TECHNICAL REPORT

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Ergonomics — Application document for International Standards on manual handling (ISO 11228-1, ISO 11228-2 and ISO 11228-3) and evaluation of static working postures (ISO 11226)

Ergonomie — Document pour l’application des Normes Internationales sur la manutention manuelle (ISO 11228-1, ISO 11228-2 et ISO 11228-3) et l’évaluation des positions statiques de travail (ISO 11226)

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Foreword

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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. www.iso.org/directives

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The committee responsible for this document is ISO/TC 159, *Ergonomics*, Subcommittee SC 3, *Anthropometry and biomechanics*.

Introduction

The ISO 11228 series and ISO 11226 establish ergonomic recommendations for different manual handling tasks and working postures.

All their parts apply to occupational and non-occupational activities. The standards will provide information for designers, employers, employees and others involved in work, job and product design, such as occupational health and safety professionals.

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

— *Part 1: Lifting and carrying*;

— *Part 2: Pushing and pulling*;

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

ISO 11226, *Ergonomics — Evaluation of static working postures*, gives recommended limits for static working postures with no, or with minimal external force exertion, while taking into account body angles and duration. It is designed to provide guidance on the assessment of several task variables by evaluating the health risks for the working population.

While ISO 11228 and ISO 11226 are each self-contained with respect to data and methods, users may need guidance in selecting or using the standards in their specific application.

This Technical Report serves as an application guide that offers a simple risk assessment methodology for small and medium enterprises and for non-professional activities. For expert users, more detailed assessment methodologies are presented in the annexes.

Ergonomics — Application document for International Standards on manual handling (ISO 11228-1, ISO 11228-2 and ISO 11228-3) and evaluation of static working postures (ISO 11226)

1 Scope

This Technical Report is an application document that guides users of the ISO 11228 series of International Standards, which address manual handling, and ISO 11226, which deals with static working postures. Specifically, it guides the user and provides additional information in the selection and use of the appropriate standards.

Depending upon whether specific risks are present, it is intended to assist the user to decide which standards should be applied.

It has a dual scope:

a) To provide all users, and particularly those who are not experts in ergonomics, with criteria and procedures:

— to identify the situations in which they can apply the standards of the ISO 11228 series and/or ISO 11226;

— according to the criteria given in the relative standard, to provide a "quick assessment" method to easily recognize activities that are "certainly acceptable" or "certainly critical". If an activity is "not acceptable" it is necessary to complete a detailed risk-assessment as set out in the standard, but it should be possible to continue with the subsequent actions. Where the quick-assessment method shows that the activity risk falls between the two exposure conditions then it is necessary to refer to the detailed methods for risk assessment set out in the relevant standard.

This scope and approach is illustrated in the flowchart in Figure 1 and is described in the main text of this Technical Report.

The user will be required to answer a short series of practical "key questions" to assist him or her in selecting and applying the appropriate standard(s).

It is emphasized that the use of the quick-assessment method is best completed using a participatory approach involving workers in the enterprise. Such involvement is considered essential to identify effectively priorities for dealing with the different hazard and risk conditions and, where necessary, to identify effective risk reduction measures.

b) To provide all users, especially those who have sufficient experience in ergonomics, or are sufficiently familiar with the standards of the ISO 11228 series, with details and criteria for applying the risk assessment methods proposed in the original standards of the series. This information is fully consistent with the methods proposed in the standards, and does not introduce any change to the application of the mathematical risk level calculations defined in the existing standards. It has been collated from additional analyses to ease the use of the standards.

This second part of the scope will be achieved through Annexes A, B, and C related to ISO 11228-1, ISO 11228-2 and ISO 11228-3, respectively. These annexes provide information relevant to the practical application of methods and procedures presented in ISO 11228 series based on application experiences of the standards. Some modifications of the methods explained in the standards are described in the present Technical Report, which are intended to be supplemental to the users, with a particular focus on applications where multiple manual tasks are performed by the same worker(s).

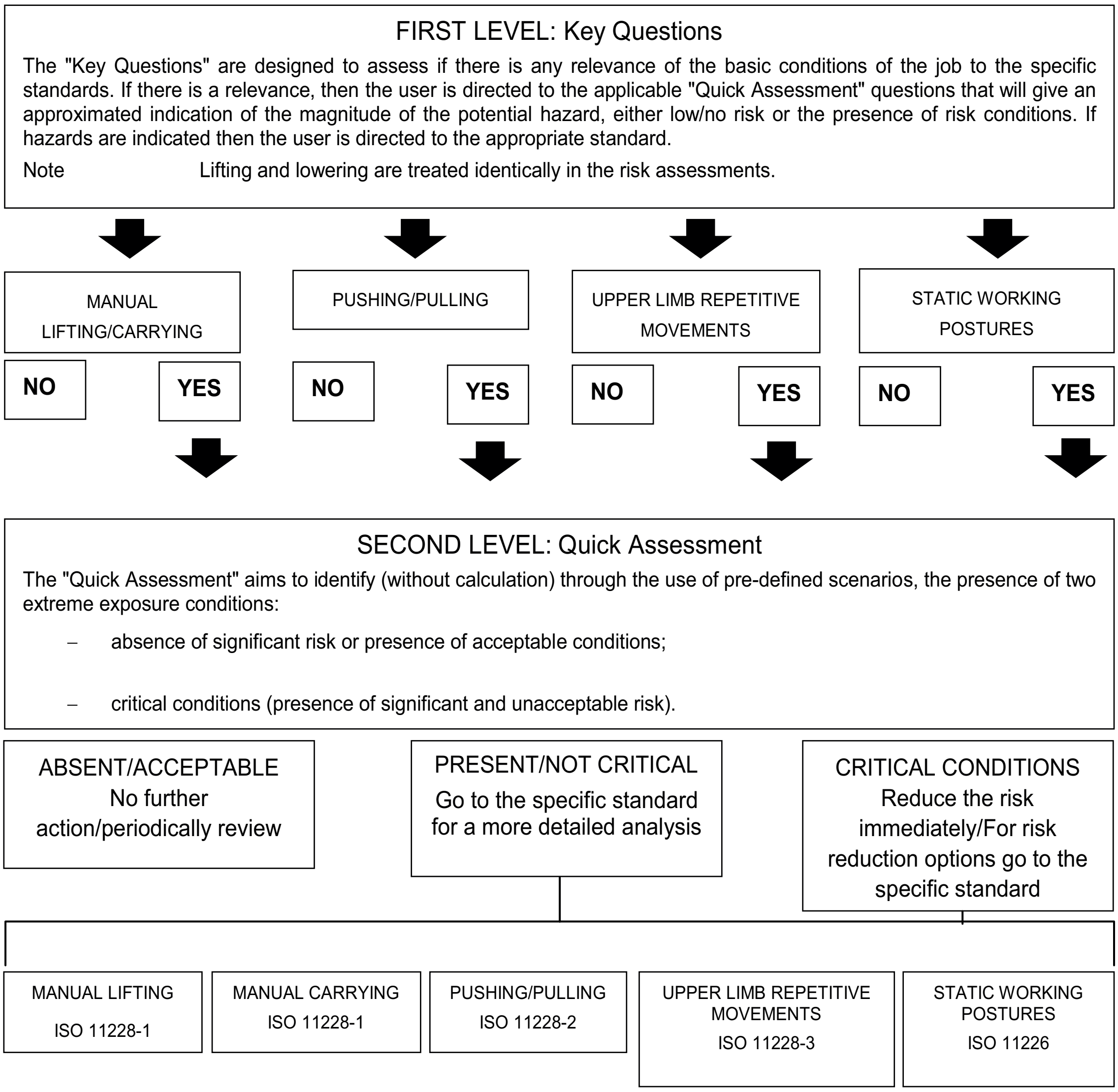


Figure 1 — The different levels of approach to ISO 11226 and the ISO 11228 series

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11226, *Ergonomics — Evaluation of static working postures*

ISO 11228-1, *Ergonomics — Manual handling — Part 1: Lifting and carrying*

ISO 11228-2, *Ergonomics — Manual handling — Part 2: Pushing and pulling*

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

ISO 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

3 Using the "Key Questions" and the "Quick Assessment"

Follow the steps below and answer each of the key questions.

3.1 Step 1 — Procedure to enter the standards: the "Key Questions"

In Step 1 the "Key Questions" will direct you to the relevant standard or standards that are appropriate for your job conditions. "Key Questions" are designed to identify if hazards are present and whether a further analysis (using relevant standards) is necessary. See Table 1.

Table 1 — The key questions

1	*Application of ISO 11228-1*		
	Is there manual lifting/lowering or carrying of an object of 3 kg or more present?	NO	YES
	if NO, then this standard is not relevant, go to the next "Key Questions" regarding the other standards **If YES** then go to step 2 " Quick Assessment"		
2	*Application of ISO 11228-2*		
	Is there a two-handed whole-body pushing and pulling of loads present?	NO	YES
	if NO, then this standard is not relevant, go to the next "Key Questions" regarding the other standards **If YES** then go to step 2 "Quick Assessment"		
3	*Application of ISO 11228-3*		
	Are there one or more repetitive tasks of the upper limbs with a total duration of 1 hour or more per shift? Where the definition of "repetitive task" is: *a task characterized by repeated work cycles* *or* *tasks during which the same working actions are repeated for more than 50% of the cycle time.*	NO	YES
	If NO, then this standard is not relevant, go to the next "Key Questions" regarding the other standards **If YES** then go to step 2 "Quick Assessment"		
4	*Application of ISO 11226*		
	Are there static or awkward working postures of the HEAD/NECK, TRUNK and/or UPPER AND LOWER LIMBS maintained for more than 4 seconds consecutively and repeated for a significant part of the working time? **For example:** - ***HEAD/NECK*** *(neck bent back/forward/sideways, twisted)* - ***TRUNK*** *(trunk bent forward/sideways/, bent back with no support, twisted)* - ***UPPER LIMBS*** *(hand(s) at or above head, elbow(s) at or above shoulder, elbow/hand(s) behind the body, hand(s) turned with palms completely up or down, extreme elbow flexion-extension, wrist bent forward/back/sideways)* - ***LOWER LIMBS*** *(squatting or kneeling) maintained for more than 4 seconds consecutively and repeated for a significant part of the working time*	NO	YES
	if NO, then this standard is not relevant **If YES** then go to step 2 "Quick Assessment"		

3.2 Step 2 — The "Quick Assessment"

The "Quick Assessment" aims to identify, without the need for calculation, the presence of two opposite exposure conditions:

— the absence of risk or acceptable risk;

— the presence of a relevant risk (or the presence of extremely hazardous risk factors that are not acceptable), also labelled as critical conditions (critical code).

When either of these conditions is met, it is not necessary to make a more detailed estimation of the exposure level using the corresponding standard (the applicable standard can still provide ideas and information for the correction of the risk factors). However, when none of the two "extreme" conditions is met, it is necessary to conduct a risk assessment by methods reported in the corresponding standard.

3.2.1 Lifting/lowering and carrying — Preliminary additional aspects

A preliminary check of some adverse environmental, object and organizational conditions is highly recommended since those conditions could represent an additional risk in manual handling.

See Table 2.

Table 2 — Lifting/lowering and carrying – Additional factors to be considered

Is the working environment unfavourable for manual lifting and carrying?		
Presence of extreme (low or high) temperature	NO	YES
Presence of slippery, uneven, unstable floor	NO	YES
Presence of insufficient space for lifting and carrying	NO	YES
Are there unfavourable object characteristics for manual lifting and carrying?		
The size of object reduces the operator's view and hinder movement	NO	YES
The centre of gravity of the load is not stable (example: liquids, items moving around inside of object)	NO	YES
The object shape/configuration presents sharp edges, surfaces or protrusions	NO	YES
The contact surfaces are too cold or too hot	NO	YES
Does the task(s) with manual lifting or carrying last more than 8 hours a day?	NO	YES
If all of the questions are answered" NO", then continue the "Quick Assessment". If at least one of the questions is answered "YES", then APPLY The standard ISO 11228-1. The consequent specific additional risks HAVE TO be carefully considered to MINIMIZE THESE RISKS.		

3.2.2 Lifting/lowering and carrying — Quick assessment

For establishing the acceptable (no) risk the following Tables 3 and 4 should be used. They follow the approach in step 1 and 2 of ISO 11228-1. If all of the listed conditions are present (i.e. "YES" answers), the assessed task is acceptable (Green area) and it is not necessary to continue the risk evaluation.

If any of the conditions is not met, apply ISO 11228-1, step 3 — Lifting equation.

The "Quick Assessment" could also be used for identifying critical conditions (for lifting and carrying). The term critical condition means that the manual lifting and/or carrying of objects is not recommended. If any of the conditions reported in Table 5 is met, a critical situation in lifting and/or carrying is present, and an ergonomics intervention is necessary to redesign the task as a high priority.

Table 3 — Lifting/lowering — Quick Assessment — Acceptable condition

3 TO 5 kg	Asymmetry (e.g. body rotation, trunk twisting) is absent	NO	YES
	Load is maintained close to the body	NO	YES
	Load vertical displacement is between hips and shoulders	NO	YES
	Maximum frequency: less than 5 lifts per minute	NO	YES
5,1 TO 10 kg	Asymmetry (e.g. body rotation, trunk twisting) is absent	NO	YES
	Load is maintained close to the body	NO	YES
	Load vertical displacement is between hips and shoulder	NO	YES
	Maximum frequency: less than 1 lift per minute	NO	YES
MORE THAN 10 kg	Loads of more than 10 kg are absent	NO	YES
If all of the questions are answered “YES”, then the examined task is in green area (ACCEPTABLE) and it is not necessary to continue the risk evaluation. If at least one of the questions is answered “NO”, then evaluate the task(s) by ISO 11228-1.			

Table 4 — Carrying — Quick Assessment — Acceptable condition

Recommended Cumulative Mass (total load (in kg) carried during the given durations for the specified distance below): is the cumulative mass carried LESS than recommended values considering the distance (more/less than 10 meters) and duration (1 minute; 1 hour; 8 hours) ?				
Duration	**Distance ≤ 10 m per action**	**Distance > 10 m per action**		
8 hrs	10000 kg	6000 kg	NO	YES
1 h	1500 kg	750 kg	NO	YES
1 min	30 kg	15 kg	NO	YES
	Awkward postures during the carrying are not present		NO	YES
If all of the questions are answered “YES”, then the examined task is in green area (ACCEPTABLE) and it is not necessary to continue the risk evaluation. If at least one of the questions is answered “NO”, then evaluate the task(s) by ISO 11228-1.				

Table 5 — Lifting/lowering and carrying — Quick Assessment — Critical condition

If one or more of the following conditions is present, consider risk as HIGH and it is necessary to proceed with task re-design.			
CRITICAL CONDITION: presence of lifting/carrying task lay-out and frequency conditions exceeding the maximum suggested			
VERTICAL LOCATION	The hand location at the beginning/end of the lift is higher than 175 cm or lower than 0 cm.	NO	YES
VERTICAL DISPLACEMENT	The vertical distance between the origin and the destination of the lifted object is more than 175 cm	NO	YES
HORIZONTAL DISTANCE	The horizontal distance between the body and load is greater than full arm reach	NO	YES
ASYMMETRY	Extreme body twisting without moving the feet	NO	YES
FREQUENCY	More than 15 lifts per min of SHORT DURATION (manual handling lasting no more than 60 min consecutively in the shift, followed by at least 60 minutes of break-light task)	NO	YES
	More than 12 lifts per min of MEDIUM DURATION (manual handling lasting no more than 120 min consecutively in the shift, followed by at least 30 minutes of break--light task)	NO	YES
	More than 8 lift per min of LONG DURATION (manual handling lasting more than 120 min consecutively in the shift)	NO	YES
CRITICAL CONDITION for lifting/carrying: presence of loads exceeding the following limits			
Males (18-45 years)	**25 kg**	NO	YES
Females (18-45 years)	**20 kg**	NO	YES
Males (<18 or >45 years)	**20 kg**	NO	YES
Females (<18 or >45 years)	**15 kg**	NO	YES
CRITICAL CONDITION FOR CARRYING: presence of cumulative carried mass greater than those indicated			
Carrying distance 20 m or more in 8 hours / Carrying distance per action 20 m or more	**6000 kg in 8 hours**	NO	YES
Carrying distance less than 20 m in 8 hours / Carrying distance per action less than 20 m	**10000 kg in 8 hours**	NO	YES
If at least one of the conditions have a "YES" response then a critical condition is present. If a critical condition is present then apply ISO 11228-1 for identifying urgent corrective actions.			

3.2.3 Whole-body pushing and pulling — Additional factors to be considered

A preliminary check of some adverse environmental, object and organizational conditions is highly recommended since those conditions could represent an additional risk in both manual lifting and whole body pushing and pulling (Table 6).

Table 6 — Pushing and Pulling — Additional factors to be considered

Working environment conditions		
Are floor surfaces slippery, not stable, uneven, have an upward or downward slope or are fissured, cracked or broken?	NO	YES
Are restricted or constrained movement paths present?	NO	YES
Is the temperature of the working area high	NO	YES
The characteristics of the object pushed or pulled		
Does the object (or trolley, transpallet, etc.) limit the vision of the operator or hinder the movement?	NO	YES
Is the object unstable?	NO	YES
Does the object (or trolley, transpallet, etc.) have hazardous features, sharp surfaces, projections etc. that can injure the operator?	NO	YES
Are the wheels or casters worn, broken or not properly maintained?	NO	YES
Are the wheels or casters unsuitable for the work conditions?	NO	YES
If the answers for all the conditions are "NO", then continue the quick assessment. If at least one of the answers is "YES", then apply ISO 11228-2. The consequent specific additional risks HAVE TO be carefully considered to MINIMIZE THESE RISKS.		

3.2.4 Whole-body pushing and pulling — Quick assessment

The "Quick Assessment" can be used for identifying *acceptable* (or Green) and *critical* (or Red) *conditions* (for pushing and pulling). For establishing the acceptable risk, Table 7 should be used (it is based upon method 1 of ISO 11228-2). If all of the listed conditions are present (reply "YES"), the examined task is acceptable and is not necessary to continue the risk evaluation. If at least one of the conditions reported in Table 8 is met, a critical situation in pushing and/or pulling is present, and an urgent ergonomic intervention is necessary to redesign the task as a high priority. The critical conditions given here are indicated in ISO 11228-2.

The suggested starting point is the estimation and evaluation of the forces necessary for performing the push-or-pull tasks under analysis. If the force is applied to the object beneath hip level or above mid-chest level one should apply the standard ISO 11228-2. This standard should also be applied in cases when the force magnitude is above approx. 50 N for continuous force exertion or approx. 100 N for peak-force application (for more information on how to measure forces see ISO 11228-2, Annex D). An approximation of these criteria is given by considering the experience of worker(s) in terms of the perceived effort. In determining the perceived effort, the use of CR-10 Borg scale [3] [4] is suggested for estimating the force developed during pushing and/or pulling. If the result is 3 or more on Borg scale (representing "moderate" level of force), one should apply the standard ISO 11228-2. If high forces are exerted or the point of force application is inappropriate (equivalently, a score of 8 or more in on CR-10 Borg Scale), a critical condition is present: it is necessary to apply ISO 11228-2 for identifying urgent corrective actions.

Table 7 — Pushing and pulling — Quick Assessment — Acceptable condition

Hazard	**Force magnitude**		
	The force magnitude does not exceed approx. 30 N (or approximately 50 N for frequencies up to once per 5 min up to 50 m) for continuous (sustained) force exertion and approx. 100 N for peak (initial) force application. Alternatively, the perceived effort (obtained interviewing the workers using the CR-10 Borg scale) shows the presence, during the pushing-pulling task(s), of an up to SLIGHT force exertion (perceived effort) (score 2 or less in Borg CR-10 scale).	NO	YES
Hazard	**Task duration**		
	Does the task(s) with manual pushing and pulling last up to 8 hours a day?	NO	YES
Hazard	**Grasp height**		
	The push-or-pull force is applied to the object between hip and mid-chest level.	NO	YES
Hazard	**Posture**		
	The push-or-pull action is performed with an upright trunk (not twisted or bent).	NO	YES
Hazard	**Handling Area**		
	Hands are held inside shoulder width and in front of the body.	NO	YES
If all of the questions are answered "YES", then the examined task is in green area (ACCEPTABLE) and it is not necessary to continue the risk evaluation. If at least one of the questions is answered "NO", then evaluate the task(s) by ISO 11228-2.			

Table 8 — Pushing and pulling — Quick Assessment — Critical condition

If one or more of the following conditions is present, consider risk as HIGH, and it is necessary to proceed with task re-design.			
Hazard	**FORCE MAGNITUDE**		
	A) Peak initial force during push-or-pull (to overcome rest state (inertia) or to accelerate or to decelerate an object): The force is at least 360 N (males) or 240 N (females). B) Continuous (sustained) push-or-pull (to keep an object in motion): The force is at least 250 N (males) or 150 N (females) Alternatively, during the pushing-pulling task(s), the perceived effort using the CR-10 Borg scale (obtained by interviewing the workers), shows the presence of high peaks of force (perceived effort) (a score of 8 or more on the Borg CR-10 scale)?	NO	YES
Hazard	**POSTURE**		
	The push-or-pull action is performed with the trunk significantly bent or twisted.	NO	YES
Hazard	**FORCE EXERTION**		
	The push-or-pull action is performed in a jerky manner or in an uncontrolled way.	NO	YES
Hazard	**GRASP HANDLING AREA**		
	Hands are held either outside the shoulder width or not in front of the body.	NO	YES
Hazard	**GRASP HEIGHT**		
	Hands are held higher than 150 cm or lower than 60 cm.	NO	YES
Hazard	**FORCE DIRECTION**		
	The push-or-pull action is superimposed by relevant vertical force components (“partial lifting”)	NO	YES
Hazard	**TASK DURATION**		
	Does the task(s) with manual pushing and pulling lasts more than 8 hours a day?	NO	YES
If one or more answers are “YES”, then a critical condition is present. If a critical condition is present then apply ISO 11228-2 for identifying corrective actions.			

3.2.5 Repetitive task(s) of the upper limbs — Quick assessment

For establishing acceptable risk use Table 9 (it incorporates the “Entry” steps in ISO 11228-3; i.e. hazard identification and preliminary simple risk estimation). If all of the listed conditions are present (i.e. reply YES), then the examined task is in the Green area (ACCEPTABLE), and it is not necessary to continue the risk evaluation. If any of the conditions is not met, address to ISO 11228-3, Method 1 and, when necessary, Method 2.

Table 9 — Repetitive task(s) of the upper limbs — Quick Assessment — Acceptable condition

Are either upper limbs working for less than 50% of the total time duration of repetitive task(s)?	NO	YES
Are both elbows held below the shoulder level for almost 90% of the total duration of the repetitive task(s)?	NO	YES
Is there a moderate force (perceived effort = max 3 or 4 on CR-10 Borg scale) exerted by the operator for no more than 1 hour during the duration of the repetitive task(s)?	NO	YES
Absence of force peaks (perceived effort = 5 or more on CR-10 Borg scale)	NO	YES
Presence of breaks (including the lunch break) that lasts at least 8 min every 2 hours?	NO	YES
Are the repetitive task(s) performed for less than 8 hours a day?	NO	YES
If all of the questions are answered "YES", then the examined task is in Green area (ACCEPTABLE) and it is not necessary to continue the risk evaluation. If at least one of the questions is answered "NO", then evaluate the task(s) by ISO 11228-3.		

A quick assessment can also be used for identifying "critical conditions". If any of the conditions are met then a critical situation is present, and an ergonomics intervention is necessary to redesign the task as a high priority (Table 10).

Table 10 — Repetitive task(s) of the upper limbs — Quick Assessment — Critical condition

If at least one of the following conditions is present (YES), the risk has to be considered as CRITICAL and it is necessary to proceed with URGENT task re-design.		
Are technical actions of a single limb so fast that it cannot be counted by simple direct observation?	NO	YES
One or both arms are operating with the elbow at shoulder height for half or more than the total repetitive working time	NO	YES
A "pinch" grip (or all kinds of grasps using the fingers tips) is used for more than 80% of the repetitive working time.	NO	YES
Peak force applied (perceived effort = 5 or more in CR-10 Borg scale) for 10% or more of the total repetitive working time?	NO	YES
There is no more than one break (lunch break included) in a shift of 6-8 hours?	NO	YES
Total repetitive working time is exceeding 8 hours within a shift?	NO	YES
If at least one of the questions is answered "YES", then a critical condition is present. If a critical condition is present, then apply ISO 11228-3 for identifying urgent corrective actions.		

3.2.6 Static working postures — Quick assessment

To establish acceptable risk use Table 11. If any of the conditions are not met, it is necessary to apply ISO 11226.

Table 11 — Static working postures — Quick Assessment

Head and trunk evaluation		
Are both the trunk posture AND the neck posture symmetrical?	NO	YES
Is the trunk flexion to the front less than 20° OR in case of backward inclination, is the trunk fully supported?	NO	YES
Is there trunk flexion between 20° and 60°, AND is the trunk fully supported?	NO	YES
Is neck extension absent OR in case of neck flexion, is it less than 25°?	NO	YES
Is backward head inclination fully supported OR, in case of head inclination to the front, is it less than 25°?	NO	YES
If sitting, is a convex spinal curvature absent?	NO	YES
Upper limb evaluation (evaluate the more loaded limb)		
Right/Left		
Are awkward upper arm postures absent?	NO	YES
Are the shoulders not raised?	NO	YES
Without full arm support, is the upper arm elevation less than 20°?	NO	YES
With full arm support, is there upper arm elevation up to 60°?	NO	YES
Are extreme elbow flexion/extension AND extreme forearm rotation absent?	NO	YES
Is extreme wrist deviation absent?	NO	YES
Lower limb evaluation (evaluate the more loaded limb)		
Right/Left		
Is extreme knee flexion absent?	NO	YES
Is the knee not flexed in standing postures?	NO	YES
Is there a neutral ankle position?	NO	YES
Is kneeling or crouching absent?	NO	YES
When sitting, is the knee angle between 90° and 135°?	NO	YES
If all of the questions are answered “YES”, then the examined task is in Green area (ACCEPTABLE), and is not necessary to continue the risk evaluation. If at least one of the questions is answered “NO”, then evaluate the task(s) by ISO 11226.		

Annex A
(informative)

Application information for ISO 11228-1

The purpose of Annex A is to provide the users of ISO 11228-1 with useful information that is needed to perform a risk assessment.

This step is essential after completing the key-questions and the quick assessment.

The annex consists of the following information.

a) A specific reference to the standard:

- reference masses to be used when considering gender and age;
- classification of the results of risk assessment, introducing the concept of the Lifting Index (LI);
- demonstration (by an example) of a task evaluation that emphasizes the need to address work organization;
- an approach (derived from the standard) for the analysis of manual lifts operated by several (2 or more) workers.

b) Notes advances the standard:

- an approach for simple lifts carried with one upper limb;
- evaluation of variable lifting tasks (when different masses are lifted while holding different body postures (by taking into account various load placement positions) with examples for the calculation of Variable Lifting Index (VLI).

A.1 Reference mass (Note: in the standard)

Table C.1 of ISO 11228-1:2003) presents Reference Masses with estimated percentages of various user populations that will be protected when these Reference Mass are used in the given lifting task assessment method. By considering the contents of Table C.1 and of similar tables in other relevant standards (see EN 1005-2),[7] the following Reference Mass (Table A.1) could be adopted as a function of age and gender of the working population.

Table A.1 — The reference masses (m_{ref})

Working population by gender and age	Reference mass (m_{ref})
Men (18–45 years old)	25 kg
Women (18–45 years old)	20 kg
Men (<18 or > 45 years old)	20 kg
Women (<18 or > 45 years old)	15 kg
NOTE A value of 23 kg is the reference mass used in the Lifting Equation by the National Institute of Occupational Safety and Health (NIOSH) of the US, and is the source of the lifting analysis method used in ISO 11228-1. The use of 23 kg as the reference mass accommodates at least 99 % of male healthy workers and at least 75 % of female healthy workers at LI = 1,0.	

A.2 Lifting Index (LI) (recommended limits for mass, frequency and object position)

A.2.1 Recommended mass (Note: in the standard)

By utilizing the reference mass (m_{ref}) reported in Table A.1, and using procedures and equations given in ISO 11228-1:2003, A.7 that consider different multipliers representing the risk level determined by job organization and the object position (ISO 11228-1:2003, step 3, page 5), it is possible to compare the Actual lifted mass (m_A) with the resulting recommended limit (m_R) by the following equation (see also Figure A.1). Lowering is treated the same as lifting in the analysis:

$$m_R = m_{ref} \times h_M \times v_M \times d_M \times \alpha_M \times f_M \times c_M$$

where (see also Figure A.1)

— m_{ref} is the reference mass for the identified user population group;

— h_M is the horizontal distance multiplier, derived from the specific equation in ISO 11228-1:2003, A.7;

— v_M is the vertical location multiplier, derived from specific equation in ISO 11228-1:2003, A.7;

— d_M is the vertical-displacement multiplier, derived from specific equation ISO 11228-1:2003, A.7;

— α_M is the asymmetry multiplier, derived from specific equation in ISO 11228-1:2003, A.7;

— f_M is the frequency multiplier;

— c_M is the coupling multiplier for the quality of gripping the object.

The following conditions are important during the comparison of lifting masses:

— m_A is $\leq m_R$ (acceptable condition);

— m_A is $> m_R$ (not recommended condition).

A.2.2 Computing the lifting index (Note: advances the standard)

An alternative way of performing a comparison between m_A and m_R is to compute the lifting index. The Lifting Index (LI) is equal to the ratio between m_A and the corresponding m_R, and is expressed as LI = m_A/ m

$$LI = m_A/m_R$$

If using the Lifting Index, the classification of assessment results coherent with the one given in ISO 11228-1, step 3 becomes:

— acceptable condition, if Lifting index ≤ 1;

— not recommended condition, if Lifting index > 1.

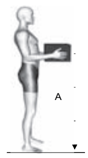
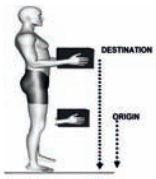
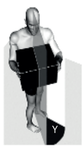
m_{ref}	Reference mass		Maximum recommended mass under optimal lifting conditions
v_M	Vertical multiplier		Distance of the hands from the floor at the start or end of lifting
d_M	Distance multiplier		Vertical distance of the load between the beginning and the end of lifting
h_M	Horizontal multiplier		Maximum distance between the load and the body during lifting
α_M	Asymmetric multiplier		Angular measure of displacement of the load from the sagittal plane
c_M	Coupling multiplier		Assessment of grip of the object (from tables)
f_M	Frequency multiplier		Frequency of lifts per minute and duration (from tables)

Figure A.1 — Multipliers used for computing the Recommended limit for mass (m_R) in ISO 11228-1, Step 3

A.2.3 Interpretation of the Lifting Index (LI) (Note: advances the standard)

For a better interpretation of the Lifting Index, especially when values are greater than 1 and, for addressing the intervention priorities, one can refer to Table A.2.

It is also encouraged to consult other relevant scientific literature to address optimum interventions.

Table A.2 — Interpretation of Lifting Index (m_A/m_R) values

Lifting Index Value	Exposure level	Interpretation	Consequences
LI ≤ 1,0	Acceptable	Exposure is acceptable for most members of reference working population.	Acceptable: no consequences
1,0 < LI ≤ 2,0	Risk present	A part of adult industrial working population could be exposed to a moderate risk level	Redesign tasks and workplaces according to priorities

Table A.2 *(continued)*

Lifting Index Value	Exposure level	Interpretation	Consequences
2,0 < LI ≤ 3,0	Risk present; high level	An increased part of adult industrial working population could be exposed to a significant risk level.	Redesign tasks and work-places as soon as possible
LI > 3,0	Risk present; very high level	Absolutely not suitable for most working population. Consider only for exceptional circum-stances where technological develop-ments or interventions are not sufficiently advanced. In these exceptional circum-stances, increased attention and consider-ation must be given to the education and training of the individual (e.g. specialized knowledge concerning risk identification and risk reduction).	Redesign tasks and work-places immediately

A simple application example of ISO 11228-1:2003, step 3 and A.7 — A simple lifting task performed by one worker lifting with two hands

After evaluating the task through Quick Assessment, if the task is found to require a full evaluation, this analysis should be performed as described in Table A.3. Begin with collecting the data required to assess the lifting index (LI).

Table A.3 — The operative steps for risk evaluation of manual lifting

	Steps	Data to be collected
A.	Identification of types of lifting tasks	Simple (or composite or variable or sequential) task
B.	Description of the workers involved in manual lifting tasks	Number, gender, age, etc.
C.	Organization analysis – Shift schedule	Evaluation of manual lifting dura-tion
D.	Identification of the number of objects manually lifted in a shift	Evaluation of lifting frequency
E.	Analysis of geometries at the origin and destination of the lifted objects	Study of the lay-out risk factors

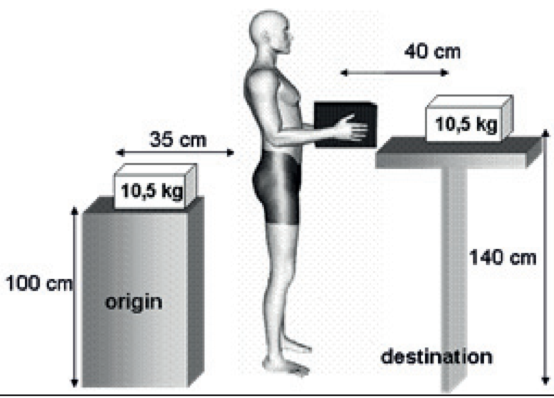
Below is an example of calculating LI.

Figure A.2 depicts the data concerning the organization and layout of the task required to be evaluated (EXERCISE 1).

For a quick evaluation (with reference to EXERCISE 1), the computation scheme shown in Figure A.3 can be used to easily compute LI associated with a simple lifting task.

SHIFT SCHEDULE															
MANUAL LIFTING TASK	other task or breaks	push pulling task	other task or breaks	MANUAL LIFTING TASK	other task or breaks	push pulling task	other task or breaks	MANUAL LIFTING TASK	other task or breaks	push pulling task	other task or breaks	MANUAL LIFTING TASK	other tasks or breaks	push pulling task	other task or breaks
60	60			60	60			60	60			60	60		

SHORT DURATION (*)	
Shift duration (min)	480
MMH Duration (including carrying) (min)	240
Total number of lifted objects	1200
Lifting frequency – actions per min	5



* For determining the duration scenario, use the following criteria:

A - Short duration, if conditions A1 & A2 = TRUE, where:
A1. each Lifting Task ≤ 60 min;
A2. each period (break or light work) following Lifting Task ≥ **100**% (time) of Lifting Task.

B - **Medium duration,** if conditions B1 & B2 & B3= TRUE, where:
B1. not Short duration;
B2. each Lifting Task ≤ 120min; B3. each period (break or light work) following Lifting Task ≥ **30%** (time) of Lifting Task.**C** - **Long duration,** if conditions C1 & C2 = TRUE, where:
C1. not Short duration;
C2. not Medium duration

Figure A.2 — EXERCISE 1: Data concerning the organization and layout required to calculate the LI in a simple task

CALCULATION OF LIFTING INDEX - SINGLE TASK

COMPANY AREA WORK PLACE TASK	OBSERVATION DATE OBSERVER

REFERENCE MASS (kg)

	male	female
18-45 Years	25	20
<18 or >45 Years	20	15

m_{ref} **25**

Distance of the hands from the floor at the start of lifting

(cm)	0	25	50	75	100	125	150	>175
VERTICAL LOCATION MULTIPLIER	0,77	0,85	0,93	1,00	0,93	0,85	0,78	0,00

V_M **0,81**

Vertical distance of the load between the beginning and the end of lifting

(cm)	25	30	40	50	70	100	170	>175
VERTICAL-DISPLACEMENT MULTIPLIER	1,00	0,97	0,93	0,91	0,88	0,87	0,86	0,00

d_M **0,93**

x

Maximum distance between the load and the body during lifting

(cm)	25	30	40	50	55	60	>63
HORIZONTAL DISTANCE MULTIPLIER	1,00	0,83	0,63	0,50	0,45	0,42	0,00

h_M **0,63**

x

Angular measure of displacement of the load from the sagittal plane

(degrees)	0	30°	60°	90°	120°	135°	>135°
ASIMMETRY MULTIPLIER	1,00	0,90	0,81	0,71	0,52	0,57	0,00

a_M **1**

x

Assessment of grip of the object

	GOOD	BAD
COUPLING MULPTIPLIER	1,00	0,90

C_M **0,9**

x

f_M **0,8**

Frequency of lifts per minute and duration

FREQUENCY	**MMH DURATION**		
ACTION/MIN.	≤ 8 H (LONG)	≤ 2 H (MODERATE)	≤ 1H (SHORT)
<0,1	1,00	1,00	1,00
<0,2 to <=0,1	0,85	0,95	1,00
0,2	0,85	0,95	1,00
0,5	0,81	0,92	0,97
1	0,75	0,88	0,94
2	0,65	0,84	0,91
3	0,55	0,79	0,88
4	0,45	0,72	0,84
5	0,35	0,60	0,80
6	0,27	0,50	0,75
7	0,22	0,42	0,70
8	0,18	0,35	0,60
9	0,00	0,30	0,52
10	0,00	0,26	0,45
11	0,00	0,00	0,41
12	0,00	0,00	0,37
13	0,00	0,00	0,00
14	0,00	0,00	0,00
15	0,00	0,00	0,00
>15	0,00	0,00	0,00
FREQUENCY MULTIPLIER FOR AREA INF TO 75 CM			

	NO	YES	
LIFT WITH 1 UPPER LIMB	X		1
LIFT 2 OPERATOR	X		1

10,5 LIFTED MASS (Kg)

RECOMMENDED MASS LIMIT (Kg) **8,5**

LIFTED MASS / **RECOMMENDED MASS**

1,2 **LIFTING INDEX**

Figure A.3 — Exercise 1— Simple scheme for Lifting Index evaluation for a simple lifting task (EXERCISE 1 — Destination)

The scheme provides quantitative values (and qualitative values only for evaluating couplings) for each risk factor, next to the relative multiplier. By applying the procedure to all the factors considered, it is possible to determine m_R.

The next step is to compute m_A (numerator) versus m_R (denominator) to obtain a synthetic risk indicator (Lifting Index).

EXERCISE 1 shows two different distances from the body (Horizontal Locations), one at the origin (35 cm) and the other at the destination (40 cm) of the lift. There are also two different heights of the hands from the floor (Vertical Locations), one at the origin (100 cm) and the other at the destination (140 cm) of the lift.

When there is significant control at the destination of the lift, the original Revised NIOSH Lifting Equation method proposes calculating a LI both at the origin and at the destination, with the risk being represented by the worse of the two.

Figure A.3 describes the analysis that led to the worse result (in this case, the destination of the lift).

Additional information is provided to ensure the proper use of this simple scheme (Figure A.3).

The numerical parameters for “distance” multipliers are supplied for small ranges of about 10 cm.

When the numerical value does not correspond to the one indicated in the scheme, use the closest number and corresponding multiplier; alternatively use interpolation.

For more precise results, compute the multipliers using the original formulas provided in the standard.

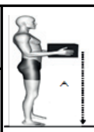
Since it is onerous to apply the relevant formula to each parameter manually, a special software package has been developed to calculate LI at both origin and destination for simple (with the data entered on a single line) and complex lifting tasks. This is discussed later.

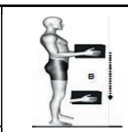
Figure A.4 shows how to enter the data into the software for obtaining an analytical estimate of the lifting index. Once the numbers are entered (see the white boxes), the corresponding multipliers appear automatically in the dark grey boxes through the application of the original formulas. Compared to the original formula, variables have been introduced for lifting by two or more workers, and for single-handed lifting.

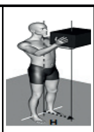
Software (ERGOepm _*tool*_eng) can be downloaded free from the website www.epmresearch.org.

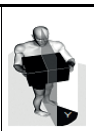
The files may be updated from time to time, so check periodically for the latest versions.

	MALE	FEMALE	
REFERENCE MASS (ISO 11228-1)	25	20	18-45 years old
	20	15	<18 or >45 years old









ACTION DESCRIPTION	lifted mass (kg)	v = vertical location (cm)		d = vertical displacement (cm)			h = horizontal distance (cm)		a = asimmetry angle (°)		c = coupling		f = freq	work duration (min)		hands doing lifting		workers doing lift		Recommended limit for mass (man)	LI (man)
AT ORIGIN	10,5	100	0,93	40	140	0,93	35	0,71	0	1,00	P	0,90	5,0	60	0,80	2	1,00	1	1,00	11,1	0,95
AT DESTINATION	10,5	140	0,81	40	100	0,93	40	0,63	0	1,00	P	0,90	5,0	60	0,80	2	1,00	1	1,00	8,4	1,24

Figure A.4 — EXERCISE 1 — Simple task— Lifting index evaluation with use of original formula and dedicated software

With reference to EXERCISE 1, in Figure A.4, LI at both origin and destination of the lift are calculated. As mentioned, the worse of the two should be considered as a representative of the task.

Comparing LI, obtained using the simplified method (Figure A.3) and with the analytical method (Figure A.4), a slight difference can be seen in the result (LI = 1,23 — simplified method versus LI = 1,24

— analytical method). This negligible difference is due to the different degrees of intrinsic accuracy of the two methods.

A.3 Lifting by 2 or 3 operators (Note: in the standard— see ISO 11228-1:2003, A.3.3)

When the lifting action is performed by 2 or 3 operators, consider, for a single operator, the actually lifted mass (m_A) as the total mass lifted divided by 2 or 3 (according the number of operators) and add another multiplier (called p_M — Persons Multiplier) to the below equation, that leads to compute the corresponding recommended mass (for a single operator of the team).

$$m_R = m_{ref} \times h_M \times v_M \times d_M \times a_M \times f_M \times c_M \times p_M$$

where

p_M = 0,67 for 2 persons lifting actions

p_M = 0,5 for 3 persons lifting actions

The two simple multipliers were obtained by these two formulas derived by the criteria exposed in the standard:

$$LI = \frac{m_A}{m_R} \times \frac{1}{2} \times \frac{2}{3} \qquad \text{FOR 2 PERSONS}$$

$$LI = \frac{m_A}{m_R} \times \frac{1}{3} \times \frac{1}{2} \qquad \text{FOR 3 PERSONS}$$

A.4 Lifting by one arm only (Note: advances the standard)

When a lifting task is performed by only one arm, add another multiplier (called o_M — One hand Multiplier) to the following equation that leads to compute the recommended mass.

$$m_R = m_{ref} \times h_M \times v_M \times d_M \times a_M \times f_M \times c_M \times p_M \times o_M$$

where o_M = 0,6.

This criterion is derived by the standard EN 1005-2 Manual handling of machinery and component parts of machinery.[7] By adding this multiplier to the above equation, one can calculate a LI during one hand manual lifting condition.

A.5 Carrying limits in other than "ideal conditions" (Note: in the standard)

The recommended limits for cumulative mass (Rec_{CuM}) to be carried per day and cumulative mass (m_{CuM}) related to distance carried (steps 4 and 5 in the risk estimation step model on ISO 11228-1:2003, page 4 and discussed in 4.3.2.1 and 4.3.2.2 of that International Standard) assume ideal conditions.

These "Ideal conditions" would include the following:

— smooth, non-slippery walking surface in good repair;

— no steps or climbing;

— good coupling for the load carriage;

— no obstructions to movement;

— good environmental conditions (temperature, humidity in moderate range);

— no obstructions to vision.

Less than ideal carrying circumstances should be evaluated carefully as to their acceptability.

Worker safety should not be compromised. Acute hazards, such as trip or fall hazards, must be eliminated or controlled.

In general the cumulative mass limits should be reduced by 33 %, if:

— loads are awkward or difficult to handle;

— environmental conditions are hot or cold;

— there are a significant number of stair steps to make while carrying;

the cumulative mass limits should be reduced by 33 %.

Table A.4 suggests a simple scheme for comparing the cumulative mass (CuM) with the recommended limits for cumulative mass (RecCuM).

Actually this comparison is performed by checking if:

CuM is ≤ Rec_{CuM} (acceptable condition)

CuM is > Rec_{CuM} (not recommended)

Table A.4 — How to calculate the cumulative mass

Number of carried objects (at least 1 m of distance) heavier than 3 kg (A)	**Carried objects mass in kg ((B)**	**Cumulative mass** (A) x (B) = Y
		0
		0
		0
		0
(mcum) Total cumulative mass = Σ (Y)	0	
Recommended cumulative mass (RecCuM) allowed for 8 h:		
6000 kg (for carrying distances ≥ 20 m)		
10000 kg (for carrying distances < 20 m)		
Recommended cumulative mass (RecCuM) allowed for 1 h		
750 kg (for carrying distances ≥ 20 m)		
1500 kg (for carrying distances < 20 m)		
Recommended cumulative mass (RecCuM) allowed for 1 min		
15 kg (for carrying distances ≥ 20 m)		
30 kg (for carrying distances < 20 m)		
If no ideal conditions are present, reduce the RECOMMENDED CUMULATIVE MASS by 33 %		

A.6 Guidance on multitask lifting analysis (Note: advances the standard)

A.6.1 General aspects

For correctly studying manual lifting, it is primarily necessary to define task characteristics as per the criteria given below:

— MONO TASKS (defined as single-task by NIOSH) are defined as tasks involving the lifting of only one kind of object (with the same load) using always the same postures (body geometry) in the same lay-out at origin and destination. In this case the “traditional” Lifting Index (LI) computational procedure could be followed[13] as also substantially reported in of ISO 11228-1, A.7 (Figure A.5).

— COMPOSITE TASK (defined as multi-task by NIOSH) are defined as tasks involving lifting objects (generally of the same kind and mass) using different geometries (collecting and positioning from/on shelves placed at several heights and/or depth levels). Practically each individual geometry is a task “variant” and takes the name of “subtask”. In this case the Composite Lifting Index (CLI) computational procedure could be applied as presented in the Applications Manual for the Revised NIOSH Lifting Equation.[14] It is to be underlined that no more than 10-12 variants or subtasks could be considered by this procedure (Figure A.5).

— VARIABLE TASK is defined as a lifting task in which both the geometry and load mass vary in different lifts performed by the worker(s) within (or during) the same period of time (Figure A.6). The Variable Lifting Index (VLI) is suggested for assessing these complex types of lifting tasks.[5]

— SEQUENTIAL TASK (Figure A.7) is defined as a job in which the worker rotates between two or more Mono tasks and/or Composite tasks and/or Variable tasks during a work shift (each task lasting no less than 30 min consecutively). For these work scenarios the Sequential Lifting Index (SLI) computational procedure could be followed.[15]

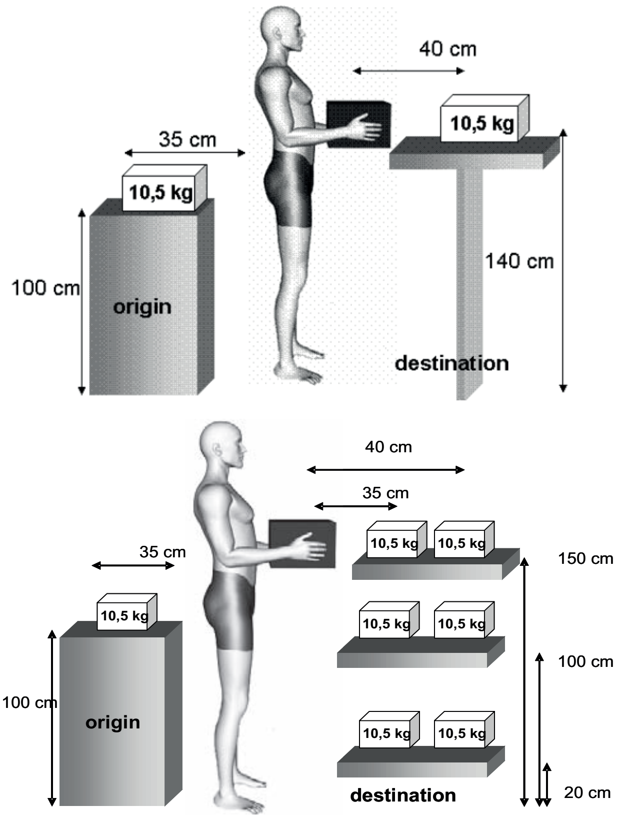


Figure A.5 — Mono and composite tasks

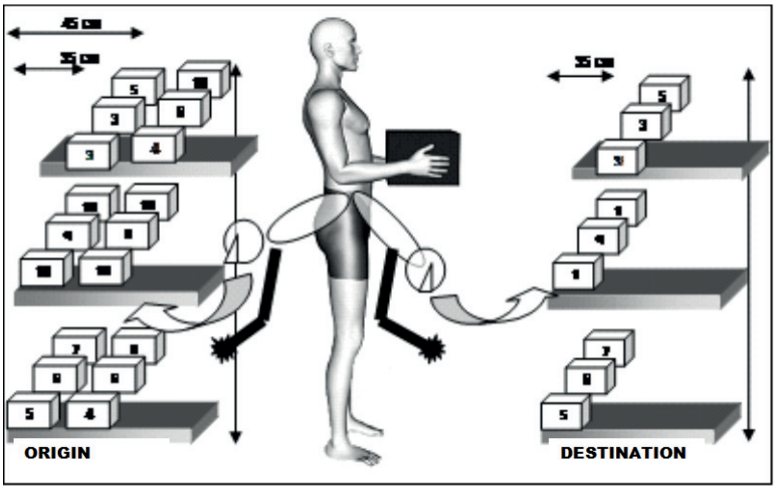


Figure A.6 — Variable task

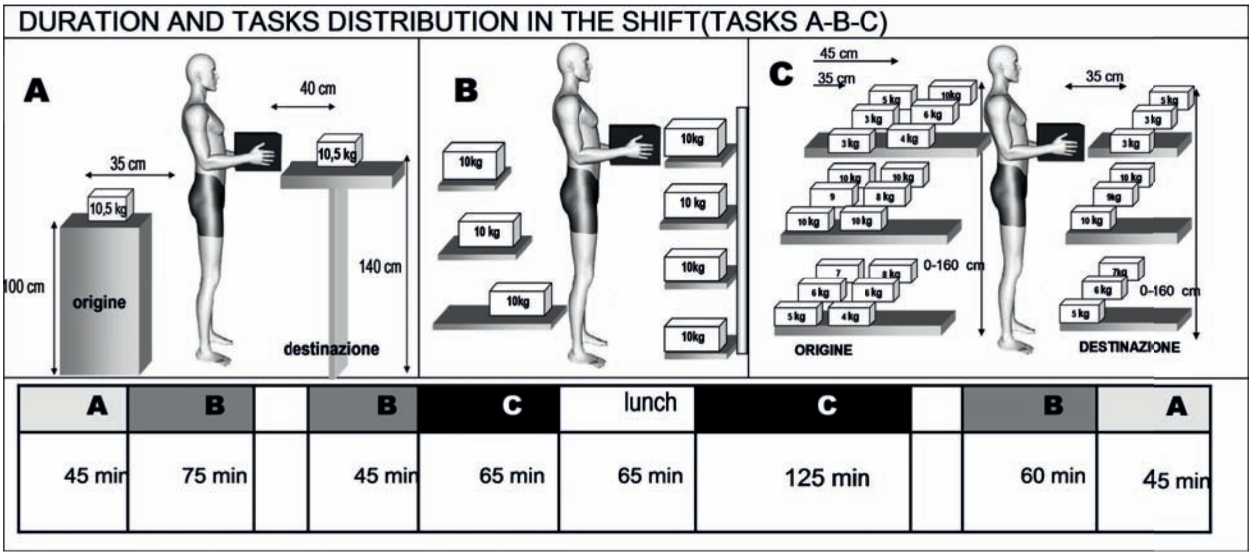


Figure A.7 — Sequential task

All procedures for analysing different types of lifting tasks are based on the original Revised NIOSH Lifting Equation (for single tasks), and is substantially addressed by ISO 11228-1 at step 3 and A.7.

New criteria are quoted below for a wider application of ISO 11228-1: these procedures allow to analyse complex lifting tasks (Composite tasks with more than 10 "variants" and Variable tasks) that were previously difficult to evaluate.

A.6.2 Criteria to evaluate the lifting index in complex lifting tasks – General outline of the procedure

Complex lifting tasks mean "tasks characterized by presence of many sub-tasks" (more than 10-12) as they occur in several Composite tasks (Figure A.8) and in a majority of Variable tasks.

A Variable lifting task is often observed in industry, but that has not been previously defined by NIOSH; it includes manual lifting tasks in which the task characteristics vary between each of the lifts during the shift, such as manual lifting in warehousing, baggage handling, construction, and certain service jobs. These latter types of tasks are the most difficult to analyse from an ergonomics perspective. In variable-task manual lifting jobs, the weight of the load being lifted and the geometry of the lift (e.g. horizontal reach, vertical height, etc.) can vary between every lift in the task/job.

The variables that increase the number of sub-tasks in a COMPOSITE or a VARIABLE TASKS may be large and may lead to long analytical times and mistakes. The RNLE Original Formula for “MULTITASK” lifting (here called “COMPOSITE”) discourages from using more than 10 variables (subtasks). Hence simplifications are needed for allowing analysis of such complex situations that are frequently encountered in a variety of workplaces.[5]

Thus, a new approach and specific procedure to assessment of variable lifting tasks is needed. It should allow practitioners to quite easily apply the contents of ISO 11228-1 provisions to analyse Variable lifting tasks.

The following general procedure is suggested.[5] Whichever the number of potential individual lifting tasks in the job, compress them into a structure that considers up to a maximum of 30 subtasks (and corresponding FILI and STLI) for different loads (weight categories) and geometries using the following approach:

— Aggregate up to 5 objects (weights) categories.

— Classification of vertical location in only 2 categories (good/bad).

— Classification of horizontal location in up to 3 categories (near; medium; far).

— Presence/absence of “asymmetry” (AM) assessed for each weight category (by threshold value for all the lifts in the category).

— Daily duration of lifting classified as in the Applications Manual.[14]

— Frequencies of lifts specifically determined or estimated for each subtask and FILI; frequency multipliers (FM) determined as in the Applications Manual.[14]

— Vertical displacement (DM) and coupling (CM) are both considered as a constant.

— At the end it will be possible to compute individual FILI and STLI for up to 30 subtasks.

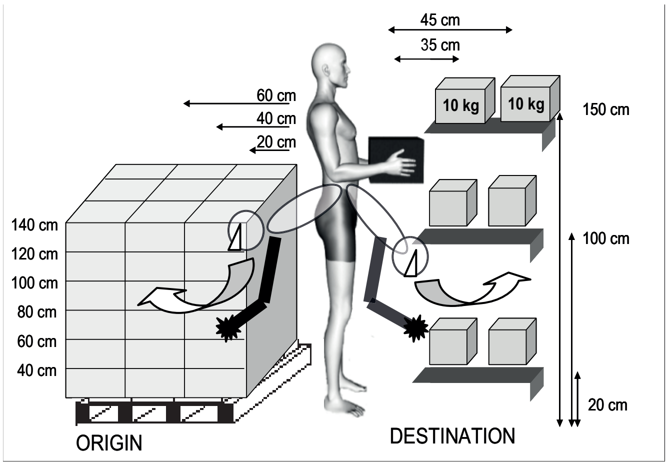
— The resulting FILI’s are then fitted into one of a fixed number (six) of FILI categories. The average values for each FILI category and the corresponding frequency of lifts in each category are then used as input into the Composite Lifting Index (CLI) equation previously published by NIOSH[14] to obtain the VLI for a variable manual lifting task.

  The new procedure maintains the original RNLE criteria via simplifications in data collection and new dedicated software. This revised procedure is not “mandatory” but could be considered as a “guideline” to all potential users on how to adequately collect and manipulate relevant data to produce the final VLI evaluation.

  Hereafter the essential and some details of the procedure that allows calculating both, CLI for a Composite task with more than 10 subtasks and the VLI for the Variable task will be presented. This evaluation can only be applied by a dedicated software (otherwise, with paper and pen approach it will be difficult to calculate). To this aim, by utilizing the websites given below, it is possible to freely download dedicated software, thereby calculating both CLI “complex” and VLI procedures (according to ISO 11228-1 provisions):

  — www.epmresearch.org (in English and Italian)

  — www.cenea.eu (in Spanish)



6 Vertical Locations at origin

3 Horizontal Locations at origin

3 Vertical Locations at destination

2 Horizontal Locations at destination

6 x 3 x 3 x 2 = 108 sub-tasks

Figure A.8 — A common example of a composite task with more than 10 subtasks

A.6.3 Criteria to evaluate the lifting index in complex lifting tasks: step by step procedure

A.6.3.1 Step 1 – Collecting organizational and production data

Collecting organizational data is preliminary for all types of tasks: Mono, Composite, Variable or Sequential. The first assessment step is to identify the worker/s and their number (1 or more) involved in homogeneous manual handling activities.

Then the manual lifting task/s and their respective duration have to be assessed in the shift. It is important to consider the real sequence of lifting activities as alternated with other "light non manual handling" activities and/or "breaks" (see Example 1 in Table A.5).

A.6.3.2 Step 2 – Identification of number of objects lifted in a shift and their mass

Identify the mass (from 3 kg up to maximum, by increments of 1 kg) and the number of objects lifted manually in a shift by the worker(s).

To obtain this object-related information, one can take assistance of person(s) who are in charge of the production or sales data of the specific organization

Information regarding the characteristics of an object mass to be lifted is actually mandatory in some countries, and should be provided in the packing (see Example 1 in Table A.6).

Table A.5 — Variable task, example 1 — How to input organization data

Kind of task – To fill shelves in supermarket with different bottles (water, wine, drinks) 10 operators doing the same task (impossible to know the precise number of pieces lifted by each person) 6 hours shift Different mass is lifted Different heights at the origin at destination are present														
	other task or breaks	MANUAL LIFTING TASK (including carrying)	other task or breaks	push pulling task	other task or breaks	MANUAL LIFTING TASK (including carrying)	other task or breaks	push pulling task	other task or breaks	MANUAL LIFTING TASK (including carrying)	other task or breaks	push pulling task	other task or breaks
minutes		**60**	**5**	10		**120**	**20**	20		**60**	**5**	10	50
shift starting	**08.00**												end
time		09.00	09.05	09.15		11.15	11.35	11.55		12.55	13.00	13.10	14.00

Table A.6 — Variable task, example 1: how to input the mass and the number of lifted objects by one person or group of workers doing the same lifting task

NO. OF WORKERS INVOLVED (GROUP)= 10				
Range of objects mass (kg)	Representative mass (kg)	No. of objects to lift per shift by the whole group (a)	No. of lifts for each mass range (b)	No. of objects lifted per shift by the whole group (a * b)
3 ≤ mass < 4	3,5	200	1	200
4 ≤ mass < 5	4,5	790	1	790
5 ≤ mass < 6	5,5	2000	1	2000
6 ≤ mass < 7	6,5	400	1	400
7 ≤ mass < 8	7,5	400	1	400
8 ≤ mass < 9	8,5	1000	1	1000
9 ≤ mass <10	9,5	800	1	800
	Total			5590

The recorded weight of the masses is aggregated into a maximum of five weight categories by dividing the span of weight values (i.e. max value – min) by five to determine the min. and max. for each category. A representative average (by frequency) mass is selected for each category (see Example 1 in Table A.7).

Table A.7 — Variable task, example 1: Aggregation of the indicated mass into a maximum of 5 categories

Categories		No. objects	Average mass (kg)	Percentage of lifted objects
From	To			
3,5	4,7	990	4,3	18%
4,7	5,9	2000	5,5	36%
5,9	7,1	400	6,5	7%
7,1	8,3	400	7,5	7%
8,3	9,5	1800	8,9	32%

From the data collected (e.g. number of workers involved in the task(s); net duration of manual lifting in the shift; total number of objects lifted during a shift; number of objects within each mass category lifted during a shift), one can determine the net manual handling duration, the overall lifting frequency (per worker), the lifting frequency per each mass category.

This approach should be complemented by allocating the corresponding appropriate Frequency Multipliers (fM) from traditional tables [14] [15] as a function of appropriate lifting duration scenario (short; moderate; long) - see Example 1 in Table A.8.

Table A.8 — Variable task, example 1: Evaluation of duration scenario and frequency

Long duration	
Number of workers involved	10
Lunch duration in minutes	30
Shift duration	360
Net duration of MMH in a shift including carrying (min)	240
Net duration of pushing and pulling (min)	40
Total number of objects lifted (mass more than 3 kg) by the group	5590
Total number of objects lifted (more than 3 kg) by each worker	559
Overall lifting frequency (lifts/min)	2,33

A.6.3.3 Step 3 – Identification of the position of the body and loads (geometries) at origin and destination – Variable Simplification

Suggested guidelines for these simplifications in the RNLE equation are given below. The key-elements of the procedure are the following.

The key-elements of the procedure are the following:

a) Classification of vertical location (and v_M) into two categories (good/bad) —Figure A.9:

— IDEAL AREA. When hands are within 51 and 125 cm; the vertical multiplier (v_M) is equal to 1.

— NON IDEAL AREAS. When hands are below 51 cm or above 125 cm (up to 175 cm); the vertical multiplier (v_M) is equal to 0,78.

NOTE According to this classification one could compute 2 subtasks for each mass category (up to 10 subtasks so far). Extreme areas (>175 cm) are considered as: an additional option, completely inadequate (no computation is possible) and to be avoided.

b) Classification of horizontal location (and h_M) into three categories (near; medium; far) — Figure A.10:

— IDEAL AREA (near). When horizontal distance is within 25-40 cm; the representative horizontal multiplier (h_M) is equal to 0.71 (for a representative value of 35 cm.)

— NON IDEAL AREAS (medium). When horizontal distance is within 41-50 cm; the representative horizontal multiplier (h_M) is equal to 0.56 (for a representative value of 45 cm.)

— NON IDEAL AREAS (far). When horizontal distance is within 51-63 cm; the representative horizontal multiplier (h_M) is equal to 0.40 (for a representative value of 63 cm.)

NOTE According to this classification, one could compute 3 subtasks for each mass category in each vertical area (up to 30 subtasks so far). Extreme areas (>63 cm) are considered as: an additional option, completely inadequate (no computation is possible) and to be avoided.

It is very easy to obtain the layout (or geometry) multipliers and input (in the software) the different positions of the mass at the origin and destination with a “X” in two boxes that represent the shelves at the origin of the lift and at their destination (example 1, Figure A.11).

c) Presence of asymmetry could be generally assessed by the presence or absence of a threshold value.

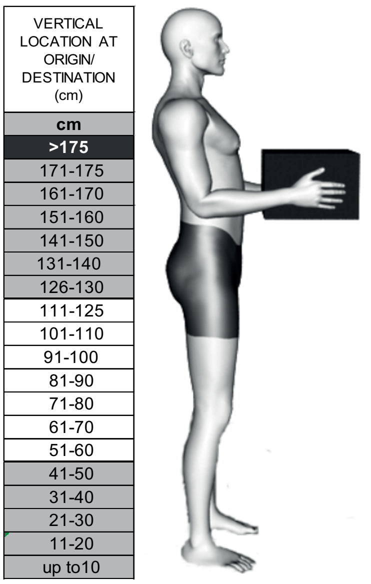
Trunk rotations are considered synthetically for each “mass category”. An asymmetric multiplier (a_M) of 0.81 is assigned to all the subtasks in the category if trunk rotations exceed 45° and are present (in that category) for over 50 % of lifting actions. Otherwise asymmetric multiplier is equal to 1.

d) Vertical travel distance (vertical distance between the height of hands at origin and at destination).

Assessment of this factor was skipped. The corresponding multiplier (d_M) is considered as a constant and equal to 1. It is to be underlined that when assessing vertical location (v_M), one should always consider height of hands at both origin or at destination of the lift.

e) Type of grip (coupling).

Assessment of this factor was skipped. Based on experience, “good grips” are quite rare; therefore the corresponding multiplier (c_M) is considered as a constant and equal to 0,90.



VERTICAL MULTIPLIER (v_M)

Vertical location

reduced to 2 areas (or geometries):

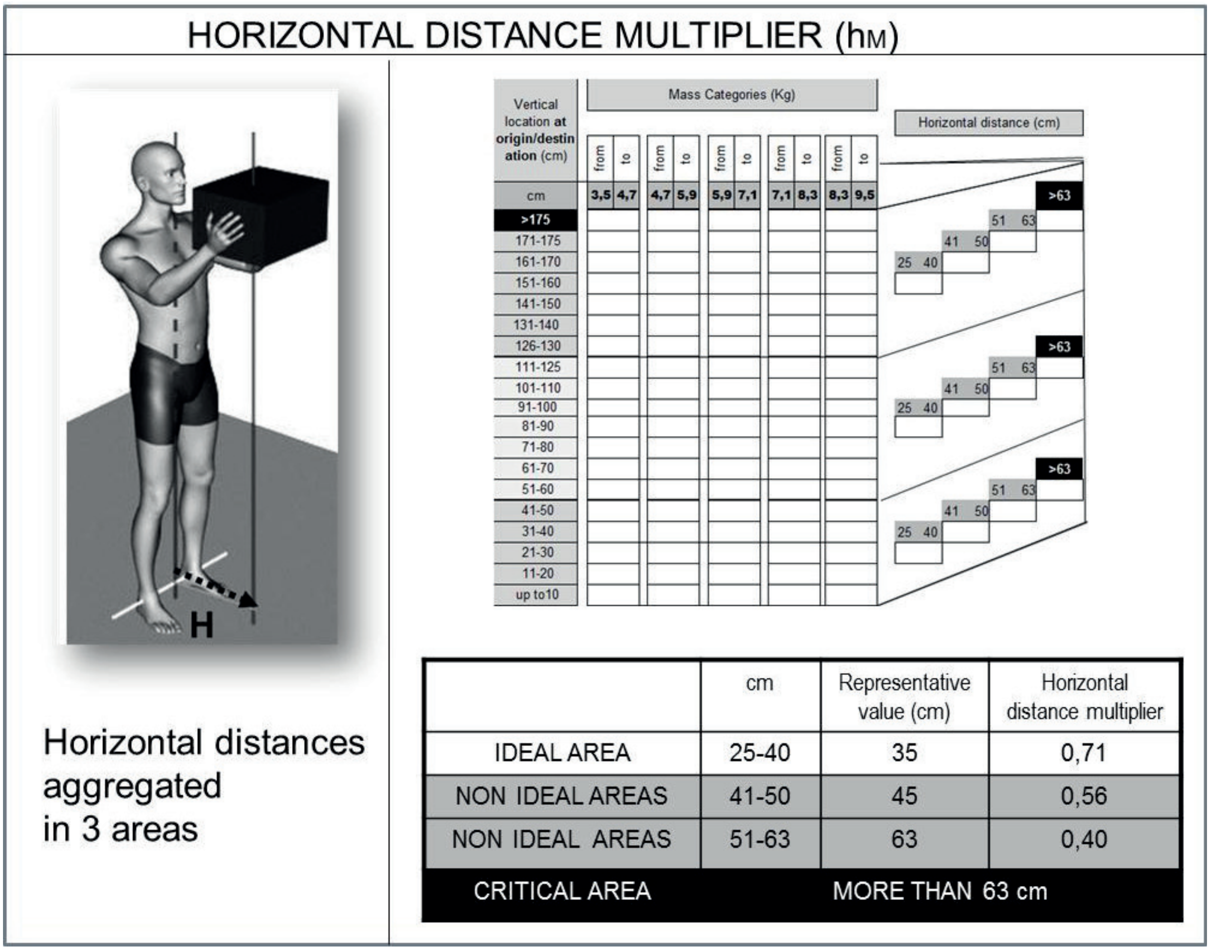
a) IDEAL AREA

b) NON IDEAL AREAS

CRITICAL AREA: unchanged

	VERTICAL LOCATION (cm)	REPRESENTATIVE VALUE (cm)	MULTIPLER
IDEAL AREA	51-125	75	**1**
NON IDEAL AREA	0-50 or 126-175	0 or 175	**0.78**
CRITICAL AREA	ABOVE 175 CM OR BELOW 0 CM		

Figure A.9 — Classification of vertical location (v_M) into two categories



	cm	Representative value (cm)	Horizontal distance multiplier
IDEAL AREA	25-40	35	0,71
NON IDEAL AREAS	41-50	45	0,56
NON IDEAL AREAS	51-63	63	0,40
CRITICAL AREA	MORE THAN 63 cm		

Figure A.10 — Classification of horizontal location (hM) into three categories

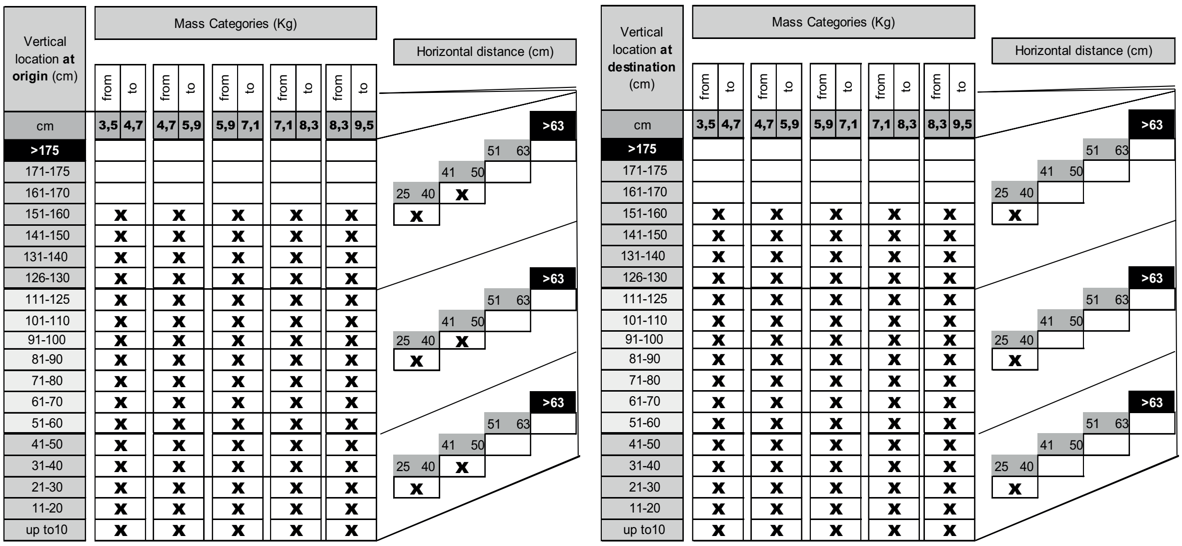


Figure A.11 — Variable task, example 1 — The two representative boxes where one can record object position at origin and destination for different mass categories

A.6.3.4 Step 4 — Aggregation of resulting LI and computation of final LI for the CLI complex and VLI

These simplifications produce up to and no more than 30 subtasks (5 mass categories × 2 Vertical Location × 3 Horizontal Areas × 1 Asymmetry condition), and the software calculates the relative LI by using the traditional Lifting Equation (Figure A.12).

For each of these subtasks, an individual frequency of lifting is estimated by a statistical approach.

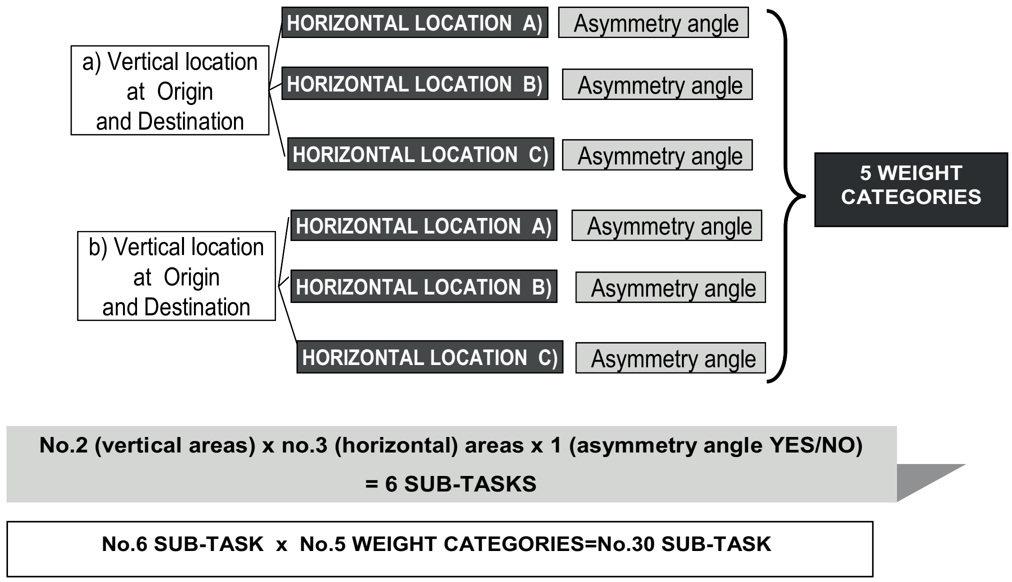


Figure A.12 — The result of the adopted simplifications: a maximum number of potential 30 sub-tasks

Among these FILI values, the "sextiles" of their distribution (corresponding to the 16,6th, 33,3th, 50th, 66, 3th and 83,3th percentiles values) are determined: these are "key" values that determine the limits for aggregating the "subtasks" results into 6 "FILI categories".

Consequently, the cumulative frequency of lifting for each of those 6 FILI categories is also considered.

Based on these aggregations, and by utilizing the software, one may compute respective FILI (single category lifting index independent from frequency) as STLI (single category lifting index considering frequency) for each one of these new 6 "LI categories".

Finally, using those data, the CLI complex and/or VLI are computed using the traditional CLI approach and equation.[14]

Results are then expressed with respect to different Reference Masses reported in Table A.1 or with respect to the load constant suggested in Original RNLE (Table A.9)

Table A.9 — The final lifting indices for the different age-gender groups using their relative reference mass

European Standard: EN 1005-2; International Standard: ISO 11228-1		
25	Men (18-45 years old)	1,31
20	Women (18-45 years old)	1,64
20	Men (<18 or >45 years old)	1,64
15	Women (<18 or >45 years old)	2,18
Original NIOSH Lifting equation		
23	NIOSH original	1,42

A.6.4 Criteria to evaluate the sequential LI in sequential tasks — Detailed procedure by steps

When a job is characterized by several different tasks (MONO, COMPOSITE, VARIABLE: see Figure A.13) in a shift, and workers rotate between a series of single or multiple task lifting rotation slots during a work shift, then we have a real MULTITASK exposition. In this case, the recommended method to asses the risk is the SEQUENTIAL TASK technique.[15]

In the Figure A.13, two different lifting tasks (A and B) are shown in three different rotation patterns during a shift: in the last, the rotation between them occurs after each hour. Having different risk levels for each task, it is a common opinion that the last scenario should present the lowest risk level.

The Sequential Lifting Index allows to calculate the Final LIfor these multitask exposition (SLI), considering the different intrinsic duration of each task and the total duration of the shift exposure to manual handling.

For the calculating a variety of these lifting combinations, the software is generally necessary and available for free download at www.epmresearch.org.

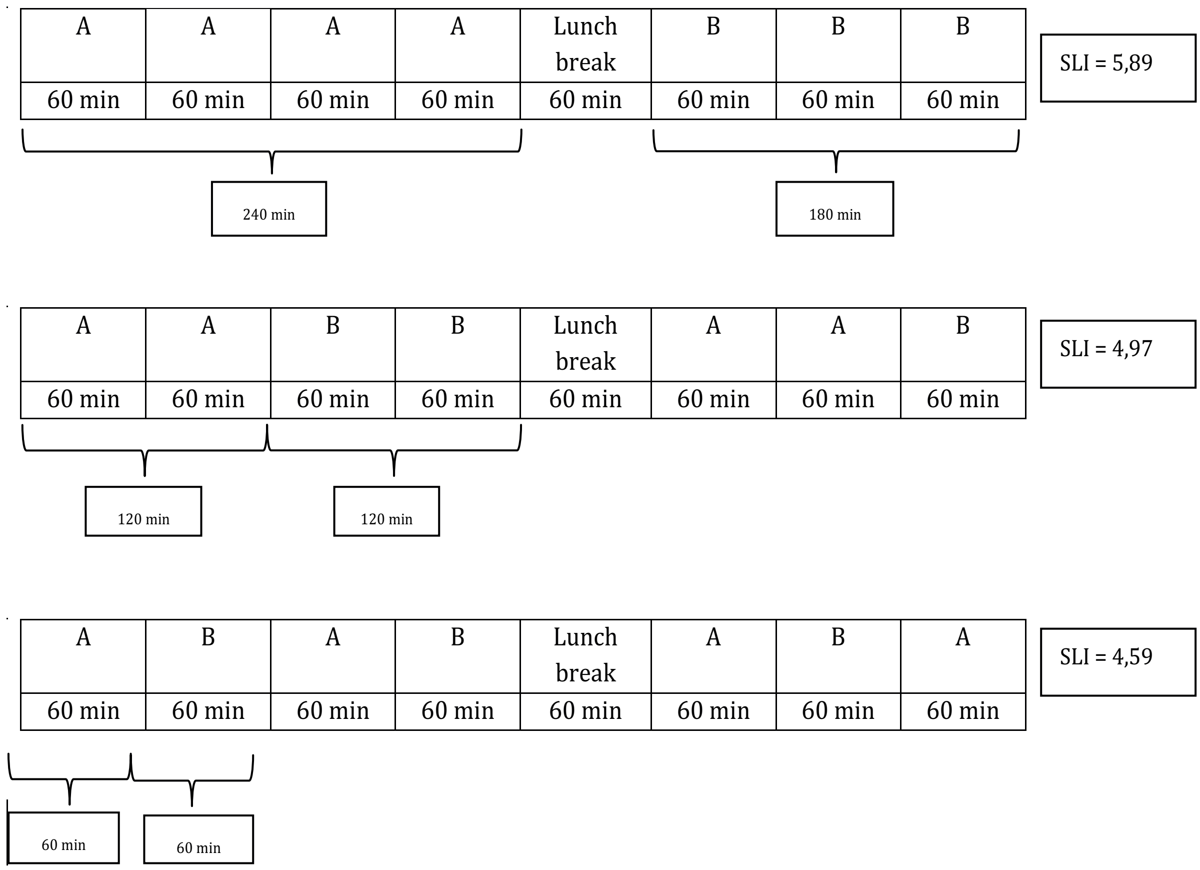


Figure A.13 — Example 2 — Different patterns of job rotation between two different tasks and corresponding SLI

The main steps for obtaining the SLI are shown below:

a) Step 1: define the tasks present in the shift and their time sequence.

b) Step 2: define the duration and time distribution of the tasks present in the shift.

c) Step 3: for each task, as per the procedures previously given for CLI complex and VLI computation, describe the number of objects lifted and geometry of the objects per shift.

d) Step 4: for each task, compute the respective STLI by considering both intrinsic duration (LI intr) and total duration (all lifting tasks) (LI max) scenarios.

e) Step 5: use the SLI Equation to obtain the SLI.

The SLI equation[15] is given below:

$$\text{SLI} = \text{LIintr1} + [(\text{LI1max} - \text{LI intr1}) \times \text{K}]$$

where

$$\text{K} = \sum \frac{\left[(\text{LI1max} \times \text{FT1}) + (\text{LI}n\text{max} \times \text{FT}n)\right]}{\text{LI1max}}$$

$$\text{FT}j = \frac{\text{Time in task } j \text{ during the shift}}{480}$$

Annex B
(informative)

Application information for ISO 11228-2

The purpose of Annex B is to provide an application aid to the users of the standard ISO 11228-2, which is focused on pushing and pulling. After completing the preliminary stages of key-questions and the quick assessment of the job, the standard ISO 11228-2 should be applied only if the potential users manifest the need to carry a proper risk assessment for pushing or pulling. A complete application manual is not enclosed here. Instead, the principle of ISO 11228-2 is described here including the underlying framework requirement enabling or excluding the application of the various risk estimation and evaluation methods. Annex B starts with an explanation of the general model of risk assessment (section B.1), followed by descriptions of the generalized and the specialized risk estimation and assessment methods (sections B.2 and B.3). In the final section, explanations of further method details are accompanied by flow charts (section B.4).

ISO 11228-2 provides guidance on the assessment of potential risk factors considered important to manual pushing and pulling. The activity of pushing or pulling is restricted to whole-body force exertions applied in a smooth and controlled way and without the usage of external support. The forces are applied in an upright non-sitting posture on objects that are located in front of the operator. The activity of pushing or pulling is performed by only one person who moves, manoeuvers or restrains an object. Therefore, ISO 11228-2 does not include object handling by two or more people and any action that is performed in a seated position.

Pulling an object is defined as a human physical effort where the force is applied in front of the body and directed towards the body as the body stands or moves backwards. In contrast, the force applied in pushing is directed to the front of, and away from the operator's body as the operator stands or moves forward. The applied force is classified into categories: initial and sustained. Initial force is defined as the force that sets an object in motion or changes the direction of movement; in analogy, stopping force is applied to bring an object to rest. Sustained force keeps an object in motion. Confounding risk factors such as unfavourable environmental conditions may give rise to additional risk of injury to the operator.

B.1 General model of risk assessment

In ISO 11228-2, an injury risk due to pushing or pulling is estimated and assessed in a multidisciplinary approach giving suitable consideration to physiological, psychophysical and biomechanical capabilities of an operator. The physiological approach is focused on energy expenditure and fatigue limits, whereas the psychophysical approach considers workers' perceptions of acceptable effort, forces and discomfort. The biomechanical approach considers an individual's muscular and skeletal strength and the risk of injury is based on: Action-induced compressive forces transferred via the intervertebral discs in the lumbar spine are considered in relation to lumbar-spine's load-bearing capacity for several target populations differing in age and gender.

The principle of the risk assessment model applied in ISO 11228-2 is shown in Figure B.1 (adapted from ISO 11228-2). After identifying the presence of workplace hazards due to force, posture, action frequency and duration, distance, object and individual characteristics, environmental conditions and other issues, the following two methods are employed to evaluate and assess the risks from pushing-or-pulling tasks:

— Method 1 utilizes a simple risk assessment checklist and psychophysically based tables, leading to a two-zone risk assessment approach (either risk acceptable or not acceptable).

— Method 2 permits the determination of the level of risk via a three-zone assessment approach (risk acceptable, conditionally acceptable or not acceptable).

In order to provide further support for estimating risk of injury as a function of frequency of operation, handle height and gender distribution, a detailed flow chart for choosing method 1 and/or method 2 is presented in Figure B.3 (see B.4.1). This flow chart reflects the procedures for risk estimation and evaluation marked by the dotted rectangle in Figure B.1.

(Numbers in parentheses correspond to the particular section in ISO 11228-2:2007.)

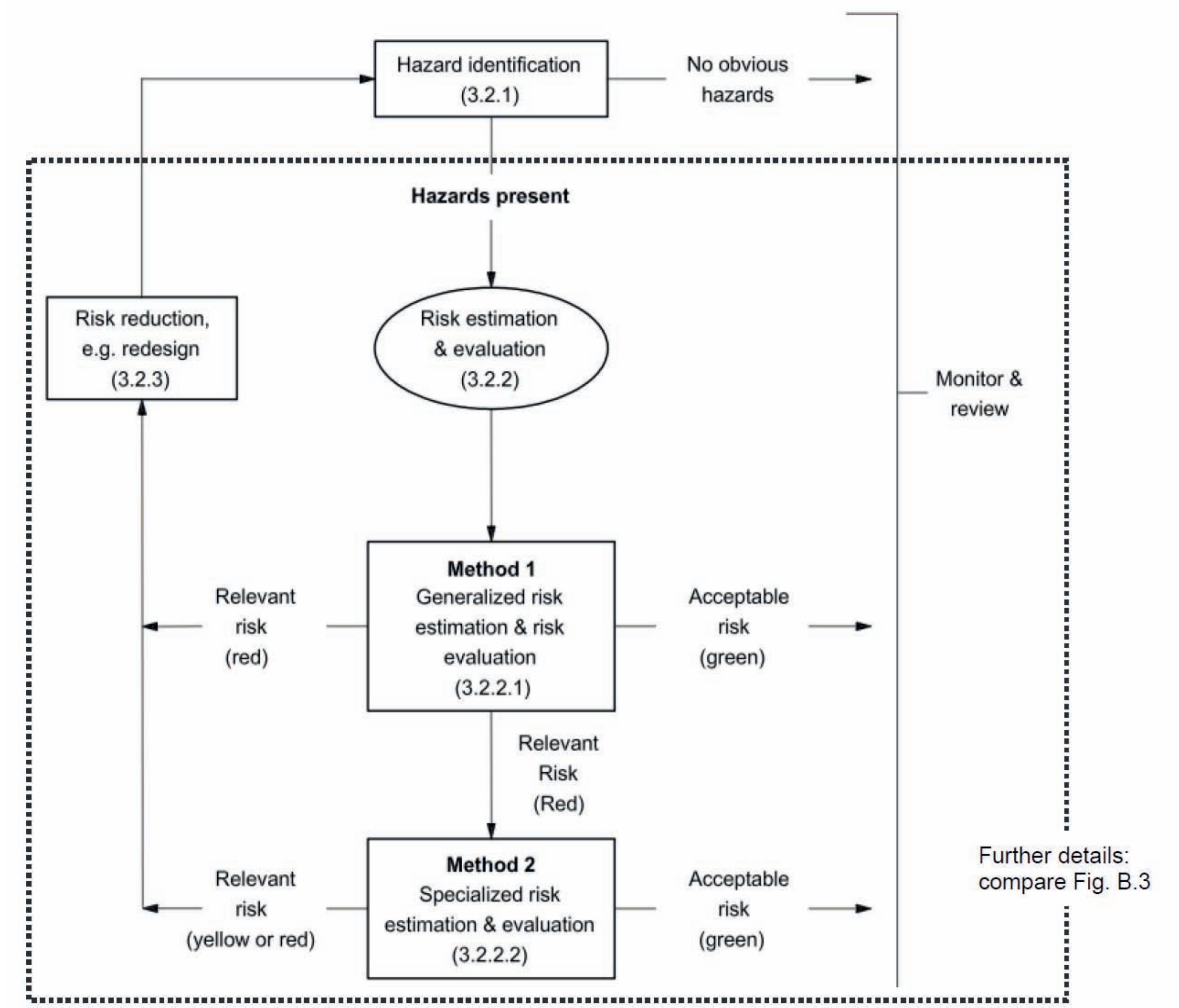


Figure B.1 — Risk assessment model

B.2 Generalized risk estimation and risk assessment — Method 1

Method 1 provides a generalized risk estimation and assessment approach. The overall risk of injury is rated applying a four-step procedure.

— Step 1: Method 1 starts with an overall subjective pre-evaluation of potential risk at a job followed by a specification of task and risk of performed operations.

— Step 2: Initially, a checklist is provided consisting of 28 issues that were grouped in 6 categories. The issues address to suggested risk factors, potential problems and their origin and to suggested possibilities of changes of remedial actions for risk reduction.

Subsequently, some task-specific variables must be determined (e.g. handle height, manoeuvre distance and frequency, initial and sustained forces), and the gender of the intended user population must be specified. Based on the acceptable initial and sustained forces provided in gender-specific psychophysically-oriented tables for pushing and pulling, actual forces are compared to recommended limits that accommodate 90 % of the intended user population.

— Step 3: The overall risk of injury is rated applying a two-zone risk rating system:

Acceptable: checklist application is “sufficient“, i.e. neither a relevant risk factor nor a predominant number of risk factors is present. Furthermore, risk estimation for the specific task and the user population is ”addressable” by psychophysical tables. In addition, neither the initial nor the sustained actual force does exceed the corresponding recommendations provided in the tables;

Not acceptable: checklist application is “insufficient“, i.e. a predominant number of risk factors are present, or risk estimation for the specific task or the user population is “not addressable” by the psychophysical tables, or the initial or sustained actual force exceeds the corresponding recommendation provided in the tables.

— Step 4: In case that the risk is rated not acceptable, further actions must be defined based on the risk factor(s) leading to the result of a non-acceptable risk in step 3. Prioritize the actions for risk reduction and redesign the work, or apply Method 2.

B.3 Specialized risk estimation and risk assessment — Method 2

Method 2 provides a specialized risk estimation and assessment. Similar to Method 1, in Method 2 the overall risk of injury is rated applying a procedure consisting of four main parts (A to D). However, Method 2 provides a three-zone risk rating system as recommended by the Machinery Directive (2006/42/EEC;EN 614). Furthermore, it addresses both professional and domestic users; and a reference is made to a couple of subpopulations (with or without age restrictions) as well as various gender distribution profiles. Method 2 represents a combined muscular (Part A) as well as skeletal strength-based approach (Part B) to the risk of injury as compared to the psychophysical-and-physiological approach suggested in Method 1. Further reference is made to various statures, in particular, in relation to handle or grasps height.

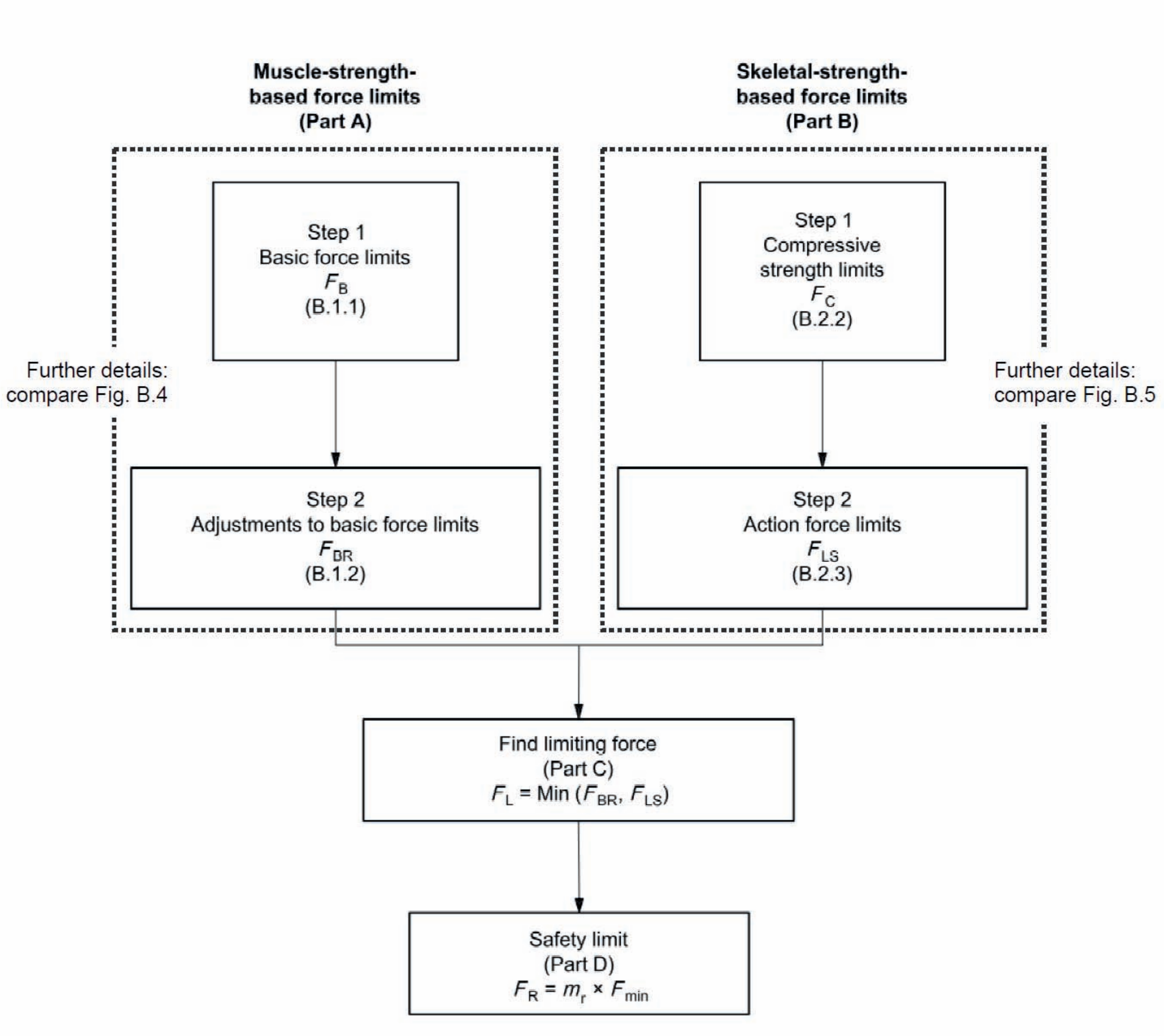


Figure B.2 — Specialized risk estimation and assessment — Method 2

(Numbers in parentheses correspond to the particular section in ISO 11228-2:2007, Annex B.)

As sketched in Figure B.2 (adapted from ISO 11228-2), Method 2 is divided into four parts:

— Part A: muscle force limits;

— Part B: skeletal force limits;

— Part C: permitted maximum forces;

— Part D: safety limits.

In order to provide further support, detailed flow charts are presented in Figure B.4 (see also B.4.2) and Firgure B.5 (see also B.4.3). These flow charts reflect the procedures for deriving the action force limits which are based on either muscle strength or skeletal strength. In Figure B.2, the procedures are sketched via the dotted rectangles.

B.3.1 Method 2 — Part A — Derivation of action-force limits based on muscular strength

This part determines force limits based on maximum isometric muscle force measurements ("muscular static strength") and subsequent adjustments to, for example, task conditions. Thereby, the maximum forces are reduced according to the characteristics of user population (i.e. age, gender and stature) and task (i.e. frequency, duration and distance of push/pull task). So, the muscle force limits are derived in a two-step procedure:

— Step 1: determining "basic force limits F_B" based on muscle strength;

— Step 2: reducing FB based on actual population and task characteristics, resulting in "F_{Br}".

B.3.1.1 Part A — Step 1

Determination of the basic force limit FB is possible in two alternative ways, named here "a" and "b":

— "a": Firstly, a comprehensive and detailed procedure can be applied including the collection of various input data on task conditions and target-population characteristics as well as their group-specific adjustment.

— "b": Secondly, bypassing the intensive procedure of "a", precalculated force limits may be used addressing a couple of provided population subgroup profiles being similar to the target population.

B.3.1.1.1 Step 1 — Alternative a

Muscular static-strength distributions of the intended user population are derived on experimental findings considering age, gender and stature. In particular:

— determine the absolute handle height of push or pull;

— determine the stature distributions with respect to age and gender;

— determine characteristic data on strength distribution, i.e. percentiles of maximum forces at several relative handle heights;

— perform a demographic fitting procedure to determine a target-group specific distribution of muscular static strength;

— determine the 15th percentile as the limit for the intended user population.

After this procedure in Step 1 of Part A, the basic force limit (F_B) is defined (go to Step 2).

B.3.1.1.2 Step 1 — Alternative b

Instead of choosing the alternative "a", muscular static-strength values can also be estimated from tables which consider working heights between near floor and about 2 m above floor, several males-to-females distribution ratios, two distinct age profiles (all ages vs. elderly) and categories of working experience (professional vs. domestic populations). In particular:

— select the subgroup being most similar to the intended user population,

— select the appropriate table (pushing vs. pulling, professional vs. domestic populations), and

— read the precalculated force limit according to population subgroup profile and working height.

After this procedure in Step 1 of Part A, the basic force limit (F_B) is defined (go to Step 2).

B.3.1.2 Part A — Step 2

Adjustments to basic force limits (F_B) are performed by considering reduction factors: distance and frequency of the push-or-pull tasks. For push-or-pull distances less than 5 m, the reduction factors are based on initial forces, whereas for longer distances they are based on sustained forces. The distance-related factor depends on the gender distribution, i.e. male-and-female percentages of the intended user population. This procedure leads to an adjusted muscle-strength-based action-force limit (F_{Br}). Applying Part B is the next step.

B.3.2 Method 2 — Part B — Derivation of action-force limits based on skeletal strength

This part determines action-force limits based on load-bearing capacity measurements on isolated segments of the lumbar section of the spine with regard to axial compression ("skeletal static strength") and on the task conditions to perform the push-or-pull action. Skeletal static strength depends on population characteristics (age, gender). Action-force limits depend on skeletal strength, task characteristics (absolute working height, direction of action force, action mode) and further population characteristics (posture and stature).

So, the action force limits are determined in a two-step procedure:

— Step 1: determining "compressive strength limits F_C" based on skeletal strength,

— Step 2: deriving "action force limits F_{LS}" from F_C and task and population characteristics.

B.3.2.1 Part B — Step 1

Determination of the skeletal compressive-strength limit FC, representing the 15th percentile of the intended user population, is possible in two alternative ways, named here "a" and "b":

"a": Firstly, a comprehensive and detailed procedure can be applied including the data collection of compressive strength based on age and gender of the intended user population.

"b": Secondly, bypassing the intensive procedure of "a", precalculated force limits may be used if the target population profile is similar to one of the provided population subgroup profiles.

B.3.2.1.1 Step 1 — Alternative a

The skeletal compressive-strength limit F_C of the intended user population is derived on "own" experimental findings considering age and gender (i.e. data are available to the user of the standard). The following steps are needed to define F_C:

— collect experimental findings on ultimate compressive strength of lumbar-spine segments;

— calculate regressions describing the effects of age in both males and females;

— determine the 15th percentile as the limit for the intended user population.

After this procedure in Step 1 of Part B, the skeletal compressive-strength limit (F_C) is defined (go to Step 2).

B.3.2.1.2 Step 1 — Alternative b

The skeletal compressive-strength limit F_C of the intended user population can easily be deduced from a table providing precalculated values for various male-to-female distribution ratios and age ranges (go to Step 2).

B.3.2.2 Part B — Step 2

Derivation of the skeletal-strength-based action-force limit F_{LS} is performed on the basis of the preceded determination of F_C in Step 1 and several task characteristics estimated for three selected statures of the intended user population. In other words, this second step determines the recommended limits of the externally applied forces so that the compressive-force limits of the lumbar spine (given in ISO 11228-2:2007, Table B.13) will not be exceeded. The following information is important to consider before deriving F_{LS}

— The final determination of the action-force limit F_{LS} is based on identifying the minimum of three (preliminary) action-force limits F which are read from diagrams showing the relation between action-force limit F and compressive-force limit F_C. These preliminary limit values correspond to three stature percentiles that are considered to reflect the variation in the user population. In order to provide further support by bypassing the diagrams, Table B.1 in section B.4.3 shows precalculated action-force limits F with respect to the user population (age and gender distributions), handling mode (pushing, pulling) and working conditions (posture, grasp height, force angle).

— According to ISO 11228-2:2007, Annex B, the respective action-force limit F is depicted from one of six diagrams - three are related to pushing and three to pulling. These diagrams are related to three working heights: at hip, abdominal or mid-chest level (0,9; 1,1; 1,4 m) that are typical for moving carts, dollies, jacks or wheeled containers. These working heights are combined with typical arm-hand positions which are described by the indicator "shoulder-joint angle". This angle reflects the vertical and horizontal distances of the grasp position in relation to the shoulder joint – in a lateral view. After selecting the right diagram for the task in question, the most appropriate "force angle" must be determined; in a lateral view again, this angle considers the proportion of vertical and horizontal components of the force applied to the object to be pushed or pulled. In many cases, a force angle equal to the shoulder-joint angle is appropriate. To enable certain variations in individual performance, three curves for three typical force angles are provided in each of the six diagrams.

In conclusion, for deriving the skeletal-strength-based action-force limit F_{LS}, the following steps are used:

— determine specific stature-distribution characteristics: 5th, 50th and 95th stature percentiles of the target population,

— for the three selected percentiles, determine the most common working posture;

— for the three selected percentiles, determine the "shoulder-joint angle" between the horizontal and the grasp-to-shoulder axis in the lateral view;

— for the three selected percentiles, determine the direction of the push-or-pull force in the lateral view ("force angle" to horizontal);

— determine the absolute handle height, i.e. the "working height" (= "grasp height" or "grip height");

— for the three selected percentiles, depict the action-force limit F from the respective diagram "F_C versus F" for various working heights, shoulder-joint angles and force angles. Select that diagram which fits the task conditions best (working height, shoulder-joint angle), and

— determine the minimum out of the three percentile-related values of F, and name this value as F_{LS}.

Application of Part C is the next step.

B.3.3 Method 2 — Parts C and Part D — Derivation of limiting action force and safety limit

B.3.3.1 Part C

Find the permitted maximum force F_L, i.e. select the lower value out of the muscle-strength-based force limit (F_{Br}) and the skeletal-strength-based force limit (F_{LS}) resulting from Part A or B, respectively. Applying Part D is the next.

B.3.3.2 Part D

Find the safety limit due to the provision of the risk multiplier m_r, which represents limiting criteria for defining the green, yellow and red zone of risk. In other words, the overall risk of injury is rated applying a three-zone risk rating system. This risk is evaluated on the basis of the actual resultant force F_R and the limiting force F_L determined in Part C. These zones are explained below:

Acceptable risk (green zone) — for $F_R \leq 0{,}85 F_L$:

— the risk of disease or injury is negligible or risk is at an acceptably low level for the entire operator population;

— no action, i.e. no redesign is required.

Conditionally acceptable risk (yellow zone) — for $0{,}85\ F_L < F_R \leq 1{,}0\ F_L$:

— there is a risk of disease or injury that cannot be neglected either for the entire or part of operator population;

— further risk estimation with analysis of contributory risk factors shall be performed, and redesign the task as soon as possible;

— if redesign is not possible, other measures to control the risk are to be taken.

Not acceptable risk (red zone) — for $F_R > F_L$:

— there is a considerable risk of disease or injury that cannot be neglected for the operator population,

— immediate action to reduce the risk is necessary (e.g. redesign, work organization, worker instruction and training).

In conclusion, after completion of Parts A to D, potential risk factors due to an actual push-or-pull operation are identified, the corresponding risk of disease or injury is evaluated, and degree and urgency of redesigning the work are rated.

B.4 Specifications

In this section, three detailed flow charts are provided to support understanding of specifications of ISO 11228-2. In particular, specific conditions leading to or excluding the application of Method 1 or 2 (B.4.1) are explained. Furthermore, specific steps in the procedures of Method 2 are sketched for deriving action-force limits based on muscle strength (B.4.2) and skeletal strength (B.4.3).

B.4.1 Comments on the decision for choosing Method 1 or Method 2

In this subsection, evidence is provided for the alternative or consecutive application of Method 1 and Method 2. Considering the general model for risk assessment sketched in Figure B.1, application of Method 1 seems obligatory if hazards are identified to be present. Both methods are, as any method, combined with application conditions which are specified in Figure B.3. Figure B.3 is organized in analogy to Figure B.1: The lateral parts reflect the potential outcomes of analysis (left: relevant risk; right: acceptable risk), whereas the centre part considers certain steps of analysis. The following conditions of working height are important to consider:

— if the push-or-pull frequency exceeds 10 actions per minute or if the working height is outside the range of floor to overhead (0 to 205 cm), neither Method 1 nor Method 2 might be applied; a relevant risk is identified and rated not acceptable so that risk reduction is needed;

— if the handle height ranges between about thigh and shoulders (females: 57 to 135 cm; males: 64 to 144 cm), Method 1 can be applied under the condition that the target population is purely either male or female. In case of mixed genders, the more restricted female-related values will then be considered;

— if the handle-height condition of "thigh to shoulders" is untrue or if the female-related values cannot be applied, Method 1 is to be bypassed, and Method 2 should be applied directly.

The consecutive steps of the procedure provided in the lower part of Figure B.3 (application of Method 1 or Method 2), are adopted from Figure B.1: If application of Method 1 shows an acceptable risk (green), no further action is necessary besides monitoring and reviewing later work. In contrast, risk reduction is needed in case of a relevant risk (red). Additional application of Method 2 may help to find task conditions leading to an acceptable risk, otherwise, redesign for risk reduction is necessary as well.

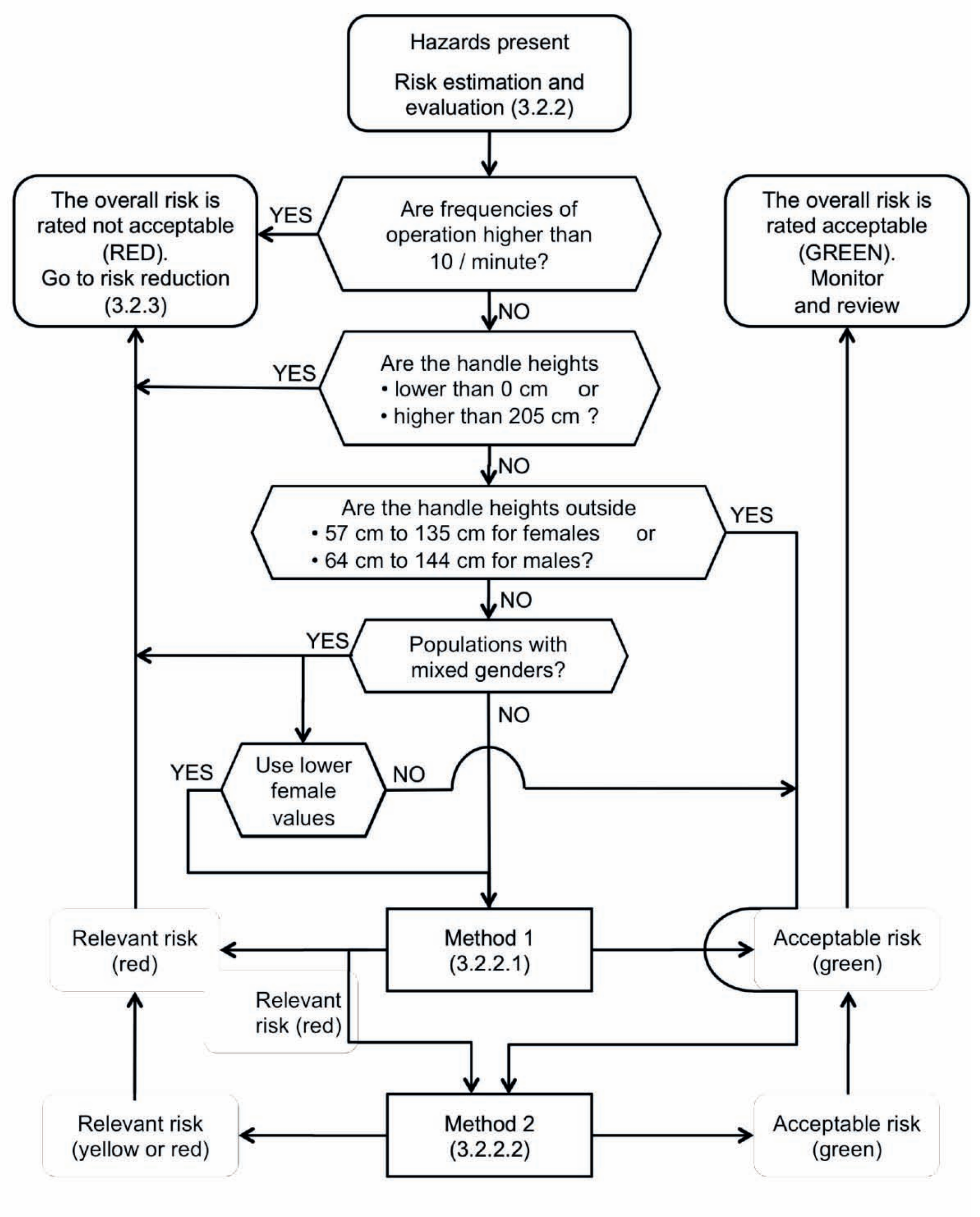


Figure B.3 — Decision conditions for choosing Method 1 or Method 2 dependant on task conditions and characteristics of the intended user population

(Numbers in parentheses correspond to the particular section in ISO 11228-2:2007, Annex B.)

B.4.2 Comments on muscle-strength-based action-force limits

As described in B.3 and visualized in Figure B.4, the derivation of action force limits based on muscular strength (Part A) represents a two-step procedure. Thereby, the first step can be performed in two ways: The advanced use may be preferred by experts whereas the standard use is recommended for analysing common cases. *Inter alia*, the advanced use considers necessarily distributions for age, gender and muscular strength and, subsequently, the application of a mathematically comprehensive fitting procedure in order to calculate the "basic force limit" F_B, In contrast, the standard use refers to tables with precalculated values of "basic force limits" F_B. Independent of the mode of the first-step procedure, a unique mode for the second step enables the derivation of reduced values F_{Br} representing the muscle-strength-based action-force limits. These limits depend on push-or-pull distance and frequency as well as target population's males-to-females distribution influencing the distance multiplier.

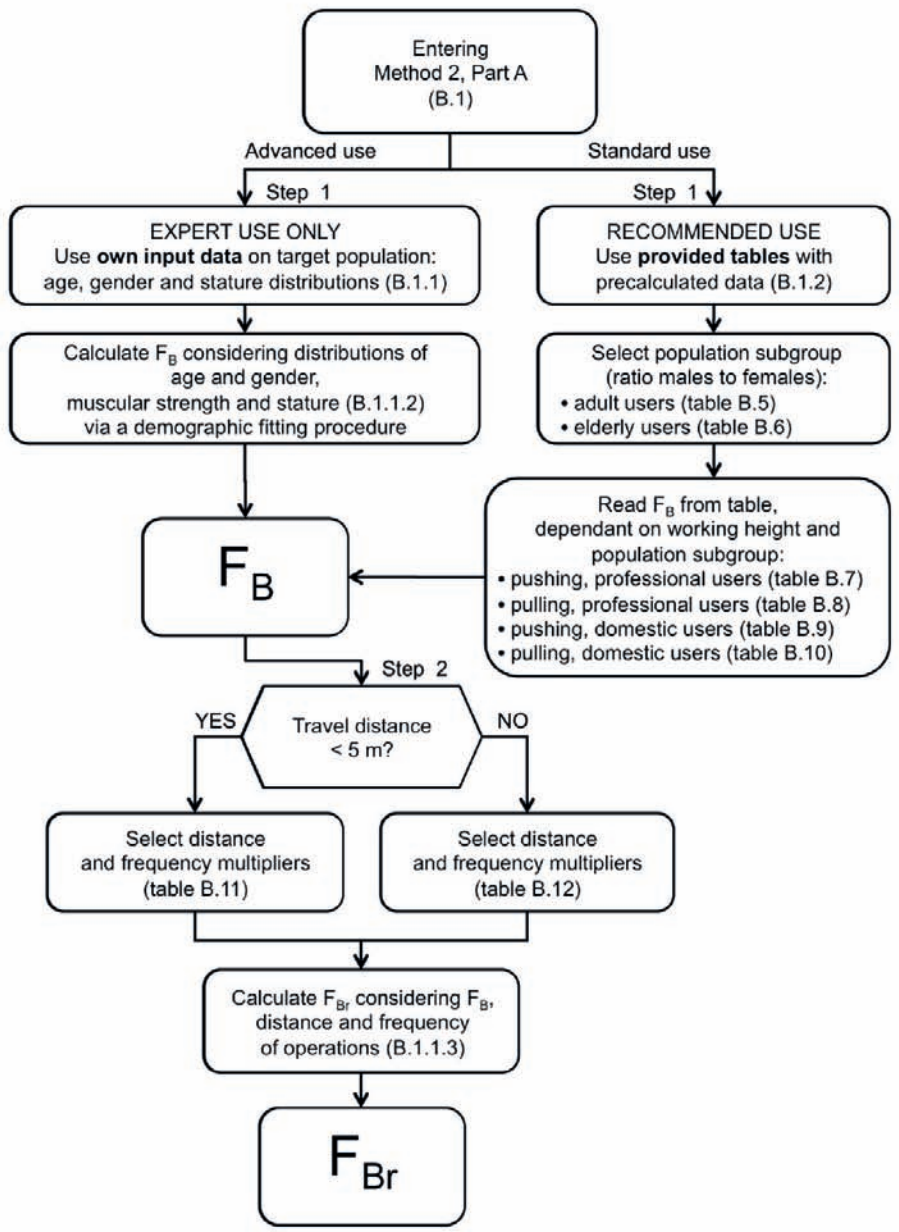


Figure B.4 — Derivation of action-force force limits F_{Br} based on muscular strength

(Numbers in parentheses correspond to the particular section in ISO 11228-2:2007, Annex B and to the particular tables of that annex.)

B.4.3 Comments on skeletal-strength-based action-force limits

As previously sketched in B.3 and visualized in Figure B.5, the derivation of action-force limits based on skeletal strength (Part B) represents a two-step procedure in main. Thereby, the first step can be performed in two ways: The advanced use may be preferred by experts whereas the standard use is recommended for analysing common cases. The advanced use considers necessarily distributions for age and gender in order to find lumbar-disc-related compressive-force limits F_C with respect to own data on the target population; regression calculations lead to the 15th skeletal strength percentile of the intended user population. By contrast, the standard use refers to a table with precalculated values of the 15th percentile of lumbar-disc compressive strength. Independent of the mode of the first-step procedure, a unique mode for the second step enables the derivation of action-force limits F_{LS} based on skeletal strength and several task variables.

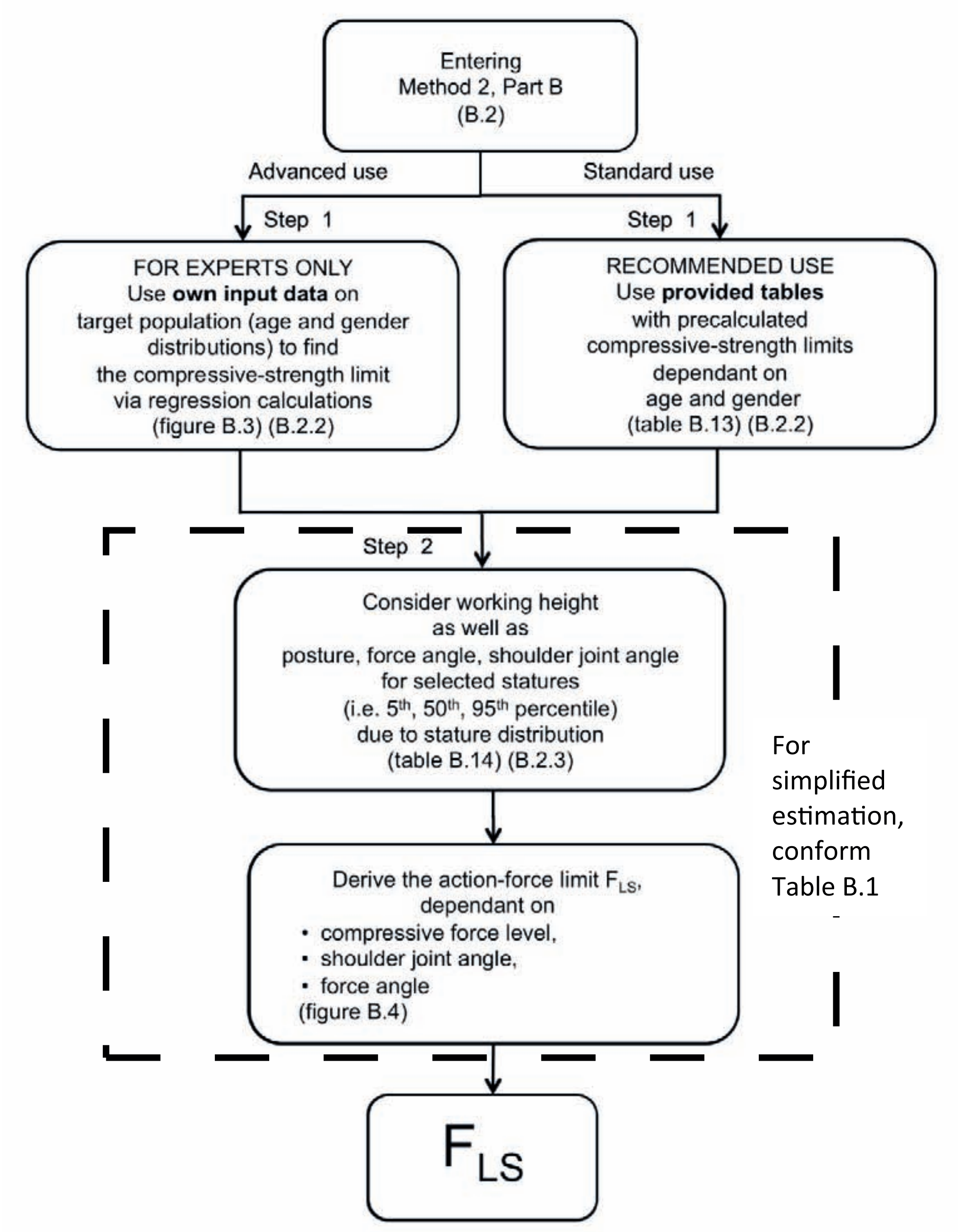


Figure B.5 — Derivation of action-force force limit F_{LS} based on skeletal strength

(Numbers in parentheses correspond to the particular section in of ISO 11228-2:2007, Annex B and to the particular tables of that annex.)

That second step is based, *inter alia*, on selected stature percentiles (5th, 50th, 95th) of the target population, on the most common postures for persons of those statures, and, in a view from lateral, two angles in relation to horizontal: (1) the direction of the action force to perform the push-or-pull operation, named “force angle”, and (2) the angle of the line between grasp point and shoulder joint, named “shoulder-joint angle”. From corresponding graphs in several diagrams, the skeletal-strength-based action-force limit can be depicted.

Table B.1 offers a simplified estimation of skeletal-strength-based action-force limits F with respect to user population (age and gender distributions and their corresponding compressive-force limits F_C), handling mode (pushing, pulling) and working conditions (posture, grasp height, force angle). For self-selected working height, pushing or pulling is commonly performed with grasping at about mid-chest level; in this case, it is recommended to assume the lowest available shoulder-joint angle. In contrast, the shoulder-joint angle is increased, especially for higher statures for a predetermined lower grasp height on hip or abdominal level. In many cases, a force angle equal to the shoulder-joint angle is appropriate and fits closest to reality. Those task conditions were assumed for precalculating the skeletal-strength-based action force limits F as provided in Table B.1.

As the action force values, listed in Table B.1 demonstrate whole-body pushing in “ergonomic working height” between approximately hip and mid-chest levels leads to relatively high action force limits (>600 N). In consequence, the skeletal strength with respect to lumbar-disc compressive force does not represent the limiting criterion in comparison to muscle-strength-based action-force limitations. However, pushing combined with lower (thigh to foot) or higher (neck to overhead reach) grasp points for force transmission may lead to higher lumbar load and, in consequence, to lower skeletal-strength-based action force limits than that are provided in Table B.1.

After applying Method 2, i.e. after determining the muscle-strength-based action force limit F_{Br} in Part A and the skeletal-strength-based action force limit F_{LS} in Part B, the lower one of both limits represents the limiting force F_L (according to Part C).This limiting force serves as the basis to calculate the safety limit F_R in Part D. The analysis is then terminated.

Table B.1 — Simplified estimation of action-force force limits F based on skeletal strength F_C

Pre-calculated skeletal-strength-based action-force limits F

Active adults (*) males: 20–64 y. females: 18–64 y.	**Pre-calculated compressive-strength-based force limits** F_C (adopted from table B.13 ISO 11228-2)	**Pushing**			**Pulling**		
Ratio males : females [%]		**shoulder-joint angle ∠SJ; grasp height h_G**	**force angle ∠F**	**action-force limit F**	**shoulder-joint angle ∠SJ; grasp height h_G**	**force angle ∠F**	**action-force limit F**
0 : 100	2,8 kN						330 N
natural	3,3 kN	30°; 0,9m	30°		40°; 0,9m	40°	420 N
100 : 0	3,9 kN						520 N
0 : 100	2,8 kN						310 N
natural	3,3 kN	20°; 1,1m	20°	> 600 N	20°; 1,1m	20°	400 N
100 : 0	3,9 kN						490 N
0 : 100	2,8 kN						190 N
natural	3,3 kN	0°; 1,4m	0°		20°; 1,4m	20°	240 N
100 : 0	3,9 kN						300 N

Active seniors males + females: 56–64 y.	**Pre-calculated compressive-strength-based force limits** F_C (adopted from table B.13 ISO 11228-2)	**Pushing**			**Pulling**		
Ratio males : females [%]		**shoulder-joint angle ∠SJ; grasp height h_G**	**force angle ∠F**	**action-force limit F**	**shoulder-joint angle ∠SJ; grasp height h_G**	**force angle ∠F**	**action-force limit F**
0 : 100	2,0 kN						200 N
natural	2,3 kN	30°; 0,9m	30°		40°; 0,9m	40°	250 N
100 : 0	3,1 kN						390 N
0 : 100	2,0 kN						190 N
natural	2,3 kN	20°; 1,1m	20°	> 600 N	20°; 1,1m	20°	240 N
100 : 0	3,1 kN						360 N
0 : 100	2,0 kN						110 N
natural	2,3 kN	0°; 1,4m	0°		20°; 1,4m	20°	140 N
100 : 0	3,1 kN						220 N

(*) ‘Active adults’ includes ‘active seniors’.

Annex C
(informative)

Application information for ISO 11228-3

C.1 Introduction

This Annex C provides additional information relevant to the practical application of methods and procedures presented and /or recommended in ISO 11228-3.

The purpose of Annex C is to provide the expert users of ISO 11228-3 with useful information when, having completed the key-questions and the quick assessment, they need to apply the standard to perform a risk assessment.

The information is related to:

— the OCRA Index method (Preferred Method 2 in ISO 11228-3) particularly regarding shoulder posture and some organizational relevant factors;

— presentation of the OCRA Checklist as a useful tool for Simple risk assessment (Method 1 in ISO 11228-3);

— further details on “Multitask Analysis” with a particular focus on applications of the OCRA Index and Checklist methods where multiple manual repetitive tasks are performed by the same worker(s) in a shift;

— other methods suggested for a detailed risk assessment (Method 2 in ISO 11228-3);

— brief references on other methods recently developed for the purposes of Simple risk assessment (Method 1 in ISO 11228-3).

C.2 Advances in the application of the OCRA Index methods

C.2.1 Shoulder posture and movements and corresponding multipliers

Consideration of awkward shoulder posture and movements should be inserted directly in posture analysis when using both method 1 and method 2.

In particular when using method 2, the OCRA Index method, special attention should be addressed to the portion of repetitive task (or cycle) time spent with an upper arm elevation (flexion or abduction) or extension.

For an acceptable condition the following criteria should apply:

— the arm(s) should not be held or moved at shoulder level (flexion or abduction at about 80°or more) for more than 10 % of cycle time;

— the arm(s) should not be held or moved in mild elevation (flexion or abduction > 45° and < 80 °) for more than 25 % of cycle time.

When these criteria are not met, one should apply the following Multipliers (Table C.1 and Table C.2) for shoulder posture/movements (P_M) within the criteria of posture analysis as reported in ISO 11228-3:2007, Annex C, C.4.4 and C.8.

Table C.1 — Shoulder flexion/abduction (upper arm elevation) more than 80°

Percentage of the cycle time	10 %	20 %	30 %	40 %	≥ 50 %
Posture multiplier (P_M)	0,7	0,6	0,5	0,33	0,07

Table C.2 — Shoulder maintained or moved in mild elevation (flexion or abduction between 45° and 80° or extension > 20°)

Fraction or percentage of cycle time	1/3 from 25 % to 50 %	2/3 from 51 % to 80 %	3/3 more than 80 %
Posture multiplier (P_M)	0,7	0,6	0,5

C.2.2 Repetitiveness (lack of variation or stereotype) multiplier, ReM

When using the OCRA Index method, this multiplier (see ISO 11228-3:2007, Annex C, C.4.5 and C.8) could be split into 3 categories (see Table C.3).

Table C.3 — Repetitiveness (lack of variation or stereotype) and corresponding multipliers ReM

Definitions	**Multiplier ReM**
The task requires the performance of similar technical actions for more than 80 % of the cycle time, or the cycle time is shorter than 8 s.	0,7
The task requires the performance of similar technical actions for 51–80 % of the cycle time, or the cycle time is equal or more than 8 s but shorter than 15 s.	0,85
All other conditions	1

C.2.3 Additional factors (work pace determined by machinery)

When using the OCRA Index method, if the work pace is partially or completely determined by machinery, consider this aspect within additional factors and use the following criteria for addressing the relevant additional multiplier, Pm (see Table C4).

Table C.4 — Additional factors — Pace determined by machinery

	Pace completely determined by machinery (no buffers)	**Pace determined by machinery but some buffers present**	**Pace independent from machinery**
Additional multiplier (P_M)	0,85	0,9	1

C.2.4 Duration (daily) of repetitive task and duration multiplier, T_m

When using the OCRA Index method, the duration multiplier, T_M should be better determined using the interpolated values reported in ISO 11228-3:2007, Annex C, C.4.9, Table C.4.

For ease of use, these values are reported in Table C.5.

Table C.5 — Duration (daily) of repetitive task and duration multiplier T_M

Time (in minutes) devoted to repetitive task(s) during a shift	< 121	121–180	181–240	241–300	301–360	361–420	421–480	> 480
Duration multiplier T_M	2,0	1,7	1,5	1,3	1,2	1,1	1,0	0,5

C.3 OCRA Checklist as a useful tool for Method 1 — Simple risk assessment

OCRA Checklist is one of the method/tools suggested in ISO 11228-3:2007, Annex A for the purposes of Method 1. Since the OCRA checklist is based on the same general framework, criteria and definition of the "Consensus Document" assumed as a reference point in the same Annex A, and the OCRA index method assumed as preferred for method 2, it seems useful to briefly report an updated (also with reference to the advances previously reported for OCRA index method) description of the tool to favour its application for the purposes of Method 1 in ISO 11228-3.

The OCRA checklist is useful to quickly identify the presence of the main risk factors for the upper limbs and classify the consequent exposure. It is therefore recommended for the initial screening of several workstations in an enterprise featuring repetitive tasks, while the complete OCRA index is useful for the (re)design or in-depth analysis of workstations and repetitive tasks.

The analysis system suggested with the OCRA checklist starts with assigning the coded scores for each of the main risk factors (number of working hours without recovery period, frequency, force, posture) and for the additional factors. For each risk factor several scenarios are presented and for each scenario a score is suggested (ranging from 0 to maximum as the potential risk increases). The sum of the partial scores (for each risk factor: frequency, force, posture, additional factors) obtained in this way produces a partial final score. To obtain the final exposure value, two multipliers must be applied to calibrate the partial final score, considering both the net duration of repetitive work and the presence of hours without adequate recovery (Figure C.1). This procedure allows estimating the actual exposure in different levels (absent, borderline, light, medium and high).

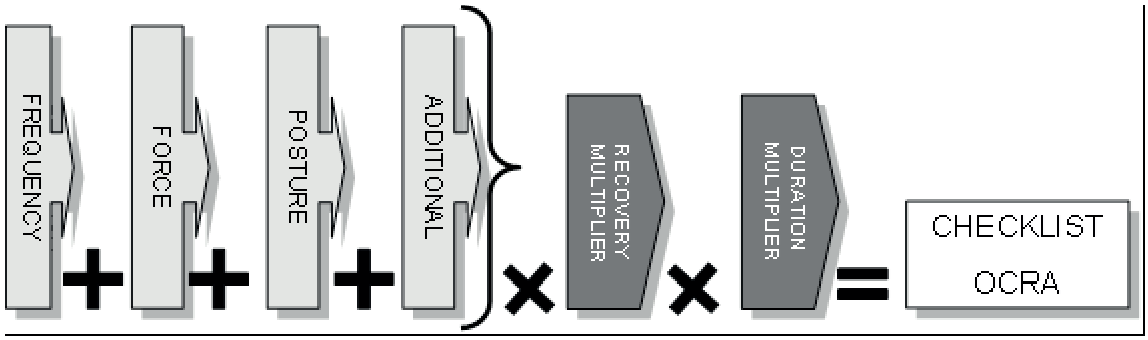


Figure C.1 — How to obtain the OCRA checklist final score

The OCRA checklist describes a workplace and estimates the intrinsic level of exposure if the workplace is used for the whole of the shift by one worker. This procedure makes it possible to quickly find out working at which workplaces generate a significant exposure level. In the next stage, it is possible to estimate the exposure indexes for the operators considering their rotation through the different workplaces (see after "Updates on OCRA Multitask Analysis").

Before starting with any evaluation, as in the OCRA index, it is necessary to study shift contents for evaluating the net duration of the repetitive/s task/s (see Table C.6).

Table C.6 — Description of shift contents for evaluating the net duration of the repetitive task(s)

		Minutes
Shift duration	Official	
	Actual	
Breaks	Official	
	Actual	
Meal break	Official	
	Actual	

Table C.6 *(continued)*

		Minutes
Non repetitive tasks (e.g. cleaning, supplies, etc.)	Official	
	Actual	
Net duration of repetitive task(s)		

If the repetitive task(s) lasts less than 7 h (421 min) within one shift it is possible to correct the OCRA checklist scores previously obtained considering actual duration by a specific multiplier (Table C.7).

Table C.7 — Multipliers for the total net duration of repetitive task(s) in the shift

Minutes	Duration multiplier
60–120	0,5
121–180	0,65
181–240	0,75
241–300	0,85
301–360	0,925
361–420	0,95
421–480	1
> 480	1,5

As described in Figure C.1 is necessary to apply another multiplier according to the presence and distribution of adequate recovery time. The number of hours in the shift without adequate recovery (count the number of hours in a shift that have within them a break of at least 8-10 min: do not count the hours before the meal and the last hour of the shift) corresponds to a specific multiplier (Table C.8).

Table C.8 — Multipliers for lack of recovery period

Number of hours without recovery period	0	1	2	3	4	5	6	7	8
Recovery multiplier	1	1,05	1,12	1,20	1,33	1,48	1,70	2,00	2,50

C.5 presents a model of OCRA checklist with all the scenarios and the scores corresponding to each risk factor.

Since the numerical scores used in the OCRA checklist have been "calibrated" to the multipliers supplied for calculation of the more exhaustive OCRA index, the final OCRA checklist score can be interpreted in terms of its correspondence to critical OCRA index values and consequently to its classification system (green, yellow, red zones) (see Table C.9).

Table C.9 — Correspondence between OCRA checklist scores and OCRA index values for classification purposes

OCRA checklist score	OCRA index	Exposure level	
≤ 7,5	≤ 2,2	Green	No risk (acceptable)
7,5 < score ≤ 11,0	2,2 < index ≤ 3,5	Yellow	Borderline or very low risk
11 < score ≤ 14,0	3,5 < index ≤ 4,5	Red light	Light risk
14 < score ≤ 22,5	4,5 < index ≤ 9,0	Red medium	Medium risk
> 22,5	> 9,0	Red high	High risk

For all the operative details about the use of the OCRA checklist, see the site: www.epmresearch.org.

A free download of a software (in excel) for mapping the risk is available.

Table C.10 and Figure C.2 report an example of mapping the exposure in several workstations of an assembly line, of a department and of all workplaces in a company.

Table C.10 — Example of results (using the OCRA checklist mapping software) of the exposure evaluation to repetitive movements in a working area: the analytical results of the single risk factors and of the single checklists, each for every workplace and the final synthetic results by gender

Net duration of repetitive task	Multiplier for net duration	Identification of workplace	Number of hours without a recovery period	Recovery multiplier	Frequency	Force	side	shoulder	elbow	wrist	hand	lack of variation (stereotype)	Posture score	Additional factors score	OCRA Checklist value	Number of daily shifts	Number of workplaces	Workplaces by gender		
																		Total	Females	Males
		LINE OR WORKING AREA																		
405	0,95	A	4	1,33	10	0	R	4	0	0	8	1,5	9,5	1	25,9	2	6	12	12	0
405	0,95	B	4	1,33	3	2	R	4	0	2	8	0	8	2	19,0	2	10	20	15	5
340	0,925	C	4	1,33	1	1	R	1	0	0	4	0	4	1	8,6	2	6	12	2	10
440	1	D	4	1,33	5	0	R	1	0	2	2	3	5	0	13,3	2	7	14	7	7
405	0,95	E	4	1,33	8	0	R	1	0	0	0	0	1	0	11,4	2	4	8	8	0
400	0,95	F	4	1,33	0	0	R	1	0	0	0	3	4	0	5,1	2	2	4	0	4

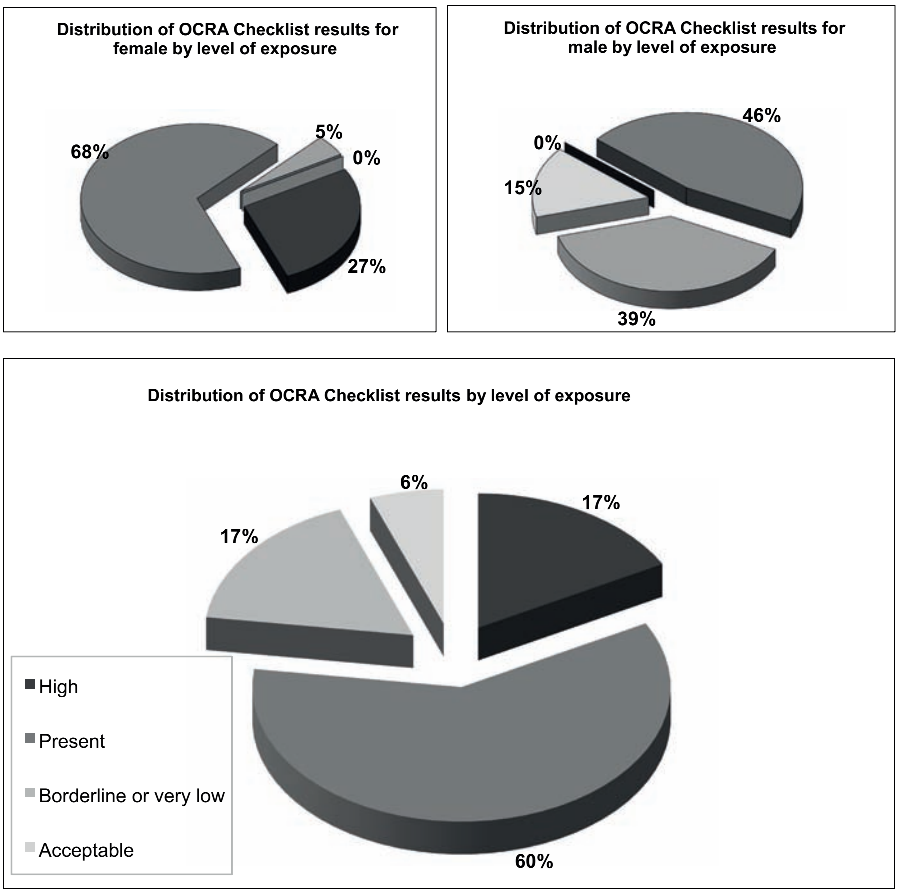


Figure C.2 — Example of the final mapping synthetic results in total and by gender considering the analysed working area

C.4 Advances on OCRA Multitask Analysis (Note: advances the standard)[10]

C.4.1 OCRA Index Multitask Average

When computing the OCRA index considering the presence of more than one repetitive task, a "traditional" procedure has been proposed both in literature and in ISO 11228-3:2007 (main text and Annex C). This approach, whose results could be defined as "time weighted average", seems to be appropriate when considering rotations among tasks that are performed very frequently, for instance almost once every 90 min(or for shorter periods). In those scenarios "high" exposures are presumed to be in some way compensated by "low" exposures that alternate very quickly between each other. As a consequence the traditional procedure for OCRA index multitask analysis is confirmed when rotation among repetitive tasks is performed almost every 90 min or when the single tasks are actually sub-tasks of a general "complex" task (whose cycle time generally lasts several minutes). The index will be defined as OCRA Index Multitask Average.

C.4.2 OCRA Index Multitask Complex

When rotation among repetitive tasks is less frequent (i.e. once every 1 and 40 min or more), the "time weighted average" approach could result in an underestimation of the exposure level (as it flattens peaks of high exposures). For those scenarios an alternative approach is based on a more realistic concept that the most stressful task is the minimum starting point. Hence the result of this approach will be between:

— the OCRA index of the most stressful task considered for its individual longest continuous duration;

— the OCRA index of the same most stressful task when it is (only theoretically) considered as lasting for the overall duration of all examined repetitive tasks.

A novel procedure allows an estimation of the resulting index within this range of minimum to maximum values. The consequent index will be defined as OCRA Index Multitask Complex.

The procedure is based on the following formula:

$$\text{OCRA Index Multitask Complex} = \text{OCRA}_{1(\text{Dum}1)} + (\Delta\text{OCRA}_1 \times \text{K})$$

where

— 1,2,3,...,*N* = repetitive tasks ordered by OCRA index values (1 = highest; *N* = lowest) computed considering respective real continuous duration multipliers (Dum_i) and Rc_M (the same for all the tasks);

— Dum_i = duration multiplier for task_i real continuous duration;

— Dum_{tot} = duration multiplier for total duration of all repetitive tasks;

— $\Delta\ \text{OCRA}_1$ = OCRA of task_1 considering Dum_{tot} - OCRA of task_1 considering $\text{Dum}_{1;}$

— $\text{K} = \dfrac{(\text{OCRA}_{1\,max} * \text{FT}_1) + (\text{OCRA}_{2\,max} * \text{FT}_2) + ... + (\text{OCRA}_N * \text{FT}_N)}{(\text{OCRA}_{1\,max})}$;

— $\text{OCRA}_{i\,max}$ = OCRA of task_i considering $\text{Dum}_{tot;}$

— FT_i = Fraction of Time (values from 0 to 1) of task_i with respect to the total repetitive time.

In order to determine the OCRA index multitask complex, software is necessary since manual computation is very difficult. For all the operative details about these evaluations see the site: www.epmresearch.org. A free download of a software (in excel) for calculating a multitask exposure is available.

C.4.3 OCRA Checklist for multitask analysis

When using OCRA checklist for analysing (Method 1 in ISO 11228-3) rotations in multiple repetitive tasks, the same considerations previously reported for the OCRA index should be taken into account.

From an operative point of view, if the operator/s work(s) in two or more workplaces implying repetitive tasks (multiple task), to obtain the specific exposure index (OCRA Checklist score) of that operator/s it is necessary to distinguish two different scenarios:

1) Rotation among repetitive tasks has a frequency of almost once every 90 min

In this case the time weighted average approach should be preferably used, employing the following formula:

Checklist final score = [(sc. A x %PA) + (sc. B x %PB) +....+(sc. N x %PN)] x duration multiplier

where “score A”, “score B”, etc., are the checklist scores obtained for the various workplaces (tasks) on which the same operators work, and %PA, %PB, etc., represent the percentage time duration of the corresponding repetitive tasks with respect to the overall duration of all repetitive tasks considered during one shift,

and duration multiplier = multiplier given by the total net duration of all repetitive tasks (A+B+...+N) in the shift (Table C.7).

2) Rotation among repetitive tasks has a frequency of less than once every 90 min

In this case, as previously discussed for OCRA Index, the "worst condition" approach should be used, employing the following formula:

Checklist final score = $score_{1(Dum1)}$ + ($\Delta score_1$ × K)

where:

— 1,2,3,...,N = repetitive tasks ordered by their exposure levels (1 = highest) considering respective continuous duration multipliers (Dum_i from Table C.7);

— Dum_i = duration multiplier for $task_i$ real continuous duration;

— Dum_{tot} = duration multiplier for total duration of all repetitive tasks;

— Δ $score_1$ = score of $task_1$ considering Dum_{tot} - score of $task_1$ considering Dum_1;

— K = (score $_{1\ max}$ * FT_1) + (score $_{2\ max}$ * FT_2) +...+(score $_N$ * FT_N);

(score 1 max)

— $score_{i\ max}$ = score of task $_i$ considering Dum_{tot};

— FT_i = Fraction of Time (values from 0 to 1) of $task_i$ with respect to the total repetitive time.

C.4.4 General approach for studying (by OCRA method) multiple repetitive tasks with rotations along weeks, months or year

While, in the industrial sectors, tasks rotate often in a similar way every day and consequently the previous procedures could be easily applied, in some productive sectors (agriculture, construction, cleaning, supermarket, etc.) exposure assessment is much more complex being characterized by the presence of several tasks over periods longer than a typical working day (weekly, monthly, yearly turnover).

For example in agriculture turnover is typically yearly. Each month of the year is characterized by different processing, each including different tasks.

Some working situations clearly show a weekly rotation pattern of repetitive tasks, for example tasks carried out in kitchens (especially for food preparation in business or school canteens), for some organizational models of cleaning, supermarkets, etc. Moreover in some cases not only do tasks vary daily but also shift duration changes over the course of the week.

Studies are reported[6] to organize models for assessing such situations where tasks rotate within weeks, months or a year. In general those studies are based on the use of the Checklist OCRA and on adaptations of the two multitask analysis approaches (average and complex) that have been previously presented.

The general procedure for studying such situations implies 3 operating stages:

1) Completing a preliminary organizational study to establish the kind of turnover: the periodicity of the different repetitive tasks as repeated in time (daily or weekly or monthly or yearly).

2) Defining the risk level "intrinsic" in each task, using the OCRA checklist. Intrinsic level means ascribing to the repetitive task a net duration of 440 min/shift with 2 breaks, 8-10 min each, and a lunch break of at least 30 min.

3) Applying specific mathematical models (adaptations of average or complex approach) considering intrinsic values as well as organizational patterns (duration, frequency and sequences) of individual tasks under study.

The choice of the most predictive model will necessarily be based on the collection of relevant epidemiological data. The preliminary data collected seem to confirm a better validity of the OCRA Multitask Complex model.

C.5 Advances on other methods suggested for a detailed risk assessment (Method 2) (note: advances the standard)

C.5.1 Strain Index

In a 2004 paper,[2] practical suggestions were given on how to apply the Strain Index method especially for jobs where multiple forces/tasks are developed. Complex SI models based on concepts similar to the composite lifting index method (Waters et al.,1994) were also used but the authors observed that simpler methods generated SI scores that were comparable to the more complicated composite SI method. In another paper the inter-rater reliability of the Strain Index was tested and was found to be valid for multiple individuals or groups and its predictive value for distal upper extremity disorders was confirmed.[12]

Users of ISO 11228-3 are directed to those and similar papers for a better knowledge on Strain index method application especially for multiple tasks.

C.5.2 HAL/ACGIH TLV

In one 2005 paper[8] from the “Michigan Group” that inspired the HAL/ACGIH TLV the authors examined the prevalence of symptoms and specific disorders among 908 workers from seven different job sites in relation to the TLV. In all instances, prevalence of symptoms and specific disorders were substantial in jobs that were below the TLV action limit, suggesting that even at “acceptable” levels of hand activity, many workers will still experience symptoms and/or upper extremity musculoskeletal disorders.

Similar findings (the action limit could be not considered as a “safe” limit) were addressed in other papers and findings in the literature and some authors [1] [11] have in some manner proposed to lower the Action Limits (for instance to a peak force of maximum 3-4 for an HAL of 1) for a broader prevention of UL WMSDs. While the HAL/TLV remains suitable as a quick and useful screening tool, most of the studies on HAL/TLV in industrial environments have failed to identify a statistical significant relationship between HAL/TLV scores and incident cases of CTS and UET. HAL/TLV only includes assessments of a normalized force and of the speed of hand activity and most studies have identified a number of additional factors that affect the overall risk of UL WMSDs.

A 2012 study[9] of both SI and HAL/TLV found that both are useful metrics in predicting carpal tunnel syndrome in a prospective cohort when adjusted for relevant covariates.

Users of ISO 11228-3 are directed to those and similar papers when using the ACGIH HAL/TLV method and interpreting the corresponding results.

C.5.3 Other recent developments

In recent years other methods have been developed that could be used for the specific purposes of a simple risk assessment (Method 1 in ISO 11228-3).

These methods are quoted here with relative references:

— HARM (Hand Arm Risk assessment Method). Developed by researchers from TNO (NL). Available at https://www.fysiekebelastingbeoordelen.tno.nl/en/page/harm . As a publication refer to *Work* Volume 41 (2012) 4004-4009. IOS Press

— ART — Tool (Assessment of Repetitive Tasks of the upper limbs). Developed by the HSE (UK). Available at www.hse.gov.uk/pubns/indg438.pdf.

— KIM-MHO (Key Indicator Method - Manual Handling Operations). Developed by German researchers from the Institute of Occupational Health, Safety and Ergonomics and the Federal

Institute for Occupational Safety and Health. Available at http://iospress.metapress.com/content/l13377271mq883q8/fulltext.pdf . As a publication refer to *Work* Volume 41 (2012) 3997-4003. IOS Press

— EAWS (Ergonomic Assessment Worksheet — section 4). Developed mainly by German researchers at the Institute of Ergonomics of Darmstadt University of Technology and based on their experience in the Automobile sector. Available at http://ergo-mtm.it/ergonomic-assessment-work-sheet-eaws-form-and-overview/ or as, publication in Theoretical Issues in Ergonomics Science (TIES) - Taylor and Francis Group. Published online: 27 Apr 2012. Manuals and training materials are made available in the main languages by the International MTM Directorate and by the Fondazione ERGO-MTM Italia (www.ergo-mtm.it).

C.6 OCRA Checklist

A shortened procedure for the identification of upper limb overload in repetitive tasks

COMPILED BY/I		
DAY		
IDENTIFICATION OF THE WORKPLACE		
BRIEF DESCRIPTION OF THE TASK		
How many work places are identical or very similar		
How many shifts are present in a day		
How many workers work in these workplaces during a day and considering all the identical work-places		
DESCRIPTION of SHIFT CONTENTS		MINUTES/UNITS (only actual time or actualnumber of units or cycles)
SHIFT DURATION (min)	Official (min)	
	Actual (min)	
BREAKS	Official (total duration in min)	
	Actual (total duration in min)	
MEAL BREAK	Official (duration in min)	
	Actual (duration in min)	
NON REPETITIVE TASKS (eg: cleaning, supplies, etc.)	Official (total duration in min)	
	Actual (total duration in min)	
NET DURATION OF REPETITIVE TASK(S)		
NO. OF UNIT (OR CYCLE)	Planned	
	Actual	
NET CYCLE TIME (sec.)		
OBSERVED CYCLE TIME		

<table>
<tr><td colspan="10">MULTIPLIERS FOR THE TOTAL NET DURATION OF REPETITIVE TASK(S) IN THE SHIFT</td><td rowspan="10">Duration multi-plier</td></tr>
<tr><td colspan="3">minutes</td><td colspan="7">duration multiplier</td></tr>
<tr><td colspan="3">60–120</td><td colspan="7">0,5</td></tr>
<tr><td colspan="3">121–180</td><td colspan="7">0,65</td></tr>
<tr><td colspan="3">181–240</td><td colspan="7">0,75</td></tr>
<tr><td colspan="3">241–300</td><td colspan="7">0,85</td></tr>
<tr><td colspan="3">301–360</td><td colspan="7">0,925</td></tr>
<tr><td colspan="3">361–420</td><td colspan="7">0,95</td></tr>
<tr><td colspan="3">421–480</td><td colspan="7">1</td></tr>
<tr><td colspan="3">> 480</td><td colspan="7">1,5</td></tr>
<tr><td colspan="10">MULTIPLIERS FOR LACK OF RECOVERY PERIOD</td><td>Recovery multi-plier</td></tr>
<tr><td>No. of hours without recovery period</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td rowspan="2"></td></tr>
<tr><td>RECOVERY MUL-TIPLIER</td><td>1</td><td>1,05</td><td>1,12</td><td>1,20</td><td>1,33</td><td>1,48</td><td>1,70</td><td>2,00</td><td>2,50</td></tr>
<tr><td colspan="11">NUMBER OF HOURS WITHOUT A RECOVERY PERIOD</td></tr>
<tr><td colspan="11">Indicate on the chart below, the distribution of breaks actually carried out and the meal break. Then count how many hours do not have adequate recovery (ratio of 5:1 between repetitive work and pause).</td></tr>
<tr><td colspan="6">Time at the beginning of the shift</td><td colspan="5">Time at the end of the shift</td></tr>
</table>

ARM ACTIVITY AND FREQUENCY OF ACTIONS

☐ RIGHT ☐ LEFT ☐ BOTH

	DYNAMIC ACTIONS
0	Arm movements are slow and frequent short interruptions are possible (20 actions per minute)
1	Arm movements are not too fast, they are constant and regular. Short interruptions are possible (30 actions per minute)
3	Arm movements are quite fast and regular, only occasional and irregular short pauses are possible (about 40 actions per minute)
4	Arm movements are fast. Only occasional and irregular short pauses are possible (about 40 actions per minute)
6	Arm movements are fast. Only occasional and irregular short pauses are possible (about 50 actions per minute)
8	Arm movements are very fast. The lack of interruptions makes it difficult to hold the pace, which is about 60 actions per minute
10	Very high frequencies (70 actions per minute or more). Absolutely no interruptions are possible
	STATIC ACTIONS
2,5	An object is held for at least 5 consecutive sec., incurring one or more static actions for 2/3 of the cycle (or observation) time.
4,5	An object is held for at least 5 consecutive sec., incurring one or more static actions for 3/3 of the cycle (or observation) time.

FREQUENCY SCORE

Choose one answer for each upper limb. It is possible to use intermediate scores. If both static and dynamic actions are present: CONSIDER both static and dynamic actions. As most representative of the task CHOOSE the one with the highest risk value.

PRESENCE OF WORKING ACTIVITIES INVOLVING THE REPEATED USE OF FORCE IN THE HANDS/ARMS

More than one answer can be selected: add up the partial scores obtained. If necessary, choose intermediate scores, and then add them together.

The working activity requires the use of almost maximal force (score 8 or more on the Borg scale): When:	**6**	2 seconds every 10 min
	12	1 % of the time
	24	5 %of the time
	32	over 10% of the time
The working activity requires the use of intense force (score 5-6-7 on the Borg scale) : When:	**4**	2 seconds every 10 min
	8	1 % of the time
	16	5 %of the time
	24	over 10% of the time
The working activity requires the use of moderate force (score 3-4 on the Borg scale): When:	**2**	1/3 of the time
	4	About half the time
	6	Over half the time
	8	Nearly all the time

FORCE SCORE

RIGHT LEFT

PRESENCE OF ADDITIONAL FACTORS for more than half the time (*choose only one answer per group of questions*)

	PHYSICAL
2	Gloves inadequate to the task are used for more than half the time
2	Vibrating tools are used for over half the time
2	The employed tools cause skin compressions
2	The task implies repeated impacts by the hand (the hand is used as a tool)
2	Cold temperature
2	Other additional factors are present :specify
3	More then 1 additional factors are present, and they occupy the whole of the time
	ORGANISATIONAL
1	Working pace is set by the machine, but there are "buffers" by which the working pace may be slowed down
2	Working pace is completely determined by the machine.

ADDITIONAL SCORE

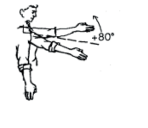
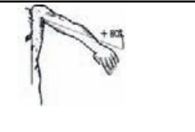
RIGHT LEFT

PRESENCE OF AWKWARD POSTURE AND MOVEMENT AND/OR LACK OF VARIATION OR STEREOTYPE

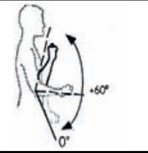
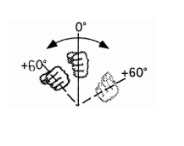
☐ RIGHT ☐ LEFT ☐ BOTH

A. ARMS/SHOULDER

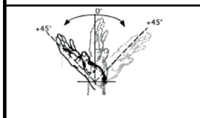
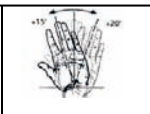
1	The arm is unsupported and is raised a little for half (or more) of the time

			The arms are kept nearly at shoulder height, without support	2	for about 10% of the time
				6	for about 1/3 of the time
				12	for about 1/2 of the time
				24	nearly all the time

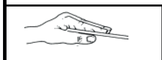
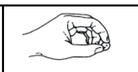
B. ELBOW

		The elbow executes wide movements (wide flexion-extension or prono-supination)	2	for about 1/3 of the time
			4	for over half the time
			8	nearly all the time

C. WRIST

		The wrist must bend in an extreme position, or must keep awkward postures (such as wide flexions or extensions, or wide lateral deviations)	2	for about 1/3 of the time
			4	for over half the time
			8	nearly all the time

D. HAND

				Grip objects, parts or tools with fingertips with constricted fingers (pinch) or with a nearly open hand (palmar grip) or keeping fingers hooked	2	for about 1/3 of the time
					4	for over half the time
					8	nearly all the time

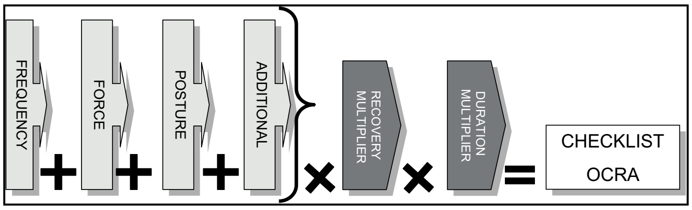
E. LACK OF VARIATION OR STEREOTYPE

1,5	Performs working gestures of the same type involving shoulders and/or elbow and/or wrist and/or fingers for 51-80% of time (or cycle time between 8 and 15 seconds, full of manual actions)
3	Performs working gestures of the same type involving shoulders and/or elbow and/or wrist and/or fingers for 81- 100% of time (or cycle time less than 8 seconds, full of manual actions)

FINAL AWKWARD POSTURES AND MOVEMENTS SCORE *Use the highest value obtained among the four groups of questions (A, B, C, D) only once, and eventually add to that of the last question E.*

POSTURE SCORE

RIGHT LEFT



OCRA CHECKLIST FINAL SCORE

RIGHT

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