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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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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

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).

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

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).

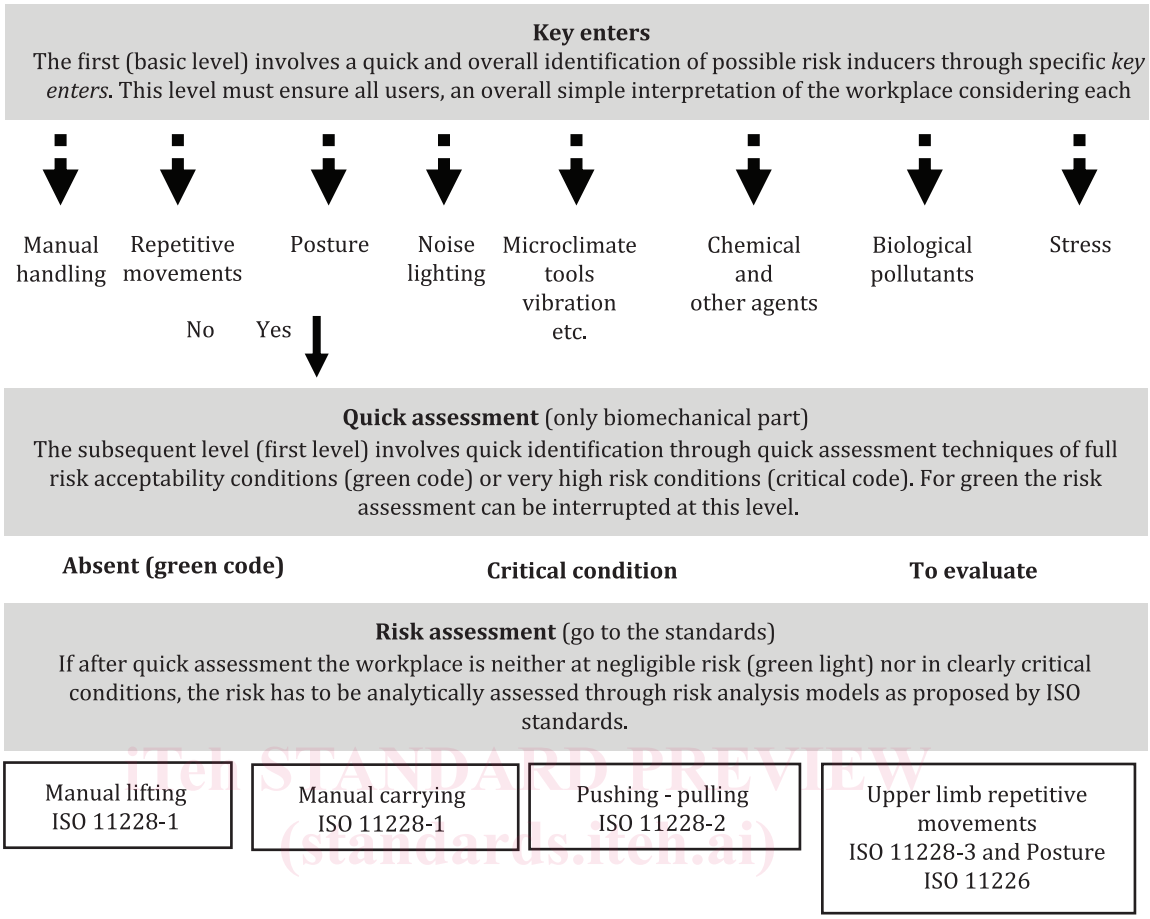


Figure 1 — Different risk assessment levels according to ISO/TR 12295 for biomechanical overload estimation

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.

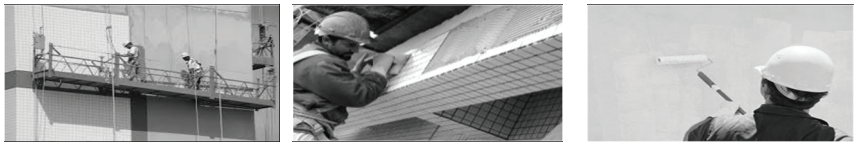
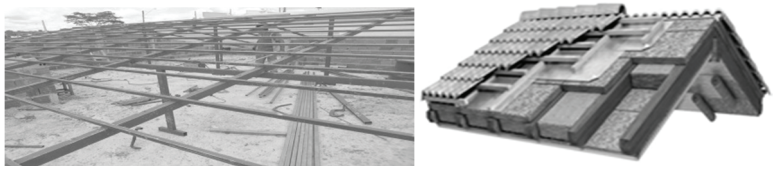
Table 1 summarizes the main macro-phases that characterize the civil construction sector, which can be summarized even more briefly in eight main construction phases: ground preparation, excavation of foundations and their reinforcement; construction of vertical and horizontal support structures (pillars 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.

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	

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 renovation

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 material transportation (aa)	crane operation - street level
		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

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 the armour irons inside the holes of the foundation
	positioning of foundation beams	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