighted average formula tends to flatten the peaks, determining lower risk scores than the MultiTask Complex formula, which is never lower than the highest peak, calculated for its actual duration.

When a homogeneous group works for half the year but working very few hours and at very low risk for three out of the six months, the discrepancy between the scores obtained using the time-weighted average versus the MultiGEI is quite remarkable. The first formula flattens the peaks for the months with low or no exposure, while the second is based on the estimated highest risk task, considering its intrinsic duration.

Here, the interpretation of the results for the attribution of risk is problematic. In these cases, with workers exposed to risk for only half the year, it can be difficult to attribute a disease or disorder to occupational factors when the workers' activities in the other half of the year are unknown.



a) Time-weighted average evaluation: 17 right, left 17 in homogeneous group n.2

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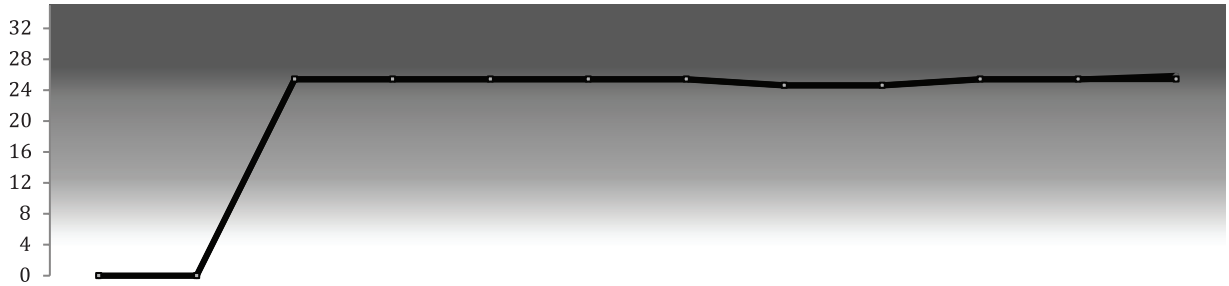

b) MultiGEI formula evaluation: right 21,8; left 21,8 in homogeneous group no.2

NOTE Considering the result of the intrinsic values of the OCRA checklist presented in the four figures, the colours used mean: white = no risk; light grey: borderline risk; medium grey: risk present; dark grey = high risk.

Figure 5 — Exposure index scores (for homogeneous group no.1 in Table 2 and for homogeneous group no.2 in Table 3, full-time) plotted by month over the whole year, using both the recommended formula

In construction, the above job organization is anything but rare. Work can be organized in many different ways with respect to annual exposure; in Figure 6 some common annual work scenarios are represented.

The aim of the approach described in this subclause is not to determine the causes and effects of many common musculoskeletal diseases and disorders, but rather to offer assessment options for tackling and discussing the problem at hand.

The use of the OCRA checklist for analysing the risk of biomechanical overload of the upper limbs in farm work can still seem very complex or at least time-consuming.

Arguably, many farming activities need monitoring all year round in order to analyse and evaluate each individual task, and often the number of tasks is extremely high. However, it has been observed that when the same techniques are used for the same crops, the tasks are always the same, and thus have the same intrinsic OCRA checklist scores. Hence, it is possible to speak of finite variable farm work, i.e. featuring uniform variables, which can be pre-set following an initial evaluation.

Going forward, efforts are being made to develop a basic software for a specific cultivation with all the specific intrinsic risk values of each task as pre-set data. To assess risk for a homogeneous group (many cultivations need the same tasks), the appraiser has only to enter the farm-specific organizational data.

8 Annual multi-task risk assessment for working postures

8.1 The meaning of postural tolerance

The earliest posture analysis methods[31],[39],[45],[58] were those suggesting a global approach towards analysing working postures. Most of the methods for working posture analysis do a satisfactory job of identifying and describing which postures to assess and how to work out the final scores, but rarely do they provide enough practical examples, especially in evaluating risk in complex multi-task activities, with complex rotation between tasks during the year.

None of the methods deliver a seamless transition from description to assessment.[11],[17],[25],[33],[39],[44],[46],[52],[55],[57],[59],[62] A meaningful contribution towards developing assessment methods will only be made when significant certainties are reported in the evaluation of postural tolerance. What criteria underpin posture evaluation and tolerance analysis? First, there needs to be a consensus that what is being assessed is not the posture itself but how it is tolerated within a specific time, space and operating environment. Hence, the question is: what postures can be defined as tolerable?

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The assumption put forward here is that for postures to be tolerable, they must not:

— cause discomfort in the short term;

— cause MSDs or diseases in the long term.

Short-term discomfort describes a feeling of fatigue, pain or both in a joint or ligament that develops within the space of minutes, hours or days. However, with regards to this first requirement, preventing incapacitating injury is not sufficient: complete wellbeing and comfort must be ensured at all times.

There can be no doubt, theoretically or otherwise, regarding the second requirement: postures must not generate specific diseases or disorders.

8.2 Analysing the tolerability of working postures for the spine when performing manual lifting tasks, and for the upper limbs when performing repetitive movements and manual lifting: specific International Standards

The specific International Standards applied to the ergonomics of designing and redesigning workplaces at risk of biomechanical overload are ISO 11228-1, ISO 11228-2, ISO 11228-3 and ISO 11226.

These standards show that in order to study biomechanical overload, and consequently the tolerability of working postures (i.e. short- and long-term risk analysis), it is necessary to:

— analyse all the risk factors present, including organizational factors; a multifactorial analysis is strictly necessary;

— consider the results of epidemiological studies (i.e. analysis and distribution of damage caused to exposed versus non-exposed workers) to first validate and then interpret the resulting scores.

The OCRA method for studying repetitive movements (see Reference [43] and ISO 11228-3), and the NIOSH method for studying manual load lifting (see References [19], [21] and [53] and ISO 11228-1), both extensively validated in the literature and suggested by the specific International Standards, ultimately reach a final risk assessment through a multifactorial approach that includes investigating organizational aspects (frequency and duration), awkward postures, subjective force and other factors. Awkward postures are therefore included in both these evaluation techniques as one of several risk factors

8.3 Analysing spinal working postures without manual load lifting and lower limb postures (primarily static)

The OCRA and NIOSH methods cannot cover every aspect of biomechanical overload due to awkward postures; there are many jobs that do not entail lifting loads but still cause biomechanical overload of the spine and lower limbs, primarily due to awkward static postures. Examples include building site workers, agricultural workers, kindergarten teachers, physiotherapists, and archaeologists.

It is emphasized that the reconstruction of the type and also the duration of exposure to postural risk factors is essential for being able to judge tolerability levels. In fact, before analysing posture it is necessary to analyse the tasks involved and how the work is organized.

Reconstructing the work of a homogeneous group of workers (or also of an individual worker) requires knowing (as already described for the study of the biomechanical overload of the upper limbs):

— what kind of task(s) are performed within the cycle (daily, weekly, monthly or yearly);

— the duration of each task;

— what postures are adopted during each task and the duration of each of the selected postures.

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Although in the literature it is not difficult to single out which postures require evaluating, there are major shortcomings regarding:

— criteria for adjusting final scores based on task duration (job risk score);

— criteria for adjusting scores for the various postures characterizing each individual task (intrinsic task score), also according to the mutual different duration of each of the postures present in each task.

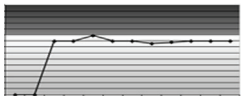
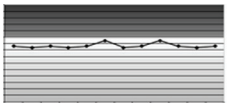
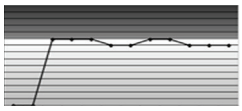
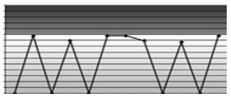
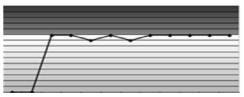
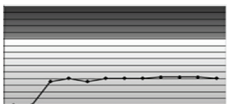
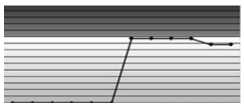
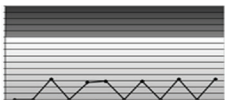
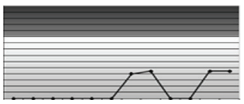
	Main tasks	% distribution over 12 months		Main tasks	% distribution over 12 months
1	**Wood structure.** Wood cutting, transport, waterproofing the wood and assembling boxes for concreting beams and columns.		6	**Preparation masonry;** preparation the mortar, masonry marking; brick transportation; raising the wall	
2	**Steel armour (beams, pillars and slabs)** folding and cutting steel bars, positioning of the steel bars in the box wood, transporting materials		7	**Internal mortar,** transport of bricks, mortar and wall mortar application	
3	**Structures in concrete** (pillar, slab, beam) cast concrete, concrete finish		8	**External mortar. Wall mortar application**	
4	**Removing wooden shapes**, cleaning; perform the sequence of removal of shapes and struts; remove shapes from hard to reach places. (04 people)		9	**Preparation ceiling and walls for painting,** manual material transport	
5	**Waterproofing beam.** Asphalt paint is applied with two or three coats of the product. (02 people)		10	**Door.** remove packaging, remove wooden locks, fix the door in the opening and apply expansive foam	

Figure 6 — Examples of different annual work scenarios in10 representative homogeneous groups in civil constructions: tasks durations distribution in the different months of the year from January to December (black area when the working time for month is higher than 160 hours)

The aim of the method proposed here is not to decide which posture should be analysed; extensive use is in fact made of the ones currently featured in the literature and in current standards. The purpose is rather to suggest how to time them correctly even in very complex scenarios, where workers are exposed to multiple tasks and work cycles lasting longer than one day.

Since the data management activities and risk score calculations are so complex, a specific simple tool (in this case the same spreadsheets before presented for repetitive movements, in which a specific sheet is dedicated to the study of postures) have been developed to gather, condense and automatically process the data.

This posture sheet, present in this simple tool, helps in implementing the strategy for calculating risk associated with exposure to awkward postures, i.e. the TACOS model.[24],[25]

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

As for the other topics in this clause, the methodological details for this topic are collected in Annex C, dedicated to the analysis of working postures.

Figure 7 lists the main postures to study, broken down by main segment, and the specific scores assigned. The postures chosen for this analysis are those used in various methods reported in the literature and in International Standards; they have only been simplified or regrouped to ensure a clear understanding.

As to the criteria adopted for assigning scores, note that the exposure scores simply rank postures from the least to the most uncomfortable (generally from neutral to the most awkward). The risk scores are assigned starting from the most comfortable posture (e.g. seated upright, reclining against a back rest) as follows:

— score 0,5 when the worker spends 1/3 of the time (approximately 20 % to 40 %);

— score 1,5 when the worker spends half the time (approximately 40 % to 60 %);

— score 3 when the worker spends 3/3 of the time (approximately 60 % to 100 %).

As the discomfort caused by the posture increases, the scores increase accordingly, starting from a duration of 1/3 of the time. The other scores start from this figure, which is then doubled or tripled. The more tiring postures receive a score even if they are adopted for short periods (approximately 1/10 of the time). Scores range from 0,5 (lowest score for comfortable positions lasting up to 1/3 of the time) to 14 (most awkward positions lasting the whole time).

In other words, these descriptive exposure indexes (as in all the other methods found in the literature) are adjusted on the basis of the awkwardness and duration of the task: they cannot yet be regarded as risk indexes based on which future health issues can be predicted (no method of assessing risk from exposure to awkward posture, present in the literature, is in fact able to predict the likelihood of illness).

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

— postures are not identified and described for each area of the body to aggregate subsequently as proposed in other ergonomic methods (e.g. RULA, REBA, OWAS);

— overall postures for different body segments (e.g. standing, sitting, squatting postures) have been defined using sketches and simple descriptions;

— postures have to 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 in function of the different durations; stopwatches are seldom required.

The figures help to group postures into five 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.

Since the maximum score is 14, a series of five categories has been arbitrarily defined, each with a different colour (from green to violet), indicating the different degrees of awkwardness, also as a function of the duration of the posture (Table 9).

This approach is adopted intrinsically for each posture and for the final outcome of the total task analysis.

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Table 9 — Definition of risk areas, with different degrees of awkwardness, as a function of the duration of the posture

Zone	TACOS values	Risk classification
Green	up to 1,5	Optimal
Green	1,6 to 2,2	Acceptable
Yellow	2,3 to 3,5	Borderline or very slight
Red-low	3,6 to 4,5	Slight
Red-medium	4,6 to 9,0	Medium
Red high	more than 9,0	High

8.5 Posture analysis of a multi-task job performed on a full-time or part-time basis with yearly job rotation

Returning to the example of homogeneous group 2, whose organizational data are shown in Table 3 and Table 7, the procedure entails the use of the specific sheet present as a simple tool (the same spreadsheet for studying all different risk factors that determine the biomechanical overload as postures, manual handling, pushing/pulling).[69]

In order to study biomechanical overload of the upper limbs as a whole, rather than examining only awkward postures, it is necessary to apply a method that investigates all related risk factors responsible for biomechanical overload. The OCRA method[21],[22],[49] for example, does just that.

The OCRA system analyses awkward postures as one of a range of risk factors. It looks at the main joint segments of both the left arm and the right arm, defining the awkward postures and assigning different scores, based on the region of the limb involved and the duration of the posture (Figure 8).

Considering the risk scores for each individual risk factor, it is clear that the contribution of the posture factor to the final task score is about 50 %. As always, these studies featuring multi-task exposure start from an assessment of the intrinsic risk of each task (as if the duration of the task corresponds to the duration of a standard shift, defined as a constant).

In Figure 9, the intrinsic values obtained for each task present in the cultivation and (sign in white line) carried out in the year by homogeneous group no.2 are provided.

Since a task can be characterized by a single posture or multiple postures, it is important to check them considering also their specific duration in the task. In each single task, the single posture present (if there is only one) represents 100 % of duration. If there are many of them, the sum of the % duration of all the postures has to be always be equal to 100 % (except when there are uncomfortable postures of the head and pedals are used, because they are added to the other postures, without being alternatives to them).

The intrinsic postural score is generated for each task as the sum (horizontal line) of the corresponding scores for each postural risk score associated with that specific task. With the intrinsic risk scores and the duration of each task for each year, the same models as for the OCRA checklist multitask analysis can be used to estimate the risk indexes for the spine and lower limbs, i.e. both the time-weighted average and the multi-task complex.

As final results (for homogeneous group no.2), the risk scores related to the study of the spine and lower limbs are evaluated, both as a whole (applying the time-weighted average and the multi-task complex formulae) broken down by the four main body areas (Tables 10 to 12): spine standing, spine sitting, lower limbs, head-neck.

Figure 10 shows the proportional distribution of the different postures of the spine and lower limbs in their entirety and Figure 11, extracted in summary from Figure 10, shows the awkward postures, indicate as absolutely inadequate according to ISO 11226.

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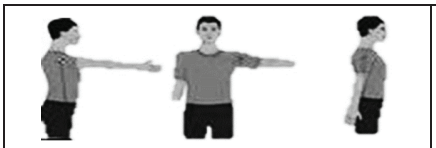
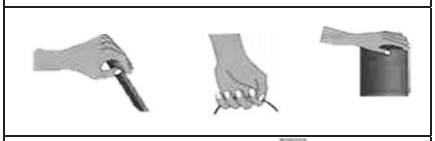
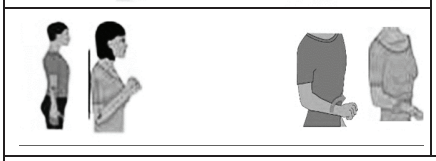
	Arm more or less at shoulder height AND/OR major extension	10 %	10 %	33 %	33 %
	Pinch or palmar or hook grip (not power grip)	66 %	66 %	66 %	66 %
	Extreme wrist deviations	50 %	50 %	10 %	10 %
	Complete object rotation (prono-supination) or wide arm-forearm (elbow) flexion-extension	10 %	10 %	10 %	10 %
Note:		Right	Left	Right	Left
		intrinsic distribution		% distribution with respect to the annual constant	

Figure 7 — Summary of awkward postures as intrinsic values for the upper limbs, obtained using the OCRA checklist method (homogeneous group no.2 full-time)

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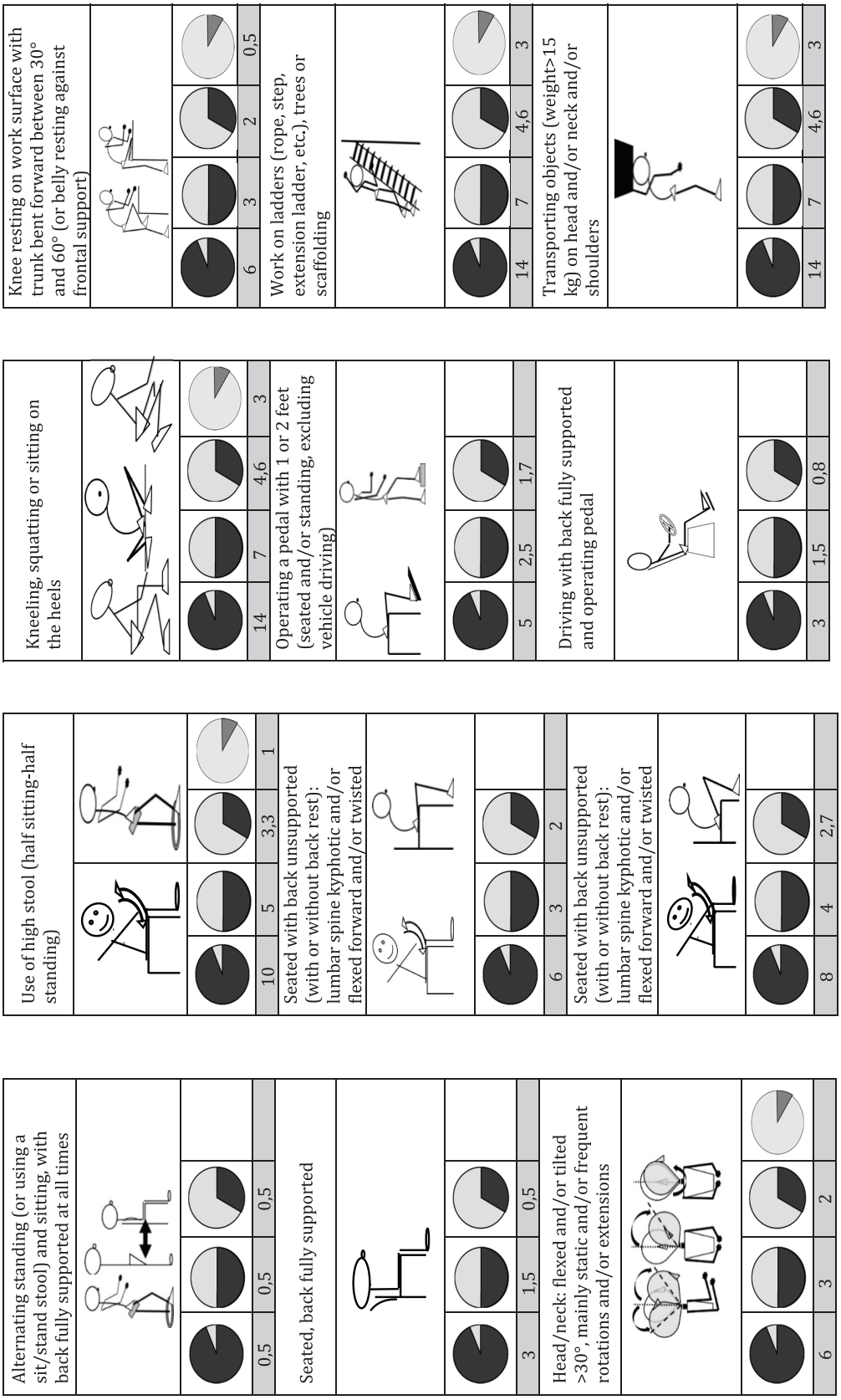

Figure 8 — Main postures analysed using the TACOS method, indicating pre-aggregated body postures and specific scores based on duration

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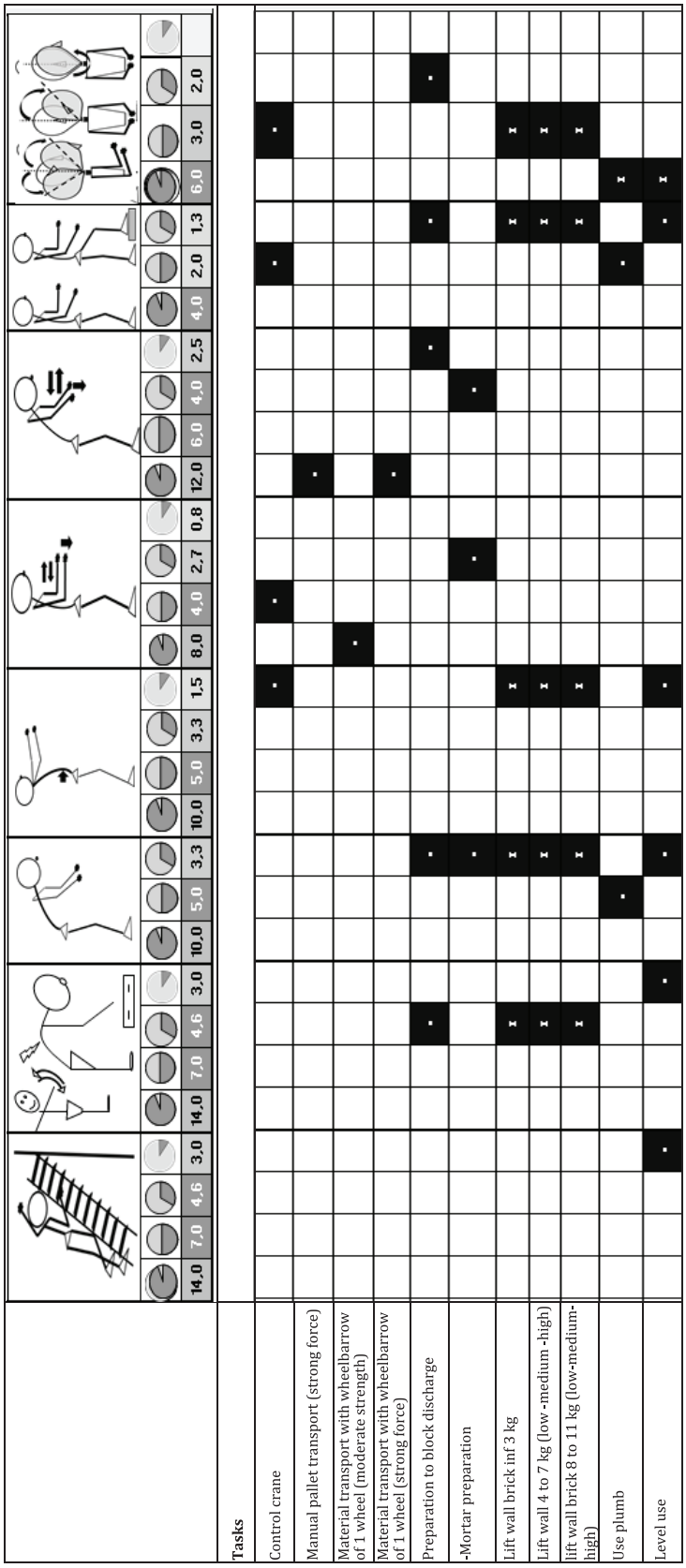

NOTE For estimation of exposure index, when a task is characterized by many postures, the sum, on horizontal lines, of the percentage duration has to always be equal to 100 %, except when awkward postures of the head and pedals are used.

Figure 9 — Estimation of intrinsic postural exposure indexes obtained by signing with "X"

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the pre-timed scores (on horizontal lines) for each posture characterizing the task (intrinsic postures involve in homogeneous group no.2)

Table 10 — Intrinsic awkward posture scores for each task performed by homogeneous group no.2

Tasks	Net worked hours	Final scores	% worked hours based on a constant
Control crane	72	10,5	4 %
Manual pallet transport (strong force)	72	12,0	4 %
Transport with wheelbarrow (moderate force)	72	8,0	4 %
Transport with wheelbarrow (strong force)	72	12,0	4 %
Preparation to block discharge	144	13,7	8 %
Mortar preparation	144	10,0	8 %
Lift wall brick inf 3 kg	144	13,7	8 %
Lift wall 4 kg to 7 kg (low - medium - high)	216	13,7	12 %
Lift wall brick 8 kg to 11 kg (low-medium-high)	216	13,7	12 %
Use plumb	144	13,0	8 %
Level use	144	18,1	8 %

Table 11 — Homogeneous group no.2: awkward postures total final exposure scores

MultiGE annual score	Time-weighted average annual score
13,9	10,7

Table 12 — Homogeneous group no.2: awkward postures final exposure scores subdivided by district

Head and neck	Spine in standing position	Spine in sitting posture	Legs
31 %	70 %	0 %	1 %
2,6	9,8	0	0,3
NOTE The sum of the percentages for scores subdivided by district can be higher than 100 %, as some postures can involve different body areas at the same time (such as the head-neck).			

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