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Indian Standard

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श्रमदक्षता शास्त्र — हस्तचालित प्रहस्तन

भाग 1 उठाना, नीचे करना और ढोना

(पहला पुनरीक्षण)

Ergonomics — Manual Handling

Part 1 Lifting, Lowering and Carrying

(First Revision)

ICS 13.180

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NATIONAL FOREWORD

This Indian Standard (Part 1) (First Revision) which is identical to ISO 11228-1 : 2021 'Ergonomics — Manual handling — Part 1: Lifting, lowering and carrying' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on recommendation of the Ergonomics Sectional Committee and approval of the Production and General Engineering Division Council.

This standard was first published in 2018 based on ISO 11228-1 : 2003. This revision has been undertaken to align it with the latest version of ISO 11228-1.

The major changes incorporated in this revision are as follows:

a) The scope now covers lowering while the previous edition only covered lifting and carrying;
b) The risk estimation method has been made more comprehensive and considers more factors, such as the load asymmetry, the hand distance from the body, the vertical travel distance, the coupling quality, and the task duration;
c) It provides more guidance on risk reduction measures, such as the ergonomic design of work, the object and the environment as well as training and education; and
d) Addition of Annex D to Annex I to include updated information on expansions of the revised NIOSH lifting equation (RNLE), more examples for lifting and carrying, and detailed information on the scientific background and recommended interpretation of the RNLE.

This standard has been published in 3 parts. Other parts in this series are:

Part 2	Pushing and pulling
Part 3	Handling of low loads at high frequency

The text of ISO standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are however , not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'; and
b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'.

Contents

Page

Introduction

0.1 General

The ISO 11228 series establishes ergonomic recommendations for different dynamic manual handling tasks. It provides information for designers, employers, employees and others involved in work, job and product design. The ISO 11228 series provides information on the evaluation of static postures.

Disorders of the musculoskeletal system are common worldwide and one of the most frequent disorders in occupational health. The risk-assessment model in this document allows the estimation of the risk associated with a manual material handling task. It takes into consideration the hazards (unfavourable conditions) related to manual handling tasks and the time spent performing them. Unfavourable conditions can include factors such as the size and mass of the object being handled, working posture (e.g. twisting, bending, overreaching), quality of grip on items, and the frequency and duration of manual handling. Any of these can, alone or in combination, lead to a hazardous handling activity and increase the risk of musculoskeletal disorders. Accordingly, these factors are considered when determining a recommended safe limit of the mass of objects being handled.

The method of determination of safe recommended limits in this document is based on the integration of data derived from four major research approaches, namely the epidemiological, the biomechanical, the physiological and the psychophysical approach.

0.2 The ergonomic approach

0.2.1 General

Ergonomics pursues the specific goals of optimizing human well-being and overall system performance. This is achieved through contributions to the design and evaluation of tasks, jobs, production, environment and systems in order to make them compatible with the needs, abilities and limitations of people. It strives to design or to modify a work system to accommodate, as far as possible, a broad range of people in order to meet the needs of workers with various characteristics, including people with special requirements. Thus, the development of special solutions for individuals can be minimized. Achieving these goals also contributes to organizational sustainability and social responsibility.

Manual handling tasks in the workplace occur within the context of work systems. Interactions of humans with items, information, environment and other people must be taken into consideration when designing or modifying tasks and work areas. The ergonomics approach can be used to prevent manual-handling-related injuries from occurring by being used proactively in the design of processes, systems or work organization, in addition to when modifications to existing systems are being considered.

The ergonomic approach considers tasks in their entirety, taking into account a range of relevant factors including the nature of the task, the characteristics of objects handled, the working environment and the individuals performing the task. It considers environmental conditions (e.g. lighting, noise, temperature), as well as an individual's characteristics and experiences. An individual's characteristics include physical and mental capabilities, skills, work techniques, behaviour and their perception of the work environment and its social characteristics.

0.2.2 Organizational considerations

Work organization (e.g. task duration, job duration, recovery time, shift patterns) is a contributing factor in the prevention or development of musculoskeletal disorders. For example, recovery periods help to mitigate possible muscular fatigue and help to avoid the overuse of similar muscle groups over the duration of the work shift. Job rotation, job diversification and job enlargement are all methods of structuring the work to facilitate variation and recovery within the work period.

Work organization includes appropriate training of workers, including how to safely perform tasks, how to recognize and respond to hazardous conditions in workplaces, and which procedures and communication channels to use to report and correct hazards. Regularly and properly maintained equipment and facilities contribute to safer work, including manual handling tasks. The selection of equipment and supplies which are appropriate for the workplace and task conditions helps to make work demands safer.

0.2.3 Psychological health and safety and the ergonomics approach

The ergonomics approach considers the cognitive or psychological demands on humans, as well as the psychosocial environment in which work takes place. Psychological response to work and workplace conditions (psychosocial factors) has an important influence on mental, physiological and musculoskeletal health. Psychosocial factors in the workplace include the design, organization and management of work, work content, job complexity, job demands (cognitive and physical), job content and the overall social environment (i.e. the context of work).

Undesirable psychosocial aspects of a job can include:

- little or no control over work methods or organization;
- high levels of attention and concentration required;
- poor use of skills;
- little or no involvement in decision-making;
- repetitive, monotonous tasks only;
- machine- or system-paced work;
- work demands perceived as excessive;
- payment systems which encourage working too quickly or without breaks;
- work systems that limit opportunities for social interaction;
- high levels of effort not balanced by sufficient reward (e.g. resources, remuneration, self-esteem, status);
- no training and skill enhancement encouraged or supported;
- poor co-worker or supervisory support.

Many of the effects of these factors on workers occur via stress-related processes, which can in turn have a direct effect on biochemical and physiological responses, which can increase the likelihood of experiencing musculoskeletal injury. Thus, for the prevention of musculoskeletal disorders (MSDs), these psychosocial stressors should be controlled in addition to the biomechanical risk factors. For more information on the effects of the psychosocial stressors on MSDs, see References [63] to [66]. For further information on psychological health and safety in the workplace, see References [1] to [42]

Indian Standard

ERGONOMICS — MANUAL HANDLING

PART 1 LIFTING, LOWERING AND CARRYING

(First Revision)

1 Scope

This document specifies recommended limits for manual lifting, lowering and carrying while taking into account the intensity, the frequency and the duration of the task. It is designed to provide requirements and recommendations on the assessment of several task variables, allowing the health risks for the working population to be evaluated.

This document applies to manual handling of objects with a mass of 3 kg or more and to moderate walking speed, i.e. 0,5 m/s to 1,0 m/s on a horizontal level surface.

This document is based on an 8 h working day, but also covers more prolonged working times, up to 12 h. It also addresses the analysis of combined lifting, lowering and carrying tasks in a shift during a day.

This document does not cover the holding of objects (without walking), the pushing or pulling of objects or manual handling while seated. The pushing and pulling of objects are covered in the other parts of the ISO 11228 series.

This document does not cover handling people or animals. (For further information on handling people, refer to ISO/TR 12296.)

This document does not address the manual lifting of objects while using lift-assistive devices such as exoskeletons and does not address the needs of pregnant women or persons with disabilities.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
manual handling
activity requiring the use of human force to lift, lower, carry or otherwise move or restrain an object

3.2
lifting
manually (i.e. without using mechanical assistance) moving an object from its initial position

3.3
lowering
manually (i.e. without using mechanical assistance) moving an object from its initial position downwards

Note 1 to entry: Included in lifting.

3.4
carrying
manually (i.e. without using mechanical assistance) moving an object which is held with either one or two hands, or positioned on one or two shoulders or on the neck, by walking one metre or more

Note 1 to entry: Does not include the use of backpacks.

3.5
risk assessment
overall process comprising a risk analysis and risk evaluation

3.6
reference conditions
set of conditions (environmental, physical, biomechanical and task-design-related) which are considered to be the ideal conditions for safe manual handling to take place

Note 1 to entry: See 4.2.1, 4.2.3.2, A.4 and H.1 for detailed definitions of lifting and carrying conditions.

3.7
repetitive lifting
lifting an object more than once every 10 min

Note 1 to entry: Infrequent lifting at one lift every 10 min is defined in Reference [57], where a multiplier of 1,0 is applied for all duration scenarios at a frequency of 1 lift per 10 min.

3.8
mid-sagittal plane
vertical plane in the anterior-posterior direction that divides a person assuming a neutral body posture into equal left and right halves

Note 1 to entry: See Figure C.1

Note 2 to entry: A neutral body posture is an upright standing posture with the arms hanging freely by the side of the body.

3.9
plane of asymmetry
vertical plane passing through the midpoint of the line between the inner ankle bones and the centre of gravity of the load when the load is at its most extreme displacement from the neutral, mid-sagittal plane

3.10
angle of asymmetry
angle formed between the lines that result from the intersections of the mid-sagittal plane and the plane of asymmetry

Note 1 to entry: If the feet are repositioned during the lift or lower sequence, the referent planes shall be determined at the point in the action sequence where the largest degree of asymmetrical twist is encountered (see Figure C.1).

3.11
reference mass
mass considered appropriate for use with an identified user population during the application of the risk-assessment method described herein

3.12
cumulative carried mass
product of the carried mass and the carrying frequency

Note 1 to entry: The cumulative mass for carrying is defined in kilograms per minute to represent the risk for short-term carrying, in kilograms per hour to represent the risk for medium-term carrying and in kilograms per 8 h to represent the risk for long-term carrying.

3.13
recovery time
time used for determining the work/recovery pattern, which is the period of light work activity Note 1 to entry: Light work activity can include monitoring activities, light assembly work using the upper limbs, work not involving lifting or lowering or carrying > 3 kg, and work not involving pushing or pulling.

4 Risk reduction for manual lifting or carrying tasks

4.1 General

Risk assessment is the overall process of risk identification, risk analysis and risk evaluation, the results of which are ultimately used in the effort to reduce risk. The goal in manual materials handling risk reduction is to take measures to improve the design of the task, the object and the working environment relative to the characteristics of the individuals performing the work.

In those cases where manual handling cannot be avoided, a risk assessment shall be completed to determine if, and to what extent, modifications are recommended. The risk assessment takes into account the mass of the object, the grip on the object, the position of the object relative to the position of the body, and the frequency and duration of a specific task.

The risk assessment is accomplished using the step-by-step approach illustrated in Figure 1 (step model). With each successive step, the evaluator analyses the interrelated aspects of the tasks.

If recommended limits are exceeded, the task shall be adapted in such a way that all questions in the step-by-step approach are satisfied.

Employees engaged in manual handling should be provided with adequate information and training on how to perform these tasks safely. The provision of this information and training does not, in isolation, ensure safe manual handling in all cases. However, it is an integral part of the ergonomics approach, and the risk of injury can be reduced by adopting safe ways of manual handling (see A.6).

4.2 Risk assessment (step model)

4.2.1 Using the step model

The step model illustrated in Figure 1 describes the steps involved in beginning, and working through, a risk assessment of manual handling tasks, including lifting and carrying. Initially, the mass of the object being handled is determined; if it is more than 3 kg, the risk assessment is continued. The task is further analysed to determine if the mass exceeds recommended limits for handling (step 1).

The user shall make modifications where limits are exceeded. In those tasks where lifting and carrying is repetitive, the assessment is continued using the quick assessment procedure (step 2). Based on the outcome of step 2, the task will possibly:

— require immediate modifications for safety (see Annex A for further information);

— be determined to be acceptable; or

— need further, more detailed, risk evaluation (step 3).

Step 3 is also used for evaluating tasks which take place using non-ideal postures.

The reference condition of manual lifting and lowering posture for manual handling is:

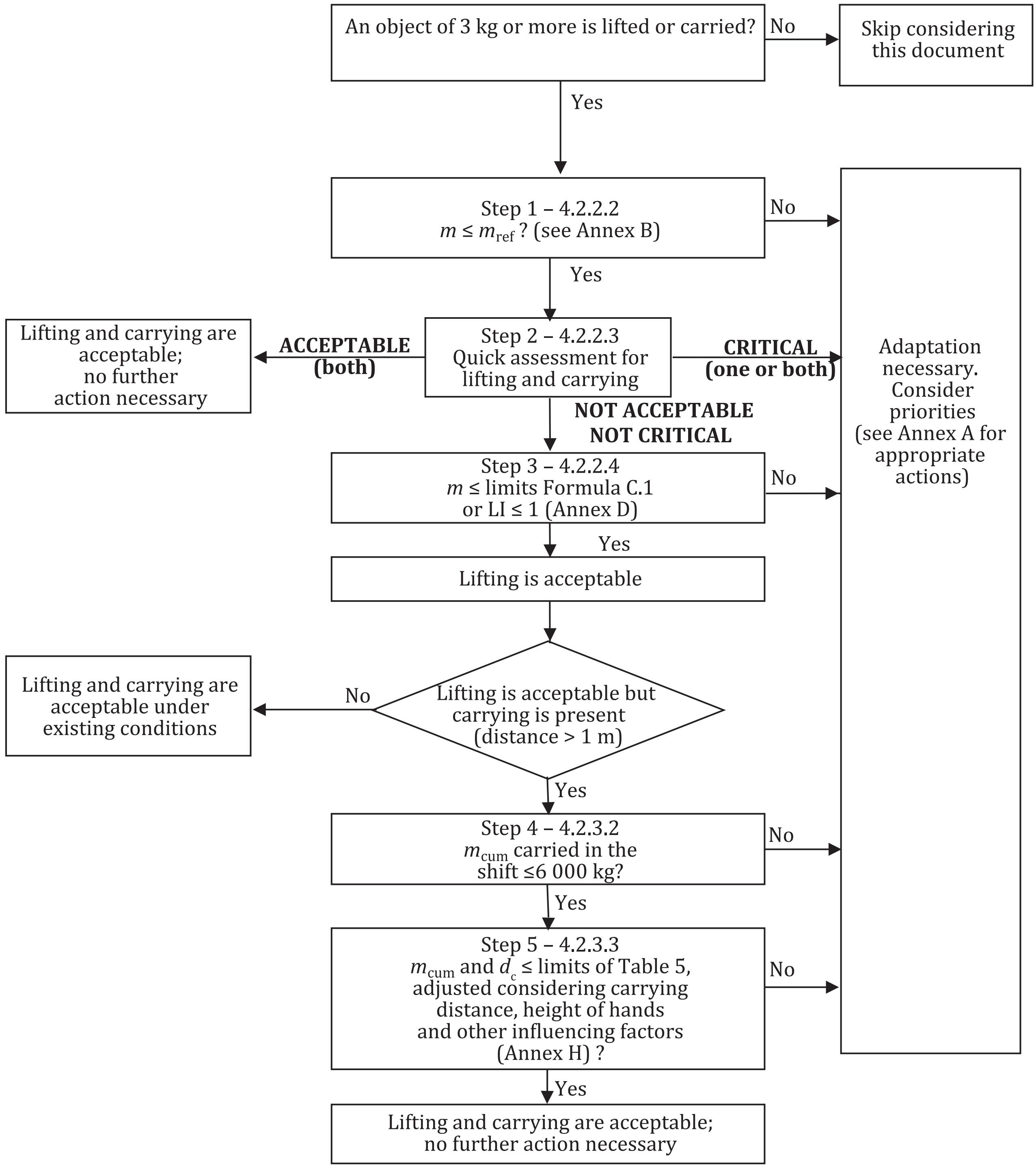
— an upright symmetrical trunk posture (no twisting or lateral bending);

— sagittal trunk inclination of no more than 15° (the minimum inclination observable with the human eye) from the vertical to accommodate the natural posture of the back;

— the horizontal distance between the object being handled and the centre of mass of the worker as close as possible;

— the grip height lying within knuckle and elbow height for lifting or between knuckle and shoulder height for carrying (for anthropometric measurements see ISO 7250-3).

Steps 4 and 5 assist with the further evaluation of the task for cumulative mass for lifting and carrying.



Key

m	mass of object to be lifted
M_{ref}	reference mass for identified user population group
M_{cum}	cumulative mass (carried)
d_c	duration (of carrying)
LI	lifting index

Figure 1 — Step model

4.2.2 Recommended limit for manual lifting, lowering and carrying

4.2.2.1 Weight of the object

Whenever an object of 3 kg or more is lifted or carried, a risk assessment shall be performed, beginning with the initial screening, step 1. Note that throughout the text whenever the term "lifting" is used the act of "lowering" is implied.

4.2.2.2 (Step 1) Initial screening

An initial screening of non-repetitive lifting and carrying (performed with reference conditions in place) requires the determination of the object's mass (step 1). The recommended limit for the mass of the object, referred to as the reference mass, m_{ref}, and based on population characteristics, is presented in Annex B. For general guidance for designers and additional information related to step 1, see Annex A.

4.2.2.3 (Step 2) Quick assessment of repetitive lifting and carrying

Screening of repetitive lifting and carrying tasks of objects of 3 kg or more is performed using the quick assessment procedure.

The quick assessment procedure aims to identify, without the need for calculation, the presence of two opposite exposure conditions:

— acceptable condition, where unacceptable risk has not been identified;

— critical condition, where unacceptable risk has been identified.

When either of these conditions is met, it is not necessary to perform a more detailed evaluation of the exposure level. Instead, either no further modifications need to be considered (acceptable risk, see Table 1 and Table 2) or modifications should be made immediately (see Annex A for guidance) due to the presence of a critical condition (see Table 3). In either case, Table 4 shall also be referenced to identify the presence of any unfavourable working environment or object circumstances which can further increase the risk of the task (additional factors).

When neither of the two extreme conditions is met, it is necessary to conduct further risk evaluation by methods presented in step 3 (see 4.2.2.4).

Table 1 and Table 2 are used for establishing the acceptable risk condition. If all of the listed conditions are present (yes for each condition), the examined task is acceptable and it is not necessary to continue with a risk evaluation. If any answers are no, then Table 3 shall be used to confirm if there are critical conditions. If any of these conditions is met (a yes response), the task shall not be performed before modifications are made.

In either case, Table 4 shall also be systematically used to identify the presence of any unfavourable working environment or object characteristics which will potentially further increase the risk of the task. These factors can be related to the work environment or to the object characteristics, and they shall be addressed to help reduce risk.

Table 1 — Lifting and lowering — Quick assessment — Acceptable condition

Lifting and lowering			
3 kg to 5 kg	Asymmetry (e.g. body rotation, trunk twisting) is absent	No	Yes
	Load is maintained close to the body (e.g. where space between the body and the item is minimized)	No	Yes
	Load vertical displacement is between hips and shoulders	No	Yes
	Maximum frequency: less than five lifts per minute	No	Yes

Table 1 *(continued)*

> 5 kg to 10 kg	Asymmetry (e.g. body rotation, trunk twisting) is absent	No	Yes
	Load is maintained close to the body (e.g. where space between the body and the item is minimized)	No	Yes
	Load vertical displacement is between hips and shoulder	No	Yes
	Maximum frequency: less than one 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 lifting task is acceptable and it is not necessary to continue the risk evaluation, except to review Table 4 for other factors to be considered. If at least one of the questions is answered no, the evaluation shall continue (see Table 3 and Table 4).			

Table 2 — Carrying — Quick assessment — Acceptable condition

Carrying				
Calculate the cumulative mass (total kg carried during the given durations for the given distance below). Is the carried cumulative mass less than or equal to recommended cumulative masses values considering distances (±5 m) and duration (1 min; 1 h; 4 h; 8 h)?				
Duration	**Distance 1 m to ≤ 5 m per action**	**Distance > 5 m to 10 m per action**		
6 h to 8 h	4 800 kg	3 600 kg	No	Yes
4 h	4 000 kg	3 000 kg	No	Yes
1 h	2 000 kg	1 500 kg	No	Yes
1 min	60 kg	45 kg	No	Yes
	Acceptable conditions for carrying: carry with two hands over a maximum distance of 10 m, picking up and setting down the object at height, where the pick-up and set-down height ranges between 0,75 m and 1,10 m, with the full cycle including returning back to the start point empty-handed over the same distance. The carrying exercise is performed in a comfortable indoor environment, on a hard, flat, non-slip floor, without any obstacles in the way, and in a workspace allowing free body movement and posture. No constraints are placed on the subject. Awkward postures during the carrying are not present.		No	Yes
If all of the questions are answered yes, then the examined carrying task is acceptable and it is not necessary to continue the risk evaluation except to review Table 4 for other factors to be considered. If at least one of the questions is answered no, the evaluation shall continue (see Table 3 and Table 4).				

Table 3 — Lifting or carrying— Quick Assessment — Critical condition

Critical condition for lifting: task layout and frequency conditions exceeding the maximum suggested			
Vertical location	The hand location at the beginning and end of the lift is higher than 175 cm or lower than the surface at the feet	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 (>63 cm)	No	Yes
Asymmetry	Extreme body twisting (to either side by more than 45°) without moving the feet	No	Yes

Table 3 *(continued)*

Frequency of lifts[56]	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 min of recovery time)	No	Yes
	More than 12 lifts per minute of medium duration (manual handling lasting no more than 120 min consecutively in the shift, followed by at least 30 min of recovery time	No	Yes
	More than 10 lifts per minute of long duration (manual handling lasting more than 120 min consecutively in the shift)	No	Yes
Critical condition for lifting or carrying: presence of loads exceeding the following limits (see Table B.2 for further information)			
Females (20 to 45 years)	20 kg	No	Yes
Females (<20 or > 45 years)	15 kg	No	Yes
Males (20 to 45 years)	25 kg	No	Yes
Males (<20 or > 45 years)	20 kg	No	Yes
Critical condition for carrying: presence of cumulative carried mass greater than those indicated also with acceptable conditions for carrying			
Carrying distance (per action) 1 m to 5 m over a 6 h to 8 h period?	6 000 kg in 6 h to 8 h	No	Yes
Carrying distance (per action) 5 m to 10 m over a 6 h to 8 h period?	3 600 kg in 6 h to 8 h	No	Yes
Carrying distance (per action) 10 m to 20 m over a 6 h to 8 h period?	1 200 kg in 6 h to 8 h	No	Yes
Carrying distance (per action) more than 20 m	Carrying distance is usually more than 20 m	No	Yes
If at least one of the conditions has a yes response, then consider risk as high and a critical condition is present. Proceed with task redesign and continue to Table 4 to identify additional factors to be considered, and then continue to Annex A for identifying urgent corrective actions.			

Table 4 — Lifting and carrying — Additional factors to be considered

Is the working environment unfavourable for lifting and carrying?		
Presence of extreme (low or high) thermal stress (e.g. temperature, humidity, air movement)	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 lifting and carrying?		
The size of the object reduces the worker's view and hinders movement	No	Yes
The load centre of gravity is not stable (e.g. liquids, items moving around inside of object)	No	Yes
The object shape or configuration presents sharp edges, surfaces or protrusions	No	Yes
The contact surfaces are too cold or too hot	No	Yes
Improper handholds or coupling		
Does the lifting or carrying task(s) last more than 8 h a day?	No	Yes
If at least one of the questions is answered yes, the specified condition shall be addressed and the risks minimized.		

4.2.2.4 (Step 3) Recommended limits for mass, frequency and object position

When none of the two conditions identified in step 2 is met, it is necessary to conduct a risk evaluation (step 3) to determine the recommended limits for the task.

To determine the recommended mass limit (RML; Annex C) while taking into account working posture, object position and lifting frequency and duration, use Formulae (C.1) to (C.5). These formulae take into account task variables (characteristics of the task). A lifting index (LI; Annex D) is also calculated for further risk exposure information. The analyst first checks if the RML for lifting is exceeded and, if so, checks if the LI exceeds appropriate limits (Table D.1). If both are exceeded then the task shall be adapted by changing the mass, the lifting frequency, the lifting duration or the object position. Table D.1 provides interpretation of the results and consequent measures. Annex E reports a simplified model for RML and LI calculation. Annex F reports procedures for analysing multiple manual lifting tasks (composite, variable and sequential lifting tasks), Annex G reports examples of analysis of simple and variable lifting tasks. Annex I reports a brief review of the relevant literature regarding the interpretation of the lifting index and is the basis for Table D.1.

4.2.3 Cumulative mass of carrying

4.2.3.1 General

For an object to be carried once for a modest distance (one or two steps or less than 1 m), only the limits for lifting shall be applied as per steps 1, 2 and 3.

For screening the cumulative mass per day for carrying (step 4), the recommended limits in 4.2.2.2 and 4.2.2.3 shall initially be used. Once this has been completed, limits recommended in 4.2.3.2 for a reference carrying condition shall be applied.

For determining the cumulative mass of carrying related to distance, time patterns and other influencing factors, refer to 4.2.3.3 (step 5).

4.2.3.2 (Step 4) Recommended limit for cumulative mass per day

The cumulative mass in a certain period is calculated as a product of mass and frequency of carrying. These two values are limited in steps 1, 2 and 3. In this way, the reference mass cannot exceed a maximum of 25 kg (i.e. mass shall decrease from 25 kg as the frequency increases) and the frequency of carrying should never exceed a maximum of 15 times per minute (i.e. frequency shall decrease from 15 times per minute when the mass being carried is increased).

Reference conditions are described as carrying an object with two hands over a distance of 2 m, picking up and setting down the object at height, where the pick-up and set-down height ranges between 0,75 m and 1,10 m, with the full cycle including returning back to the start point empty-handed over the same distance. The carrying exercise is performed in a comfortable indoor environment, on a hard, flat, non-slip floor, without any obstacles in the way, and in a workspace allowing free body movement and posture. No constraints are placed on the subject.

Reference conditions regarding distance, way back and environmental and workspace conditions shall be adopted for carrying on shoulder(s) or neck. The height of picking up and object release is about shoulder height (125 cm to 155 cm). Alternatively, these actions are performed by a co-worker, for example a co-worker placing a load on the shoulder of another worker who then carries it.

With reference conditions in place, the recommended limit for cumulative mass of carrying is 6 000 kg per 8 h.

4.2.3.3 (Step 5) Recommended limit for cumulative mass of carrying related to time patterns, distance and other influencing factors

For carrying with reference conditions in place, the recommended limits for cumulative mass considering the different duration scenarios for carrying are presented in Table 5[11],[28],[36],[38].

Table 5 — Recommended limits in the carrying reference conditions for cumulative mass related to carrying duration during the shift (for general working population)

Carrying distance > 1 m and ≤ 2 m	kg per min	kg per 1 h	kg per 2 h	kg per 3 h	kg per 4 h	kg per 5 h	kg per 6 h to 8 h
Recommended limits for cumulative mass for manual carrying	75	2 500	3 400	4 200	5 000	5 600	6 000

To evaluate the cumulative mass carried, the duration of the carrying tasks in a period of time shall be considered. Table 5 provides recommended limit values of cumulative mass based on time devoted to manual handling (including loads that are both lifted and then carried) in the shift and represents the product of handling different possible masses at different frequencies. For example, the limit of a cumulative mass of 75 kg for a single minute can be achieved by a mass of 12,5 kg × 6 times/min.

When carrying conditions differ from the reference condition, recommended limits in Table 5 shall be adjusted by applying correction ratios (multipliers) into the calculation. The multipliers represent true conditions of the task as observed (e.g. carrying distance, height of pick up or set down and other relevant conditions). Multipliers are provided in Annex H.

4.3 Risk reduction

Risk reduction can be achieved by minimizing or excluding hazards resulting from the task, the object, the workplace, the work organization or the environmental conditions; examples are given in A.3 to A.5.

4.4 Additional considerations

Health surveillance should be provided by the employer with respect to work-related risks.

Health surveillance is preventive in nature and should ensure, before starting the job and then on an ongoing basis, that the relationship between the individual's health status and his or her working conditions is satisfactory.

More specifically, health surveillance aims to:

— identify any negative health conditions at an early enough stage to prevent them from worsening;

— identify people who require greater protective measures in addition to those adopted for other workers;

— contribute, based on appropriate feedback, towards enhancing the accuracy of collective and individual risk assessments;

— monitor preventive measures to ensure their continuing adequacy;

— collect exposure or injury data in order to compare different groups of workers and different scenarios;

— collect data on absences caused by specific disorders so as to estimate the cost of non-prevention.

Health surveillance related to manual handling should be focused both on the spine and on other parts of the body, especially considering the involvement of the shoulders and the upper limbs. Personal mental health (e.g. depression) and work-related psychosocial factors (e.g. job satisfaction, supervisory support) should also be considered in health surveillance for comprehensive prevention of musculoskeletal injuries or disorders in the workplace.

Technical or mechanical means of reducing risk should be provided and complemented with information and appropriate training on how to use manual materials handling aids appropriately (see A.6). All workers should be provided with information regarding work-related hazards, their risks and how to safely minimize exposure.

Annex A
(informative)

Ergonomics approach to the design of lifting and carrying tasks

A.1 General

Scientific knowledge stresses the importance of an ergonomic approach in removing or reducing the risk of manual-handling-related injury. Ergonomics focuses on the design of work and its accommodation of human needs and physical and mental capabilities.

In seeking to avoid injury from manual handling, it is pertinent to ask whether manual handling which is hazardous or presents a risk of injury can be eliminated altogether. Those designing new systems of work, or installing new plants, should consider introducing an integrated handling system that, where appropriate, fully utilizes powered or mechanical handling rather than a manual system. It should, however, be remembered that the introduction of automation or mechanization can create different risks. Mechanization, for example, by the introduction of a lift truck, hoist, trolley, sack truck, chute or pallet inverter, needs to be well maintained and a defect-reporting and -correction system should be implemented. All handling aids should be compatible with the rest of the work system, effective, appropriately designed and easily operated. Training concerning handling aids should cover their appropriate usage, and knowledge of safe storage and procedures to be used in the event of breakdown. Training should also include techniques on appropriate body positioning when using the equipment. Operating instructions and safety concerns should be clearly placed on the equipment.

If manual handling cannot be avoided, technical aids should be available. Handling devices such as hand-held straps, slide mats, hooks or suction pads can simplify the problem of handling an object.

A.2 Design of the work: task, workplace and work organization

A.2.1 Task

Stress levels on the back increase substantially as the distance between the object and the body increases. Therefore, in the planning of tasks it is relevant to avoid long reaching, twisting, stooping, bending and awkward movements or postures. Being able to gain secure and close footing to the object is central to designing for good posture. Often obstacles that prevent this can be avoided; a common example is long reaches across to an object from the far side of a pallet, which can be resolved by the use of pallet-rotating equipment. Another example where awkward postures are seen and alternatives are achievable is retrieving objects from the rear of deep shelves or racks less stressfully by installing rollers. The best height for storage is between the mid-thigh and chest height of the workers involved, with lighter items being stored above or below this region.

A good grip is essential for avoiding accidents with respect to handling and is often determined by the characteristics of the object. This means that the object should normally be equipped with suitable handles, cut-outs or finger slots. Objects with large dimensions should have two handles. The handles should be of sufficient dimensions and should be placed so that the centre of gravity falls at the midpoint of the line between the two handles.

A.2.2 Workplace

The work area should be designed to minimize the amount of manual effort, thus reducing the need for twisting, bending, reaching and carrying. The distance that both typical and infrequently handled objects have to be moved should be taken into account, together with the heights between which objects can be transferred.

Gangways and other working areas should be large enough to allow adequate room to manoeuvre. Sufficient space is a prerequisite for efficiently carrying out work in appropriate working postures. Also, the use of suitable mechanical devices often requires more room than manual lifting.

A person carrying an object should have a clear view ahead, unobstructed by the object. Lifting and carrying on stairways and on ladders should be avoided.

It is important to provide adequate space around the object and in the gangways, as well as sufficient headroom to avoid stooping postures while handling an object.

Floor or ground surfaces should be level, well maintained, not slippery and clear of obstacles to avoid potential slipping or tripping accidents. The presence of steps, steep slopes and ladders can increase the risk of injury by adding to the complexity of movement when handling objects. Debris and materials (e.g. used wrapping materials) can also pose tripping and slipping hazards and should be cleared.

A.2.3 Work organization

The amount of work undertaken in fixed postures is also an important consideration. Recommendations on this issue are made in ISO 11226. The frequency of handling an object can influence the risk of injury. Particular care is necessary where the handler cannot control or vary the rate of work. Consideration should, therefore, be given to whether there are adequate opportunities for rest (i.e. momentary pauses or breaks from work) or recovery (i.e. changing to another task which uses a different set of muscles). Job enrichment, job enlargement and job rotation have a key role to play in countering potential fatigue and maintaining levels of safe production output, though this issue is complicated by a large variation in individual susceptibility to fatigue.

Handling by two or more people can render possible an operation that is beyond the capability of one person or reduce the risk of injury to a single person. The object that a team can handle safely is less than the sum of the masses that the team members can cope with individually. Additional difficulties can arise if team members impede each other’s vision or movement and if the object offers insufficient suitable handholds.

When engineering or other controls do not provide adequate protection, personal protective equipment should be used only as a last resort. Advance planning is especially important in dealing with hazardous materials or other potentially dangerous loads. It can be necessary to give special attention to handling methods and provision made for dealing with an emergency, including emergency equipment and clear instructions. Where the wearing of personal protective equipment cannot be avoided, its implications for the risk of manual handling injury should be taken into consideration. For example, gloves can impair manual dexterity; other clothing, such as uniforms, can inhibit free movement during manual handling. Personal protective equipment, such as gloves, aprons, overalls, gaiters or safety footwear, should be well fitting. Footwear should provide adequate support, be stable, have a non-slip base, have anti-fatigue qualities and provide proper protection.

A.3 Design of the object

The object to be handled can constitute a hazard because of its mass or resistance to movement, size, shape, rigidity or the absence of handgrips. In determining if a load represents a risk, proper account shall also be made of the circumstances in which the load is handled. For example, postural recommendations, frequency and duration of handling, workplace design and aspects of work organization, such as incentive schemes and piecework, should be considered.

The shape of an object affects the way in which it can be held. In general, if any dimension of the object exceeds about shoulder width or if it is not a compact object, its handling is likely to pose an increased risk of injury. This is especially the case where this size is exceeded in more than one dimension. The risk is further increased if the object does not possess convenient handholds.

If the centre of gravity of the object is not positioned centrally within the object, an inappropriate handling style can result. Sometimes, as with a sealed and unmarked carton, an offset centre of gravity is not visibly apparent. In these circumstances, the risk of injury is increased since the handler can unwittingly hold the object with its centre of gravity further from the body than is necessary.

Consideration should be given to using pack filling for objects liable to shift when being handled. Equally, greater care is needed when handling objects which are inherently difficult to grasp. In addition, there can be physical or chemical hazards which should also be indicated, for example the object can have sharp edges, be too hot or too cold to touch, or contain materials or substances which can be hazardous if spilled.

A.4 Design of the working environment

General environmental conditions, including illumination, noise and climate, should be within tolerable levels. It is recommended to apply ISO 7730 for thermal comfort requirements. Extra care should be taken if work has to be done at extremes of temperature. For example, high temperatures or humidity can cause rapid fatigue; work at low temperatures can require gloves to prevent numbness of the hands but can also lead to a loss of manual dexterity. Air circulation (indoor and outdoor) is also a factor that influences body temperature. Rapid air circulation cools the body and should be avoided as far as possible. In very hot climates or working conditions, rapid air circulation can be desirable. It is important that there should be sufficient light to enable the workers to see clearly what they are doing and also prevent poor working postures. High noise levels can lead to reduced vigilance. For outdoor work, account needs to be taken of the effects of changing weather conditions. Extra care is needed in strong winds or where gusts are likely, for example around buildings. Assistance or mechanical devices can be especially necessary when carrying large sheets or bulky objects in such conditions.

Reference conditions for manual materials handling include the following criteria:

— moderate ambient thermal environment;

— two-handed operation only;

— unrestricted standing posture;

— handling by one person only;

— smooth lifting;

— good coupling between the hands and the objects handled;

— good coupling between the feet and the floor;

— manual handling activities, other than lifting, are minimal;

— the objects to be lifted are not cold, hot or contaminated;

— vertical displacement of the load is less than or equal to 0,25 m and does not occur below knuckle or above shoulder height;

— the trunk is upright and not rotated;

— the load is kept close to the body;

— the load is carried less than 20 m.

A.5 Individual considerations

Manual handling injuries are associated with the nature of the operations, the way they are organized and variations among individual physical capabilities. It is a fact that the ability to lift and carry does vary among individuals.

In general, the lifting strength for women as a group is up to two-thirds that of men. However, the range of strength and ability among individuals is large and means that some women can deal safely with heavier objects than some men. In those cases where neither manual lifting nor carrying can be eliminated in the short term, special demands on the physical capability of the worker, regardless of gender, can be necessary.

Young and old workers can have particular needs. For example, younger people are likely to be less skilled. Older people are more susceptible to sudden strains due to a decreasing elasticity of parts of the musculoskeletal system. With age, there is a reduction in physical capability, which becomes more significant after the age of 45.

There is good evidence that an individual with a medical history of a back disorder is more susceptible to recurrent episodes of back pain. Workers with a history of back disorders should be assessed and monitored. Eventually, it can become necessary to make modifications to prevent further recurrence of back problems.

Workers who suffer from spinal pathologies (Table A.1), both malformative and degenerative in nature, both work-related and not work-related, that are influenced by biomechanical overload, should be exposed to a lower level of manual handling than the general healthy population[18],[24],[25],[26],[62].

To accommodate these workers in workplaces, the reference masses given in Table B.1 which are protective for almost 99 % of the population (10 kg or 15 kg) can be used for calculating the appropriate RML and LI. This results in lifting conditions where the RML is not exceeded or the LI is less than or equal to 1.

In particular, also considering the type and severity of spinal pathologies reported in Table A.1:

— for males with pathologies of medium severity, the RML and the LI are calculated using 15 kg as the reference mass;

— for females with medium to severe pathologies and males with severe pathologies, the RML and the LI are calculated using a reference mass of 10 kg;

Loads shall only be lifted vertically between the height of the knees and the shoulders, and the frequency and duration of time assigned to lifting in the shift shall be limited.

It is important to recognize that these provisions for defining “acceptable” weights for lifting, by subjects with spinal pathologies, be used with caution and using a practical approach, possibly involving physician monitoring where appropriate. They are based on research-derived conclusions. However, the effectiveness of individual measures to restrict exposure to risk on a case-by-case basis is required in the field (through close follow-up of individual health and working conditions).

Table A.1 — Classification of moderate and severe spinal pathologies[19],[25],[61],[62]

“Moderate” pathologies
Significant scoliosis (20° Cobb with torsion 2; 30° Cobb with torsion 1+)
Baastrup syndrome
Scheuermann disease (with structured curving of the spine)
Klippel-Feil syndrome (even with only one synostosis)
Cervical and/or dorsal hernia
Grade 1 spondylolisthesis, spondylolysis
Sacralization (fully or partially fused or articulated)
Spinal canal stenosis without neurological signs
Severe lumbar disk disease (spondylodiscopathy)
Inverted lumbar lordosis with disc disease
Slight vertebral instability (10 % or 15 % in the presence of certain pathologies)
Lumbar protrusion with dural sac impingement
Surgically reduced lumbar disc herniation without adverse outcomes
“Severe” pathologies
Herniated disc
Surgically reduced lumbar disc herniation with adverse outcomes
Spinal canal stenosis with root or dural sac impairment
Grade 2 spondylolisthesis (>25 % slippage)
Klippel-Feil syndrome (cervical or dorsal synostosis with vertebral instability)
Significant scoliosis (at least COBB 30° and torsion 2)
Scheuermann disease with approximately 40° structured curving of the spine and lumbar disc disease
Severe vertebral instability (i.e. spondylolisthesis, Klippel-Feil syndrome, disc disease, fractures with vertebral slippage of 25 %)
Degenerative or newly formed lesions of the bones and joints (e.g. severe osteoporosis, vertebral angioma)
Systemic disease with severe spinal impairment

A.6 Information and training

As a complement to a safe system of work, effective training has an important part to play in preventing and reducing manual handling injuries. To be effective, training shall be work-related and reinforced at regular intervals.

Elements within a training program can include:

— how to recognize potentially hazardous handling operations, how to advocate improvements, how to deal with unfamiliar handling operations;

— the appropriate use of handling aids and personal protective equipment;

— ergonomic principles of task, object and working environment design;

— safe handling techniques, including practical training elements.

Additional elements to be included within a training program are anatomy and physiology of the back, body mechanics and proper lifting techniques, and exercises to stretch and strengthen the back muscles.

A good technique is one where the person is balanced, in complete control throughout the task, and uses the minimum amount of effort to achieve, where possible, a smooth, uninterrupted movement. When lifting or carrying the object, it should be kept as close to the body as possible and both hands should be used. When applying effort, jerky or twisting movements and stooped postures should be avoided.

Annex B
(informative)

Reference mass determination

B.1 Reference mass determination (step 1)

Step 1 of the determination of the RML for manual handling involves an initial screening of an object's mass. To determine if the mass is at or below a recommended limit for the population in question, the actual weight being handled (or planned to be handled) can be compared to a reference mass, m_{ref}, for that population. Table B.1 gives the reference masses, taking into consideration different populations.

Table B.1 — Reference mass, m_{ref}, for different populations

<table>
<tr><th rowspan="2">Field of application</th><th>m_{ref}</th><th colspan="3">Percentage of user population protected</th><th colspan="2" rowspan="2">Population group</th></tr>
<tr><th>kg</th><th>F and M</th><th>F</th><th>M</th></tr>
<tr><td rowspan="2">Non-occupational use</td><td>5</td><td colspan="3">Data not available</td><td>Children and the elderly</td><td rowspan="2">Total population</td></tr>
<tr><td>10</td><td>99</td><td>99</td><td>99</td><td>General domestic population</td></tr>
<tr><td rowspan="4">Professional use</td><td>15</td><td>95</td><td>90</td><td>99</td><td rowspan="2">General working population</td><td rowspan="4">Working population</td></tr>
<tr><td>20</td><td>90 to 95</td><td>85</td><td>99</td></tr>
<tr><td>23</td><td>90</td><td>75</td><td>99</td><td rowspan="2">Adult working population</td></tr>
<tr><td>25</td><td>85</td><td>70 to 75</td><td>95 to 99</td></tr>
</table>

Key

F female

M male

NOTE 1 The reference mass of 23 kg has been used most often in the NIOSH lifting equation and has been found to be protective for at least 99 % of healthy male workers and at least 75 % of healthy female workers at LI = 1,0.

NOTE 2 Data on the percentage of user population protected derive from different studies they represent as representative mean results[10],[14],[24]–[26],[31],[42].

B.2 Special considerations

In order to lower the risk for people at work, particularly those with less physical capability, the recommended limit for mass should not exceed 15 kg. This increases the level of health protection afforded to the working population by up to 95 %. In this instance, a reference mass of 15 kg instead of 25 kg should be used in Formula (C.1) (see C.1.3.3).

As workplaces are expected to be accessible to everyone within the working population, exceeding the recommended limit mass of 25 kg should be regarded as an exception. When exceeding the recommended limits, working conditions must remain safe. In these cases, it is especially important that workers are well trained and instructed for these specific tasks.

B.3 Age and gender considerations

In circumstances where age and gender need to be more specifically considered (beyond the intent of Table B.1) in the general healthy working population, the reference masses in Table B.2 can be adopted.

Table B.2 — Suggested reference masses, m_{ref}, considering gender and age, in the general healthy working population[18],[31],[38],[39],[42],[43]

Working population by gender and age	Reference mass m_{ref}
Females (aged 20 to 45)	20 kg
Females (aged < 20 or > 45)	15 kg
Males (aged 20 to 45)	25 kg
Males (aged < 20 or > 45)	20 kg
NOTE Table B.2 is included in step 1.	

Annex C
(informative)

Assessment method for recommended limits for mass, frequency and object position

C.1 Assessment method for recommended limits for mass, frequency and object position

C.1.1 Recommended mass limit

The RML is the mass of a load that nearly all people in a specific population of people can handle over a substantial period of time without an increased risk of developing lifting-related lower back pain. The formula used to derive the RML [Formula (C.1)] is a product of multipliers assigned to various conditions (variables) present in the handling task. Formula (C.1) and the multipliers are described in detail in this annex.

C.1.2 Non-repetitive lifting tasks

The mass of an object or the working postures used to manipulate the load in non-repetitive lifting tasks can lead to health risks. Masses which are higher than the reference mass (Annex B), and unfavourable postures like a bent or twisted trunk or a far reach, should be avoided.

To estimate the influence of an unfavourable posture, use a frequency multiplier of “1” in the risk-assessment model formula [Formula (C.1)]. The horizontal multiplier indicates the severity of a possible far reach; vertical, distance and asymmetry multipliers show the negative influence of a twisted or bent trunk.

C.1.3 Repetitive lifting tasks

C.1.3.1 Assumptions

The recommended limits are derived from a model assuming that:

— they are only valid for smooth lifting with no sudden acceleration effects (i.e. jerking);

— they cannot be used for tasks where the worker is partly supported (e.g. one foot not on the floor);

— the width of the object 0,75 m or less;

— they are only valid for unrestricted lifting postures;

— they are only valid when good coupling exists (i.e. hand holds are secure and shoe or floor slip potential is low);

— they are only valid under favourable conditions (see Table 4 for details).

C.1.3.2 Primary task variables

The primary task variables include the following information (see also Table C.1):

— RML;

— object mass, *m*, in kilograms;

— horizontal distance, *h*, in metres, measured from the mid-point of the line joining the ankles to the centre of gravity of the object grasped.

NOTE The location of the centre of mass of the object is approximately the vertical projection of the midpoint of the line between the hands at the grasping location in a two-handed operation or by the vertical projection of the hand grasping the object in a one-handed operation. The location of the centre of the mass of the worker is approximately the midpoint of the line between the inner points of the ankles.

— vertical location, *v*, in metres, determined by measuring the distance from the floor to the point at which the hands grasp the object;

— vertical travel displacement, *d*, in metres, from origin to destination of lift;

— frequency of lifting, *f*, expressed as average number of lifts per minute;

— duration of lifting, in hours or, alternatively, in minutes;

— angle of asymmetry, *α*, in degrees;

— quality of gripping, *c*;

— one-handed operation, *o*;

— two-persons operation, *p*;

— extended (more than 8 h) manual handling time, *e*, in hours.

C.1.3.3 Recommended mass limit formula and multipliers

The first step towards the assessment of the acceptability (safety) of a lifting task is to compare the mass of the object being handled, *m*, with the RML.

If $m \leq$ RML, it is a recommended condition.

If $m >$ RML, it is not a recommended condition. In these cases, calculate an LI (Annex D), assess the level of exposure and establish priorities according to Table D.1.

The RML is derived using Formula (C.1) which considers the impact of each task variable. These are represented in the formula by "multipliers" ($_M$) as follows:

$$\text{RML} = m_{ref} \times h_M \times v_M \times d_M \times \alpha_M \times f_M \times c_M \times [o_M \times p_M \times \varepsilon_M] \quad \text{(C.1)}$$

where

m	is the lifted object mass;
m_{ref}	is the reference mass for the identified user population group (Tables B.1 and B.2);
h_M	is the horizontal distance multiplier, derived from Formula (C.2);
v_M	is the vertical location multiplier, derived from Formula (C.3);
d_M	is the vertical-displacement multiplier, derived from Formula (C.4);
α_M	is the asymmetry multiplier, derived from Formula (C.5) (see also Figure C.1);
f_M	is the frequency multiplier (see Table C.2);
c_M	is the coupling multiplier for the quality of gripping (see Table C.3);

o_M is the one-handed operation *additional* multiplier, to be used for lifts performed with only one hand; if true, o_M = 0,6; otherwise, o_M = 1,0 (see also C.1.4);

p_M is the two or more person *additional* multiplier to be used when two or more persons perform the same lift; if true, p_M = 0,85; otherwise, p_M = 1,0 (see also C.1.5);

e_M is the extended time *additional* multiplier to be used when manual handling is performed for more than 8 h per shift; if true, see C.1.6 and Table C.5; otherwise, e_M = 1,0.

See Table C.1 for an illustration of the factors and multipliers.

The multipliers for Formula (C.1) are obtained from Formulae (C.2) to (C.5) and Tables C.2 to C.5. If a multiplier in Formulae (C.2) to (C.5) exceeds a value of 1, its value should be taken as 1.

$$h_M = \frac{0,25}{h} \tag{C.2}$$

If h < 0,25, then h_M = 1.

If h > 0,63, then h_M = 0.

$$v_M = 1 - 0,3 \times |0,75 - v| \tag{C.3}$$

If v > 1,75, then v_M = 0.

If v < 0, then v_M = 0.

$$d_M = 0,82 + \frac{0,045}{d} \tag{C.4}$$

If d > 1,75, then d_M = 0.

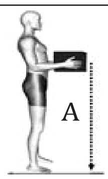
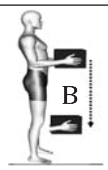
If d < 0,25, then d_M = 1.

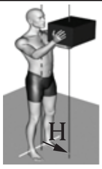
$$\alpha_M = 1 - 0,003\ 2 \times \alpha \tag{C.5}$$

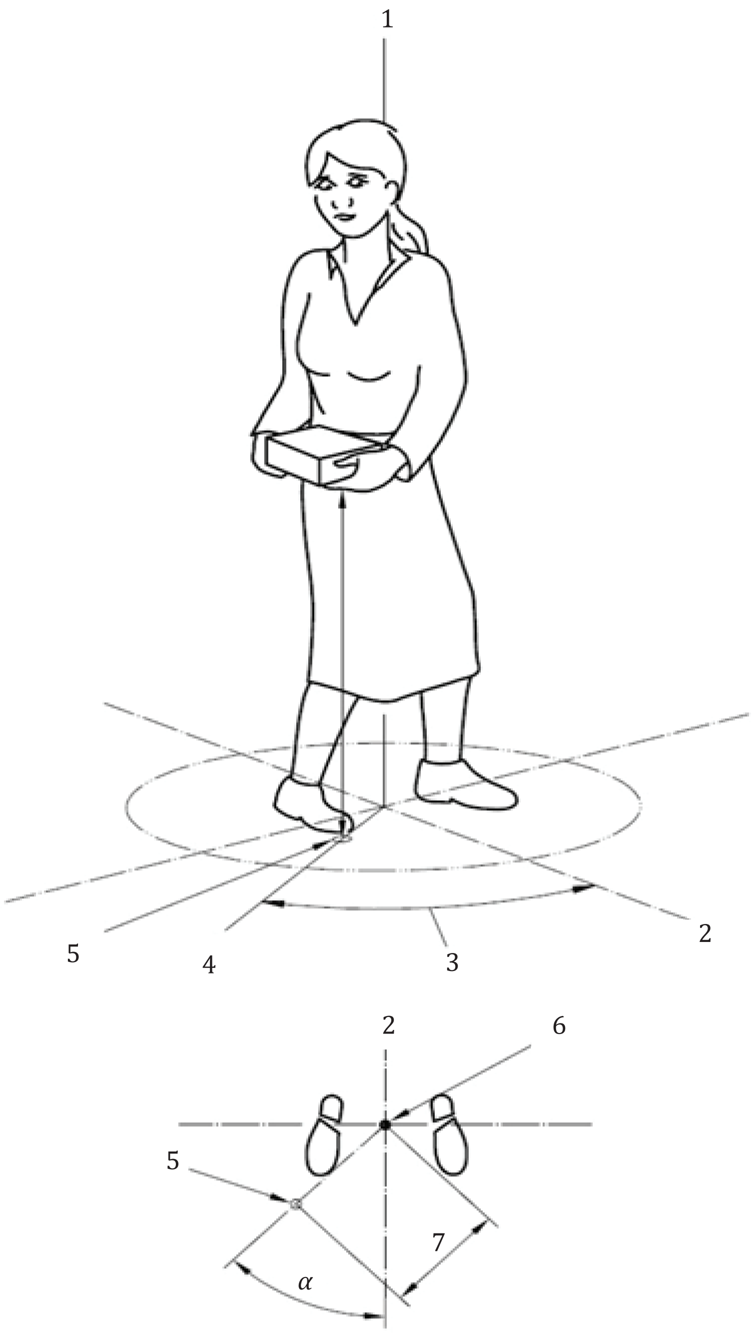
If α > 135, then α_M = 0.

Additional multipliers concerning frequency, one-handed lifting, team lifting and extended handling time are provided in C1.4 to C1.6.

Table C.1 — Main task variables in the RML formula

Task variable symbol	Task variable		Task variable description
m_{ref}	Reference mass		Maximum recommended mass under reference conditions for manual handling
v_M	Vertical multiplier		Distance of the hands from the floor at the start or end of lifting (A)
d_M	Distance multiplier		Vertical distance of the load between the beginning and the end of lifting (B)

Task variable symbol	Task variable		Task variable description
h_M	Horizontal multiplier		Maximum distance between the load and the body during lifting (H)
α_M	Asymmetry multiplier		Angular measure of displacement of the load from the mid-sagittal plane (angle α)
c_M	Coupling multiplier		Assessment of grip of the object (from Table C.3)
f_M	Frequency multiplier		Frequency of lifts per minute and duration (from Tables C.2 and C. 4)
o_M	One-hand multiplier		Lifting by only one hand (from C.1.4)
p_M	Team lifting multiplier		Lifting by two or more operators (from C.1.5)
e_M	Extended time multiplier		Manual handling lasting more than 8 h per shift (from C.1.6 and Table C.5)



Key

1 vertical
2 mid-sagittal plane
3 asymmetry angle (α)
4 asymmetry line along the plane of asymmetry
5 projection from centre of gravity of load
6 mid-point between inner ankle bones
7 horizontal distance (from 6 to 5)

Figure C.1 — Angle of asymmetry

The RML formula needs to be calculated for the start-point of each task. If there is a definite precision placement involved at the end then end-point calculations will possibly be necessary. In these cases, the lower RML value (between the start and end points) should be used in the analysis and for the computation of the LI (Annex D). If the item is thrown or dropped into place without undue stress on the body in the extended position, then calculating the end-point value is not strictly necessary.

C.1.3.4 Asymmetry multiplier

To decide if an asymmetry multiplier < 1 should be assigned, observe the “primary” working position of the worker both at the origin and the destination of the lift. If the mid-sagittal plane coincides with the plane of asymmetry both at the origin and at the destination (the object is always in front of the body in the primary position and the worker uses their feet to change the primary position from origin to destination), then there is no asymmetry ($\alpha_M = 1$). If the worker cannot use their feet to change the primary position (for lack of adequate space or for high frequencies), then consider the angle of asymmetry both at origin and destination.

C.1.3.5 Frequency multiplier

The appropriate frequency multiplier, f_M, is determined first by considering the continuous duration of the repetitive lifting task and then considering the duration of the recovery period that immediately follows the repetitive lifting task. The recovery period is defined as the duration of light physical work following a period of continuous lifting. Examples of light work include activities such as sitting at a desk, monitoring operations and light assembly work. Manual handling activities other than lifting (i.e. whole body pushing and pulling) should not be considered as recovery periods.

The categories of continuous, repetitive lifting tasks, their durations and the required duration of the recovery period that is to immediately follow the lifting task are provided in Table C.2.

It is critical to note that the combination of the work period and the recovery period shall be jointly considered to be a work-recovery cycle, wherein the recovery period provides sufficient opportunity for the worker to recover following a continuous period of lifting-related work. Accordingly, if two successive work periods are separated by a recovery period of inadequate duration, then the worker cannot adequately recover and the entire period (the two work periods plus the recovery period) shall be treated as if it were a single, continuous work period. The impact of such circumstances is to make the resultant work period substantially longer, resulting in the value for the frequency multiplier, f_M, being lowered.

The value of f_M is then determined from Table C.3 The use of Table C.3 requires three components of information:

— the frequency of lifting (number of lifts per minute);

— the duration, t_L, of the continuous, repetitive lifting task (note that the determination of the frequency multiplier is based on the three duration categories: <1 h, 1 h to 2 h and > 2 h);

— the vertical location, v, of the hands on the object to be lifted at the beginning of the lift.

C.1.3.6 Coupling multiplier

Coupling, or the quality of gripping (Table C.4), is defined as follows:

— Good: if the object can be grasped by wrapping the hand comfortably around the object or handles or hand-hold cut-outs of the object, or the object itself, without significant deviations from the neutral wrist posture. An optimal handle design has a diameter of 1,9 cm to 3,8 cm, a length of ≥ 11,5 cm, a cylindrical shape and a smooth, non-slip surface[56].

— Fair: if the object has handles or cutouts that do not fulfil the criteria of good quality of gripping or if the object itself can be grasped with a grip in which the hand can be flexed by about 90°.

— Poor: if the criteria of good or fair quality of gripping are not fulfilled or the object is bulky, hard to handle or has sharp edges.

Table C.2 — Continuous lifting tasks and their required recovery periods

Categories	Duration, t	Required recovery period
Short duration	$t \leq 1$ h	100 % of duration of the continuous, repetitive lifting task[51]
Medium duration	1 h < $t \leq 2$ h	30 % of duration of the continuous, repetitive lifting task
Long duration	2 h < $t \leq 8$ h	No amount is specified; normal morning, afternoon and lunch breaks are presumed
NOTE For respective frequency multipliers see Table C.3.		

Table C.3 — Values of frequency multiplier, f_M, of Formula (C.1)

Frequency of lifting	Values of f_M					
Number of lifts per minute	$t_L \leq 1$ h		1 h < $t_L \leq 2$ h		2 h < $t_L \leq 8$ h	
	v < 0,75 m	$v \geq$ 0,75 m	v < 0,75 m	$v \geq$ 0,75 m	v < 0,75 m	$v \geq$ 0,75 m
≤ 0,2	1,00	1,00	0,95	0,95	0,85	0,85
0,5	0,97	0,97	0,92	0,92	0,81	0,81
1	0,94	0,94	0,88	0,88	0,75	0,75
2	0,91	0,91	0,84	0,84	0,65	0,65
3	0,88	0,88	0,79	0,79	0,55	0,55
4	0,84	0,84	0,72	0,72	0,45	0,45
5	0,80	0,80	0,60	0,60	0,35	0,35
6	0,75	0,75	0,50	0,50	0,27	0,27
7	0,70	0,70	0,42	0,42	0,22	0,22
8	0,60	0,60	0,35	0,35	0,18	0,18
9	0,52	0,52	0,30	0,30	0,00	0,15
10	0,45	0,45	0,26	0,26	0,00	0,13
11	0,41	0,41	0,00	0,23	0,00	0,00
12	0,37	0,37	0,00	0,21	0,00	0,00
13	0,00	0,34	0,00	0,00	0,00	0,00
14	0,00	0,31	0,00	0,00	0,00	0,00
15	0,00	0,28	0,00	0,00	0,00	0,00
> 15	0,00	0,00	0,00	0,00	0,00	0,00

Table C.4 — Coupling multiplier (c_M) for the quality of gripping

Quality of gripping	Values of c_M	
	h < 0,75 m	$h \geq$ 0,75 m
Good	1,00	1,00
Fair	0,95	1,00
Poor	0,90	0,90

C.1.4 Lifting one-handed

When the lifting is performed one-handed, add the one-hand multiplier (o_M) to Formula (C.1) to calculate the RML.

o_M = 0,6[10],[14],[18],[28],[33],[36]

C.1.5 Lifting by two or three people

When the lifting action is performed by two or three people, the RML for each person should be derived by using the true lifted mass, m_A, dividing by two or three (according to the number of people lifting) and adding the persons multiplier, p_M, to Formula (C.1). Adding this multiplier allows the RML for each person in a lifting team to be calculated.

$p_M = 0{,}85$[10].

C.1.6 Handling for more than 8 h per shift

When manual handling activities are performed for more than 8 hours per shift, another multiplier, e_M, should be added to Formula (C.1) using the information provided in Table C.5.

Table C.5 — Extended time multiplier, e_M, for manual handling tasks lasting more than 8 h per shift[18],[43]

Hours (with MMH) in the shift	≤ 8	8 to 9	9 to 10	10 to 11	11 to 12
e_M (extended time multiplier)	1	0,97	0,93	0,89	0,85
NOTE Only apply to RML calculation when the frequency is ≥ 0,2 lifts per minute and a long duration scenario is present (from Table C.2).					

Annex D
(informative)

Lifting index

D.1 Calculating the lifting index and its derivatives

The LI is the ratio of the object mass (m) to the RML for a particular lifting condition [see Formula (D.1)]. It provides an indication of the level of exposure to overall physical demands for repetitive lifting activities. It can be used to compare risks across different lifting tasks.

$$LI = m/RML \quad (D.1)$$

If LI ≤ 1, it is an acceptable condition.

If LI > 1, assess the level of exposure and establish priorities (see Table D.1).

The above equation for the LI is derived to include three additional metrics: the composite lifting index (CLI), the sequential lifting index (SLI) and the variable lifting index (VLI) (see Annex F for detailed calculation methods).

D.2 Interpretation of the LI and its derivatives

The LI and its derivatives (CLI, SLI and VLI) indicate the level of exposure to overall physical demands for repetitive lifting activities. Table D.1 provides information on exposure levels related to different LI values, as well as their interpretation (based on current scientific literature) and some possible recommended actions. See Annex I for a discussion on exposure and risk[61].

Depending on task specifics, the analyst can supplement the lifting analysis with additional analyses for low back loading. This can be desirable where extreme postures or movements are used in the lifting tasks, or for establishing metabolic demands of all of the tasks involved.

Table D.1 — Interpretation of LI (m_A/RML) values

LI value	Exposure level/risk implication	Recommended actions[a]
LI ≤ 1,0	Very low	None in general for the healthy working population.
1,0 < LI ≤ 1,5	Low	In particular pay attention to low frequency/high load conditions and to extreme or static postures. Include all factors in redesigning tasks or workstations and consider efforts to lower the LI values < 1,0.
1,5 < LI ≤ 2,0	Moderate	Redesign tasks and workplaces according to priorities to reduce the LI, followed by analysis of results to confirm effectiveness.
2,0 < LI ≤ 3,0	High	Changes to the task to reduce the LI are a high priority.

[a] To be used in conjunction with considerations outlined in the Introduction and Annex A regarding general use of ergonomics principles and approaches that should be used at all workplaces.

Table D.1 *(continued)*

LI value	Exposure level/risk implication	Recommended actions[a]
LI > 3,0	Very high	Changes to the task to reduce the LI are needed immediately.
For any level of risk or exposure	Identify any workers who have special needs or vulnerabilities in lifting tasks and assign or design the work accordingly. Training workers on safe manual handling methods and recognizing material handling hazards is beneficial. Limiting the weight to be lifted to less than the reference mass may also be considered.	

[a] To be used in conjunction with considerations outlined in the Introduction and Annex A regarding general use of ergonomics principles and approaches that should be used at all workplaces.

Annex E
(informative)

Simplified model for RML and LI calculation

E.1 Simplified model for calculating recommended mass limit and lifting index

The RML and LI can be calculated using a simplified approach (pen and paper) without manually calculating the main multipliers with Formulae (C.1) to (C.5), but by deriving them from tables instead.

For this simplified risk evaluation, the procedure shown in Figure E.1 provides the quantitative values for each influencing factor, next to the relative multiplier. When the numerical value does not correspond to the one indicated in Figure E.1, use the closest number and corresponding multiplier. Alternatively, find the closest interpolation. By applying the procedure in Figure E.1 to all the factors (and multipliers) considered, it is possible to determine the RML for each job.

The next step is to enter the weight actually lifted (numerator) versus the RML (denominator) to obtain the LI.

The LI is obtained by calculating the RML first [i.e. entering the appropriate reference mass (25 kg, 23 kg, 20 kg or 15 kg) and the various multipliers]. The actual weight of the object being lifted is then divided by the RML, thereby showing the LI.

NOTE See Table C.5 for discount factors for working durations of over 8,0 h.

CALCULATION OF THE RECCOMMENDED MASS LIMIT AND OF THE LIFTING INDEX

COMPANY AREA WORKPLACE TASK	DATE OBSERVER

REFERENCE MASS (kg.)

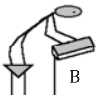
	MALES	*FEMALES*	NIOSH ORIGINAL
20-45 YEARS	25	20	23
<20 and >45 YEARS	20	15	

	mref
X	X

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

height (cm)	*0*	*10*	*20*	*30*	*40*	*50*	*60*	*70*	*75*	*80*
MULTIPLIER	0,78	0,81	0,84	0,87	0,90	0,93	0,96	0,99	1,00	0,99
height (cm)	*90*	*100*	*110*	*120*	*130*	*140*	*150*	*160*	*175*	*>175*
MULTIPLIER	0,96	0,93	0,90	0,87	0,84	0,81	0,78	0,75	0,70	0,00

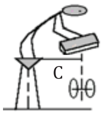
	vM
X	X



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

distance (cm)	*≤ 25*	*40*	*55*	*70*	*85*	*100*	*170*
MULTIPLIER	1,00	0,93	0,90	0,88	0,87	0,87	0,86
distance (cm)	*115*	*130*	*145*	*160*	*175*	*>175*	
MULTIPLIER	0,86	0,86	0,85	0,85	0,85	0	

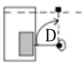
	dM
X	X



Horizontal distance between the load C. of G. and the body C. of G. during lifting

distance (cm)	*≤ 25*	*28*	*30*	*32*	*34*	*36*	*38*	*40*	*42*	*44*
MULTIPLIER	1,00	0,89	0,83	0,78	0,74	0,69	0,66	0,63	0,60	0,57
distance (cm)	*46*	*48*	*50*	*52*	*54*	*56*	*58*	*60*	*63*	*>63*
MULTIPLIER	0,54	0,52	0,50	0,48	0,46	0,45	0,43	0,42	0,40	0,00

	hM
X	X



Angular measure of displacement of the load from the sagittal plane

angle in degrees	*0°*	*15°*	*30°*	*45°*	*60°*	*75°*	*90°*	*105°*	*135°*	*>135°*
MULTIPLIER	1,00	0,95	0,90	0,86	0,81	0,76	0,71	0,66	0,57	0,00

	αM
X	X

Assessment of quality of grip of the object (coupling)

Assessment	*GOOD*	*FAIR*	*POOR*
MULTIPLIER	1,00	0,95	0,90

	cM
X	X

Frequency of lifts per minute in relation to duration

FREQUENCY LIFTS/MIN.	LIFTING TASK DURATION (CONTINUOUS) ≤ 8 HOURS (LONG)	≤ 2 HOURS (MEDIUM)	≤ 1 HOUR (SHORT)
<0,1	1,00	1,00	1,00
≤0,1 to <0,2	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
MULTIPLIERS FOR AREAS < 75 CM			

	fM
X	

	NO	YES
LIFT WITH ONE ONLY UPPER LIMB	1,00	0,60
LIFT BY 2 OR MORE OPERATORS	1,00	0,85

	oM
X	

	pM

WEIGHT EFFECTIVELY LIFTED(Kg.)		Kg.	RECCOMMENDED MASS LIMIT		Kg.

	LIFTING INDEX (LI)
LIFTED WEIGHT ――――― RECOMMENDED MASS	

Figure E.1 — Simple model for the RML and LI evaluation in single lifting tasks

Annex F
(informative)

Multi-task manual lifting

F.1 General aspects

Jobs which involve single-task lifting are different from multi-task lifting jobs. The task variables in single-task lifting jobs do not vary significantly from task to task or from lift to lift, whereas in multi-task lifting jobs they do.

Multi-task lifting jobs are more difficult to analyse than single task jobs, as each task needs to be analysed separately and as a group. The method used to study tasks as a group shall avoid averaging out good and bad task variables and other potential inaccuracies. There are additional analysis complications if the multi-task job involves the lifting of a large variety of objects or if there is a sequential handling of objects due to job rotation or other variations in work patterns.

The following criteria are to be used when defining task characteristics for the purpose of analysing lifting tasks:

— Single (or mono) tasks 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 layout at origin and destination. In this case, or if only one lift is of interest, the traditional LI calculation can be used (Annex D). Although this type of lifting task is not common, it is the basis for the calculations and procedures used for more complicated and variable lifting or lowering tasks.

— Multiple composite tasks are defined as tasks involving lifting objects (generally of the same kind and mass) and collecting and positioning them from or to various different heights, depths or both. Object location is one of the variables considered in the analysis of a lifting task. Practically each individual location of the object's placement is a new task variant and is considered to be a subtask in this type of analysis. In this case, the composite lifting index (CLI) calculation is applied[56]. No more than 10 subtasks should be used in this calculation (Figure F.2). The variable lifting index (VLI) is suggested for assessing jobs with more than 10 subtasks.

— Multiple variable tasks are defined as lifting tasks in which both the locations and load mass vary in different lifts performed by the worker(s) within (or during) the same period of time (Figure F.3). The VLI is suggested for assessing these complex types of lifting tasks[18],[55].

— A sequential task (Figure F.4, Table F.1) is defined as a job in which the worker rotates between two or more mono tasks, 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) calculation can be used[18],[53].

Figure F.1 gives criteria for the use of the different approaches outlined here when analysing different handling tasks.

NOTE The interpretation criteria for LI reported in Table D.1 are also valid for interpreting CLI, VLI and SLI results.

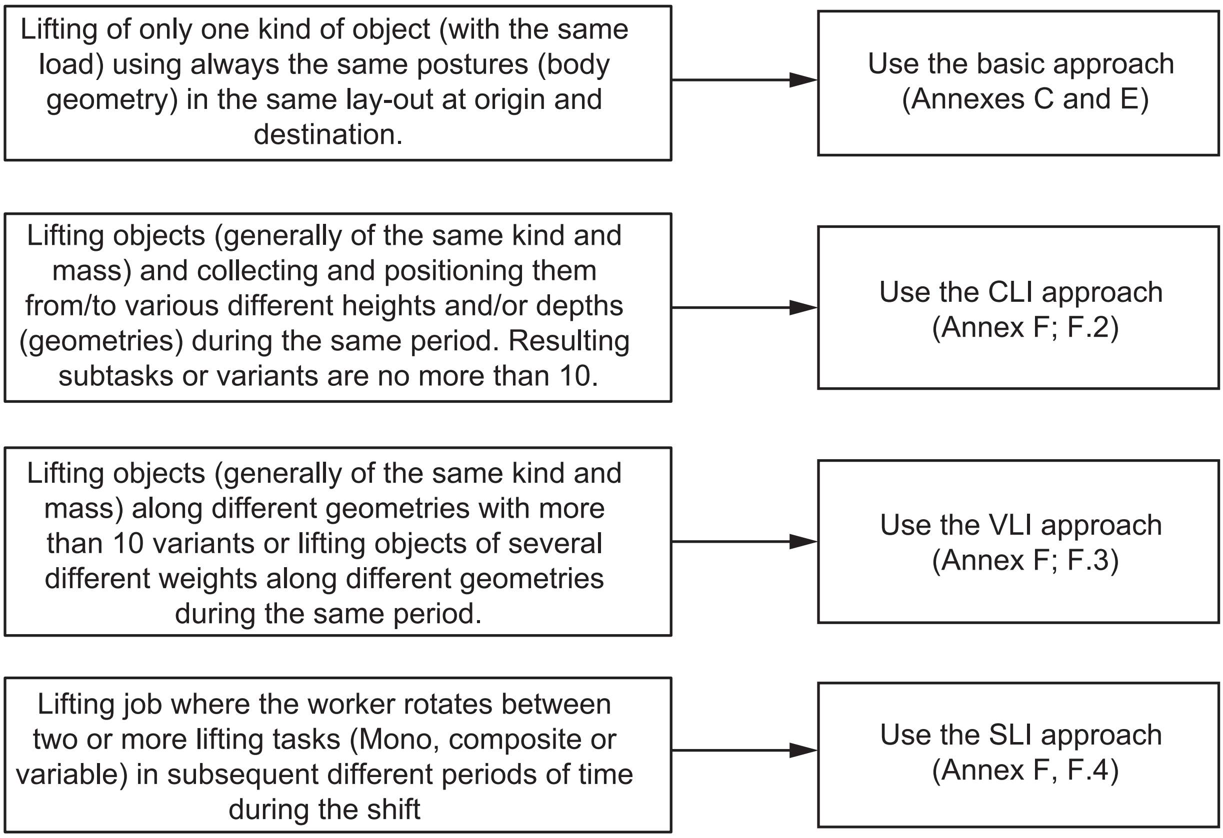
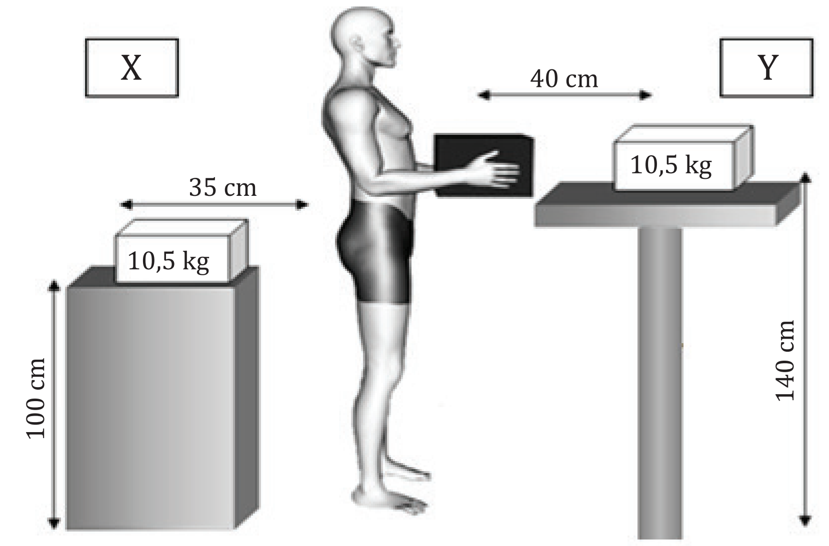
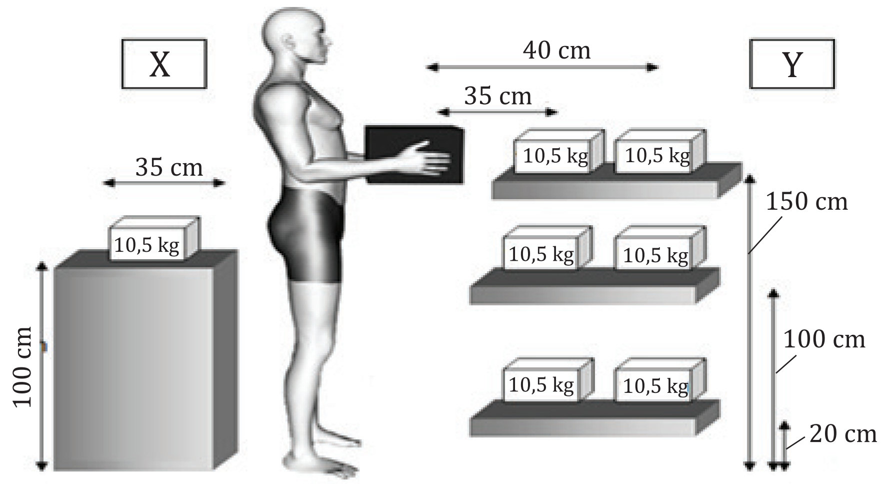


Figure F.1 — Different types of lifting tasks and consequent computation approaches



a) Single task



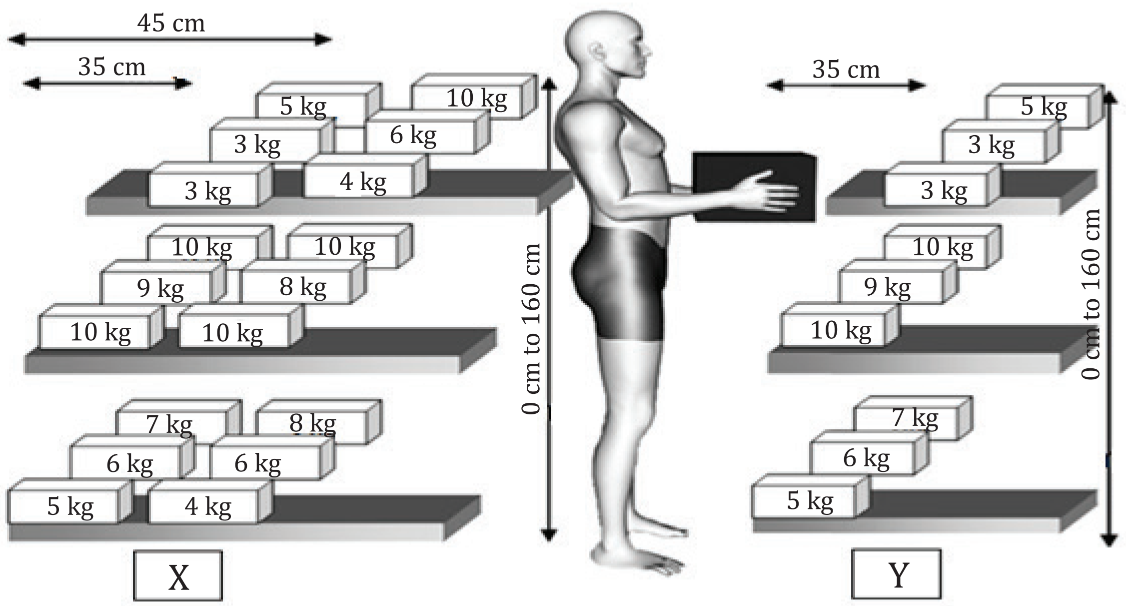
b) Composite task

Key

x origin

y destination

Figure F.2 — Single and composite tasks

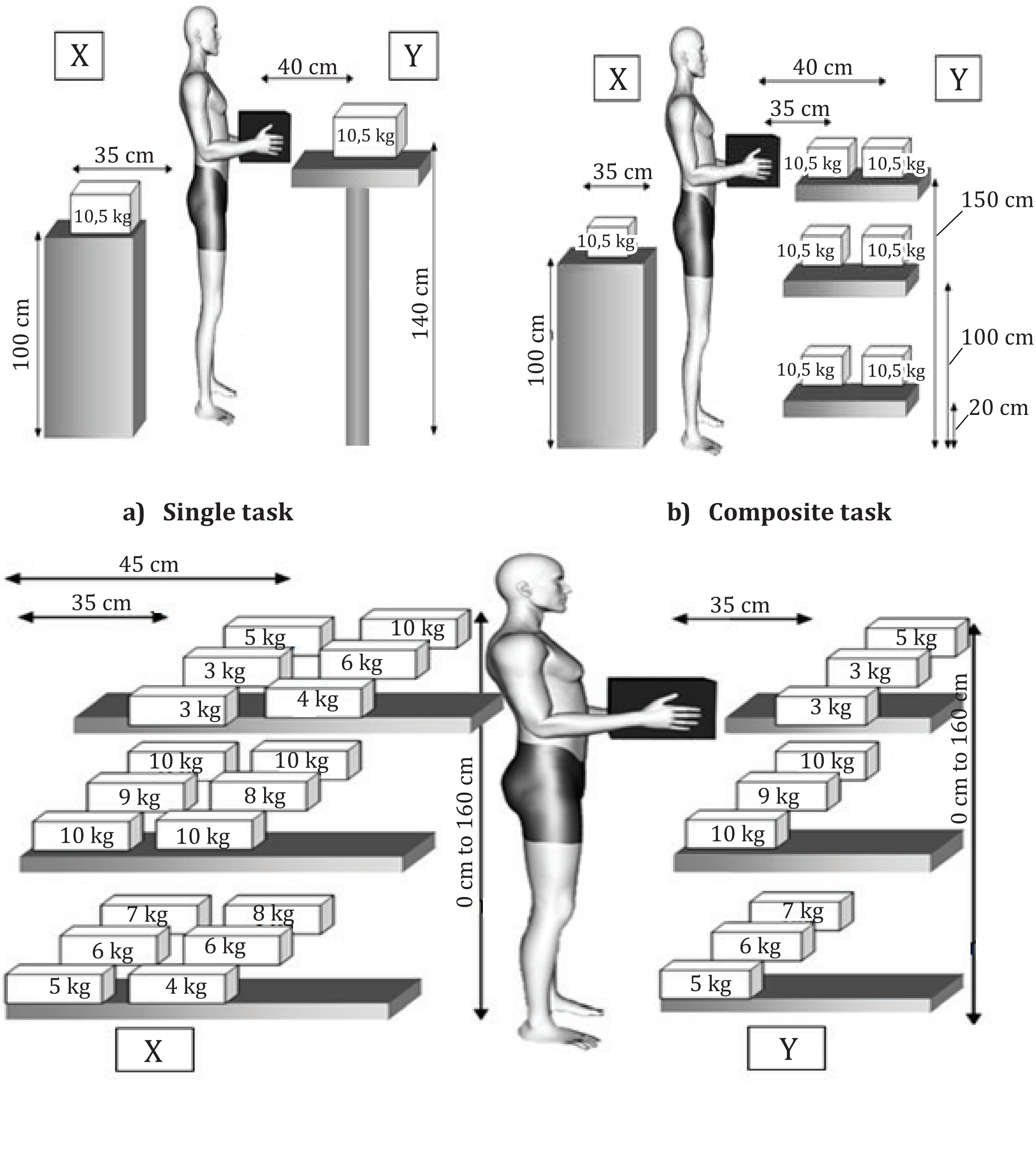


Key

x origin

y destination

Figure F.3 — Variable task



c) Variable task

Key

x origin

y destination

Figure F.4 — Sequential task as a combination of a single, composite and variable task

Table F.1 — Sequential task: example of duration and distribution of tasks of Figure F.4 in a 480-min shift

Single task	Compos-ite task	Break	Compos-ite task	Variable task	Lunch	Variable task	Break	Compos-ite task	Single task
45 min	75 min	10 min	45 min	65 min	65 min	125 min	10 min	60 min	45 min

F.2 Composite lifting tasks and CLI

Where composite lifting tasks are performed, i.e. tasks where the weights are the same but they are moved to several different locations (e.g. height, depth) (Figure F.2) or where few different weights are moved over a variety of heights, depths or both, every variant of location is defined as a subtask.

In such cases, it is recommended that the CLI[52] is calculated using Formula (F.1), which represents the collective demand for that task or job. It is equal to the sum of the largest single (sub)task lifting index (STLI) and the incremental increase in the CLI as each subsequent subtask is added. The incremental increase in the CLI for a specific subtask is defined as the difference between the STLI of that subtask at the cumulative frequency for all the subtasks and the STLI of the same subtask at its own actual frequency.

$$\mathrm{CLI} = \mathrm{LI}_1 + \sum \Delta\, \mathrm{LI}_n \qquad \text{(F.1)}$$

where

$$\sum \Delta LI_n = (FILI_2 X\ (\frac{1}{FM_{1,2}} - \frac{1}{FM_1}))$$

$$+\ (FILI_3 X\ (\frac{1}{FM_{1,2,3}} - \frac{1}{FM_{1,2}}))$$

$$+\ (FILI_4 X\ (\frac{1}{FM_{1,2,3,4}} - \frac{1}{FM_{1,2,3}}))$$

$$+\ (FILI_n X\ (\frac{1}{FM_{1,2,3,4,\ldots,n}} - \frac{1}{FM_{1,2,3,\ldots,(n-1)}}))$$

NOTE 1 The numbers in subscript refer to the new LI task in order of relevance.

NOTE 2 The FM values are determined from the frequency Table C.3.

Steps for the CLI calculation:

— Calculate the frequency-independent recommended mass limit (FIRML), i.e. the RML without considering the frequency/duration multiplier, and the single task recommended mass limit (STRML) for each subtask as in single task analysis.

— Calculate consequently the frequency-independent lift index (FILI) and single task lift index (STLI) for each subtask.

— Renumber the subtasks in order of decreasing STLI values.

— Calculate the composite lifting index (CLI) for the overall lifting task or job.

Subtasks are defined in relation to variants of weight and geometries (e.g. vertical height, horizontal distance). Consider a task where a worker removes objects of the same weight from three shelves of different heights and places them on a conveyer belt of constant height. At each of the three shelf heights, there are two different distances from the body. Therefore, there are six subtasks (three heights × two horizontal distances) which are treated like six single tasks. Each single task shall first be evaluated separately and then the CLI is estimated.

To accurately calculate the CLI, there shall not be more than 10 subtasks, since the overall frequency has to be divided by the number of subtasks. If there are more than 10 subtasks, the final result can be unreliable[47],[48]. In cases where the number of subtasks exceeds 10, it is recommended that the simplified procedures of the variable lifting task are used to calculate the VLI.

F.3 Variable lifting tasks and VLI

F.3.1 General

A 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) during the same period of time[18],[55].

Examples of this category of task can include lifting in warehouse operations, baggage handling and small lot material delivery in assembly line manufacturing operations.

The variables that increase the number of subtasks in composite or variable tasks can be large and lead to long analysis times and errors. The original formula for composite lifting tasks discourages the use of more than 10 variables (subtasks). Hence, simplifications are needed for allowing analysis of such complex lifting tasks.

The concept for the VLI is similar to that of the composite lift index (CLI). However, in the VLI calculation, individual lifting tasks (subtasks) are grouped together into defined frequency-independent lift index (FILI) categories. These FILI categories are then treated as if they were individual lifts in the CLI calculation. Although as many as nine FILI categories can be used, it is suggested that six categories be used for ease of use.

F.3.2 Calculating VLI

The following general procedure for calculating VLI is suggested.

Whatever 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 five object (weight) categories.

— Classify the vertical location into two categories (good; bad).

— Classify the horizontal location into up to three categories (near; medium; far).

— Assess the presence or absence of asymmetry for each weight category (by threshold value for all the lifts in the category).

— Classify the daily duration of lifting as in Table C.2.

— Determine or estimate the frequency of lifts for each subtask and FILI. Determine the frequency multipliers (f_M) as in Table C.3.

— Consider both vertical displacement (DM) and coupling (CM) as a constant.

In the end it is possible to calculate individual FILI and STLI for up to 30 subtasks.

The resulting FILIs are then fitted into six 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 CLI to obtain the VLI for a variable lifting task. The procedure maintains the original criteria reported in Annex C via simplifications in data collection.

F.3.3 Calculating CLI (for a composite task with more than 10 subtasks) and VLI for variable tasks

The procedure is based on a systematic assessment of the job using existing job and task data (for durations, weights, workstation design and overall and partial frequencies) or probability distribution data (for geometries and sub partial frequencies). The assessment requires knowledge of the total duration of the lifting tasks during the work shift, number and weight of the different objects lifted, number of workers who do the lifting, total and partial frequency of lifts and the work/recovery pattern for the job.

a) Identify the mass (from 3 kg up to maximum, by increments of 1 kg) and the number of objects lifted in a shift. The recorded weight of the masses is aggregated into a maximum of five weight categories by dividing the span of weight values (i.e. maximum value – minimum value) by five to determine the minimum and maximum for each category. A representative average (by frequency) mass is selected for each category.

From the data collected (e.g. number of workers involved in the task(s), net duration of 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) and the lifting frequency per each mass category.

b) Simplify the geometry variables according to these criteria:

— Vertical location (height of hands at lifting origin or destination). This variable is reduced to 2 areas:

  — ideal area (good): hands are between 51 cm and 125 cm vertical height. The vertical multiplier, v_M, is equal to 1;

  — non-ideal areas (low or high): hands are at or below 50 cm or above 125 cm (up to 175 cm) vertical height. The vertical multiplier, v_M, is equal to 0,78.

  In cases where the vertical height exceeds the maximum recommended vertical height (>175 cm), the lift is considered unsafe.

— Horizontal location (maximum hand grasp point away from the body during lifting). The horizontal distances are simplified into 3 areas:

  — near: horizontal distance is within 25 cm to 40 cm. The representative horizontal multiplier, h_M, is equal to 0,71 (for a representative value of 35 cm);

  — mid: horizontal distance is within 41 cm to 50 cm. The representative horizontal multiplier, h_M, is equal to 0,56 (for a representative value of 45 cm);

  — far: horizontal distance is within 51 cm to 63 cm. The representative horizontal multiplier, h_M, is equal to 0,40 (for a representative value of 63 cm).

  In cases where the horizontal distances exceed the maximum recommended value (>63 cm), the lifts are considered unsafe (no calculation is possible).

— Asymmetry (angular displacement of loads off to the side of the body): asymmetry is considered collectively for each weight category. An asymmetry multiplier, α_M, of 0,81 is assigned to all the subtasks in a weight category if asymmetry of 45° or more is observed for over 50 % of lifting actions in that category. Otherwise, the asymmetry multiplier is set to 1.

— Vertical travel distance (vertical distance between the height of hands at origin and at destination): the contribution of this factor has been considered as non-influent. The corresponding multiplier, d_M, has thus been taken as a constant, equal to 1. Even if the vertical distance multiplier, d_M, is set as a constant, the height of the hands at both the origin and destination of the lift should always be measured and considered.

— Coupling (quality or type of grip): the contribution of this factor has also been defined as constant. Experience has taught that ideal couplings are very rare, so the corresponding multiplier, c_M, is defined as a constant equal to 0,90.

By adopting these simplifications and procedures, it is possible to analyse a variable lifting task scenario and produce up to (and no more than) 30 sets of FILI and STLI values, one for each of 30 different subtasks (five weight categories × two vertical location × three horizontal areas × one asymmetry condition) (Figure F.5).

For each of these subtasks, an individual frequency of lifting is calculated or estimated by a statistical approach and the subsequent frequency multiplier, f_M, is derived from Table C.3.

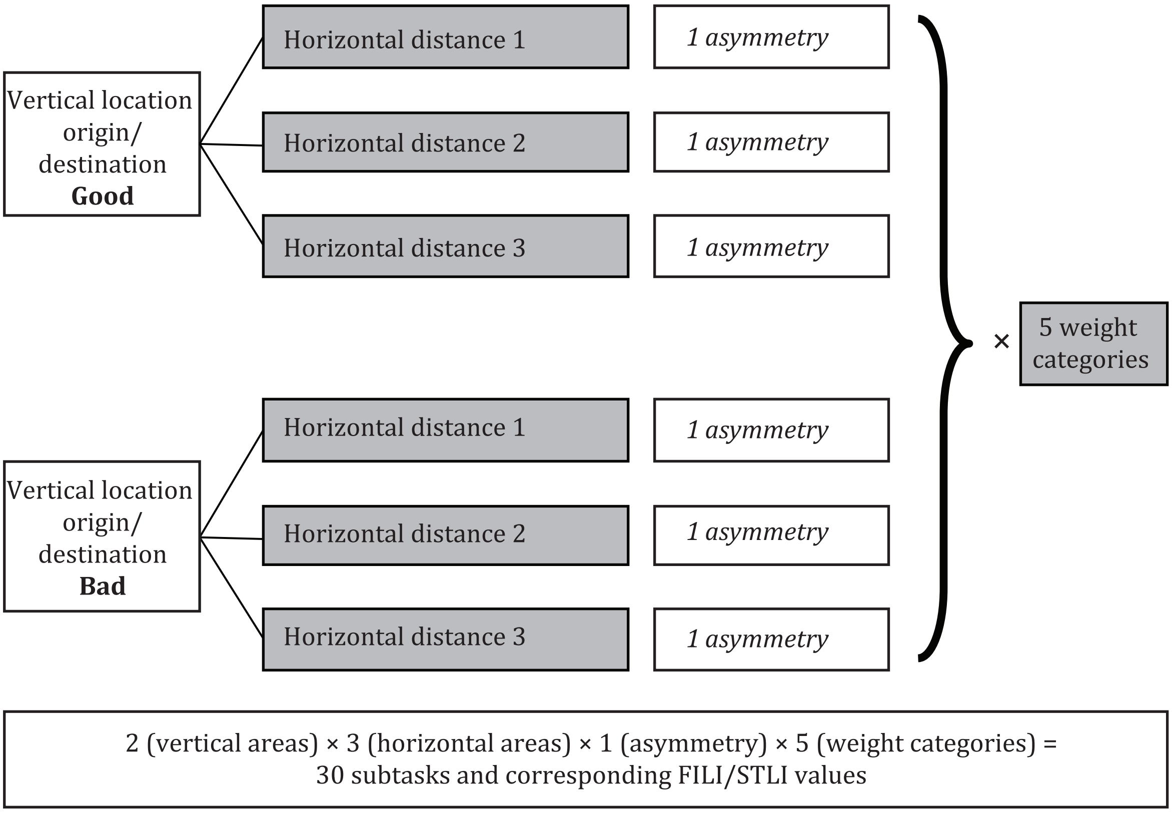


Figure F.5 — The result of the adopted simplifications: a maximum of 30 potential subtasks

c) Aggregate the resulting LI and calculate the final VLI (or CLI with more than 10 subtasks). 30 subtasks with corresponding FILI and STLI is still too many. For correctly applying the variable task analysis, it is necessary to further reduce and group the number of subtasks to six LI categories (each with a representative FILI and STLI value) and then to apply the traditional CLI formula.

To this end:

— the entire set of FILI values are assigned into six LI categories;

— the LI categories are defined by assigning the FILI values according to “sextiles” of the corresponding FILI distribution (16,66th, 33,33th, 50th, 66,66th and 83,33th percentiles values);

— consequently, the cumulative frequency of lifting for each of those six LI categories is also determined;

— once the LI categories have been aggregated, a representative FILI and STLI value is chosen within each category and the categories are reordered (mean value for categories 2 to 6; highest value for the first category).

The final VLI can then be calculated using Formula (F.2), similar to the traditional CLI formula applied to the six LI categories.

$$VLI = STLI_1 + \sum \Delta LI_n \qquad (F.2)$$

where

$$\sum \Delta LI = (FILI_2 X \left(\frac{1}{FM_{1,2}} - \frac{1}{FM_1}\right))$$

$$+ (FILI_3 X \left(\frac{1}{FM_{1,2,3}} - \frac{1}{FM_{1,2}}\right))$$

$$+ (FILI_4 X \left(\frac{1}{FM_{1,2,3,4}} - \frac{1}{FM_{1,2,3}}\right))$$

$$+ (FILI_5 X \left(\frac{1}{FM_{1,2,3,4,5}} - \frac{1}{FM_{1,2,3,4}}\right))$$

$$+ (FILI_6 X \left(\frac{1}{FM_{1,2,3,4,5,6}} - \frac{1}{FM_{1,2,3,4,5}}\right))$$

The VLI calculation is very difficult to complete manually and is best completed using dedicated software. Free downloadable software is available at various websites[59].

F.4 Sequential lifting tasks and SLI

When a job is characterized by several different lifting tasks (mono, composite, variable) in a shift, and workers rotate between a series of single or multiple lifting task rotation slots during a work shift, a clear multitask job is presented. In this case, the recommended method to assess the risk is the sequential lifting task technique[18],[51]. The SLI allows the calculation of the final LI for multitask jobs, considering the sequence of lifting tasks, the different intrinsic duration of each task and the total duration of exposure to manual handling during the shift.

The main steps for obtaining the SLI are:

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 lifting tasks present in the shift.

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

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

e) Step 5: use Formula (F.3) to obtain the SLI.

The SLI calculation is:

$$SLI = LI_1 intr + (LI_1 max - LI_1 intr) \times K \tag{F.3}$$

where

$LI_1 intr$ is the STLI of the most stressful task considering its continuous duration;

$LI_1 max$ is the STLI of the most stressful task considering overall duration of all lifting tasks;

$K = \Sigma\ ((LI_1 max \times FT_1)+(LI_2 max \times FT_2)+....+ (LI_n max \times FT_n))/ LI_1 max$;

FT_j is the time (in min) in task j during the shift/480 min (i.e. 60 min × 8 h)

The SLI approach can be used for analysing lifting tasks that vary along periods longer than a day (a week, a month or also a year). In such cases, the approach should be properly adjusted considering the effective and proportional duration of each rotating task within the whole considered period as well as the duration of tasks not involving manual handling activities.

Annex G
(informative)

Examples of manual handling of objects

G.1 Review of steps for lifting risk evaluation

After performing the quick assessment procedure (step 2), if the lifting task is found to require a full evaluation (Step 3: 4.2.2.4), this should be performed as described in Table G.1, beginning with collecting the fundamental data required to calculate the RML and the LI.

Table G.1 — Steps for risk evaluation of lifting

A	Identification of types of lifting tasks	Simple (or composite or variable or sequential) task
B	Description of the workers involved in lifting tasks	Number, gender, age
C	Organization analysis – shift schedule	Evaluation of lifting duration
D	Identification of the number of objects lifted in a shift	Evaluation of lifting frequency
E	Analysis of geometries at the origin and destination of the lifted objects	Study of the layout risk factors

G.2 Example 1: A simple lifting task performed by one worker lifting with two hands

A worker has to lift boxes weighing 10,5 kg each from a conveyor belt to a shelf. He or she lifts 1 200 boxes in a shift but continuous periods of lifting last no more than 60 min systematically followed by almost 60 min of light work. Practically, he or she devotes 240 min in the shift to lifting.

Figure G.1 sets out the data concerning the organization and layout of the task required to calculate the risk associated with the given task

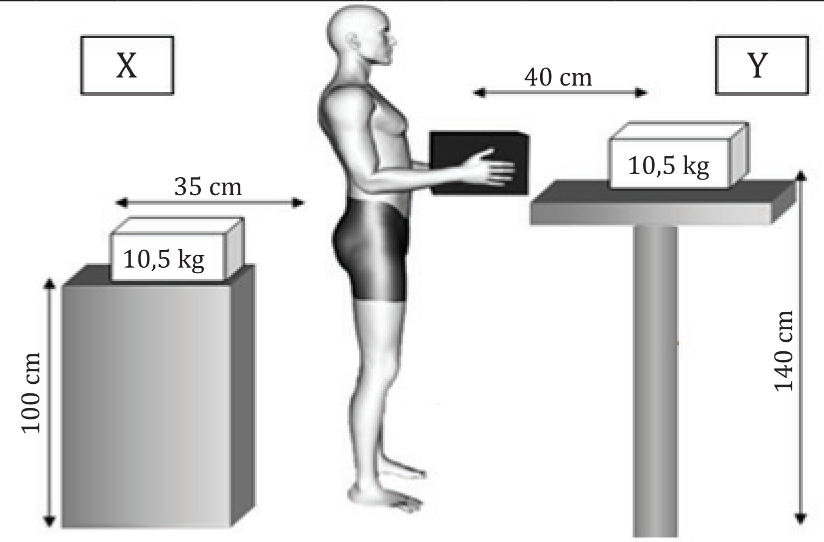
Lifting is performed using both arms. There is no trunk twisting during the lifts (no asymmetry). The boxes have no handles, so the coupling is poor and there is significant control when placing the boxes at the destination.

Figure G.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.

In general, but especially when there is significant control at the destination, the original RNLE (revised NIOSH lifting equation) method proposes calculating an LI both at the origin and at the destination, with the risk being represented by the worst of the two. In this example the worst condition is at destination.

	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 task or breaks	Push pulling task	Other task or breaks	**Manual lifting task**	Other task or breaks
	60	60			**60**	60			**60**	60			**60**	60	**60**

Short duration	
Shift duration: min.	**480**
MMH duration (including transport): min.	**240**
Total number of lifted objects	**1 200**
Lifting frequency: actions per min.	**5**



Key

x origin

y destination

Figure G.1 — Example 1: Data concerning the organization and layout required to calculate the LI in a simple task

According to data in Figure G.1, one can derive the multipliers from tables or calculate them using Formulae (C.1) to (C.5).

In this example, the reference mass was set to 25 kg.

By applying the simplified procedure in Annex E, the model in Figure G.2 can be used for the worst condition at destination. The resulting LI is 1,23.

CALCULATION OF THE RECCOMMENDED MASS LIMIT AND OF THE LIFTING INDEX

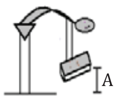
COMPANY AREA WORKPLACE TASK	DATE OBSERVER

REFERENCE MASS (kg.)

	MALES	FEMALES	NIOSH ORIGINAL
20-45 YEARS	25	20	23
<20 and >45 YEARS	20	15	

25	mref

X X

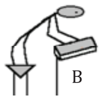


Distance of the hands from the floor at the start of lifting

height (cm)	0	10	20	30	40	50	60	70	75	80
MULTIPLIER	0,78	0,81	0,84	0,87	0,90	0,93	0,96	0,99	1,00	0,99
height (cm)	90	100	110	120	130	140	150	160	175	>175
MULTIPLIER	0,96	0,93	0,90	0,87	0,84	0,81	0,78	0,75	0,70	0,00

0,81	vM

X X

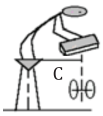


Vertical distance of the load between the beginning and the end of lifting

distance (cm)	≤ 25	40	55	70	85	100	170
MULTIPLIER	1,00	0,93	0,90	0,88	0,87	0,87	0,86
distance (cm)	115	130	145	160	175	>175	
MULTIPLIER	0,86	0,86	0,85	0,85	0,85	0	

0,93	dM

X X

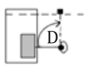


Horizontal distance between the load C. of G. and the body C. of G. during lifting

distance (cm)	≤ 25	28	30	32	34	36	38	40	42	44
MULTIPLIER	1,00	0,89	0,83	0,78	0,74	0,69	0,66	0,63	0,60	0,57
distance (cm)	46	48	50	52	54	56	58	60	63	>63
MULTIPLIER	0,54	0,52	0,50	0,48	0,46	0,45	0,43	0,42	0,40	0,00

0,63	hM

X X



Angular measure of displacement of the load from the sagittal plane

angle in degrees	0°	15°	30°	45°	60°	75°	90°	105°	135°	>135°
MULTIPLIER	1,00	0,95	0,90	0,86	0,81	0,76	0,71	0,66	0,57	0,00

1	αM

X X

Assessment of quality of grip of the object (coupling)

Assessment	GOOD	FAIR	POOR
MULTIPLIER	1,00	0,95	0,90

0,9	cM

X X

0,8	fM

Frequency of lifts per minute in relation to duration

FREQUENCY LIFTS/MIN.	LIFTING TASK DURATION (CONTINUOUS) ≤ 8 HOURS (LONG)	≤ 2 HOURS (MEDIUM)	≤ 1 HOUR (SHORT)
<0,1	1,00	1,00	1,00
≤0,1 to <0,2	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
MULTIPLIERS FOR AREAS < 75 CM			

X

	NO	YES
LIFT WITH ONE ONLY UPPER LIMB	1,00	0,60
LIFT BY 2 OR MORE OPERATORS	1,00	0,85

1	oM

X

1	pM

WEIGHT EFFECTIVELY LIFTED(Kg.) **10,5** Kg.

RECCOMMENDED MASS LIMIT **8,54** Kg.

LIFTED WEIGHT / RECOMMENDED MASS	LIFTING INDEX (LI)
	1,23

Figure G.2 — Example 1 — Calculation of RML and LI by a simplified procedure at destination of the lift

Otherwise, always considering destination, the RML can be calculated with Formula (C.1) with:

$m_{ref} = 25$

$h_M = 0{,}25/0{,}40 = 0{,}625$

$v_M = 1 - 0{,}3 \times (0{,}75 - 1{,}40) = 0{,}805$

$d_M = 0{,}82 + (0{,}045/0{,}40) = 0{,}932\ 5$

$\alpha_M = 1 - 0{,}003\ 2 \times 0 = 1$

$f_M = 0{,}8$ (from table)

$c_M = 0{,}9$ (from table)

It gives: RML = 25 × 0,625 × 0,805 × 0,932 5 × 1 × 0,80 × 0,9 = 8,44.

Since the mass actually lifted is 10,5 kg, the resulting LI can be calculated using Formula (D.1).

It gives: LI = 10,5/8,44 = 1,24.

The mass actually lifted is higher than the corresponding recommended mass and the resulting LI is calculated to be 1,24. Based on Table D.1, this corresponds to a low level of exposure.

G.3 Example 2: Analysis of a variable lifting task

In a metal-working plant, workers load and unload plastic containers of in-process materials to and from assembly lines for processing. The task is organized in cycles. During each cycle, the worker handles various containers in different body postures due to different heights (of the hands) at the origin and destination and different horizontal distances. The shift lasts 480 min (from 8 am to 5 pm). Work starts at 08:00. There is a 10-min break at 10:00. Lunchtime is at 12:10 (it lasts 60 min, out of official working time). In the afternoon, the activity is the same as in the morning with a 10-min break at 03:10 and the last 40 min are devoted to light work (no manual handling). Hence, the total manual handling duration during the shift is 420 net minutes.

Table G.2 shows the sequence of lifting tasks, breaks and light work during the shift.

Table G.2 — Sequence and duration of lifting tasks, light work and breaks for the case study in an 8 h shift

	Lifting task	Other light task or break	Lifting task	Other light task or break	Lifting task	Other light task or break	Lifting task	Other light task or break
Minutes	120	10	120	60	120	10	60	40
Shift starts/ends at	Start: 08:00							End: 17:00
Notes		Break		Lunch		Break		
Time in the shift	08:00 – 10:00	10:00 – 10:10	10:10 – 12:10	12:10 – 13:10	13:10 – 15:10	15:10 – 15:20	15:20 – 16:20	16:20 – 17:00

The containers have three different weights (6 kg, 8 kg and 13 kg.); the respective number of pieces lifted during the shift is shown in Table G.3.

Table G.3 — Type of weights and number of cartons lifted by the worker during an 8 h shift and consequent lifting frequency per type of weight

No. of containers	Weight	Frequency of lifts per minute
494	6 kg	1,18
1 235	8 kg	2,94
123	13 kg	0,29
1 852	All containers	4,41

Since 1 852 containers are lifted during a 420-min period, the overall lifting frequency is 4,41 lifts per minute. The partial lifting frequencies for each type (weight) of container are as follows: 1,18 lifts per minute for 6 kg containers, 2,94 lifts per minute for 8 kg containers and 0,29 lifts per minute for 13 kg containers.

The duration for the job is categorized as long duration (continuous period of manual handling of 120 min + a break of only 10 minutes + 120 min of manual handling).

The lifting activities are performed at different heights (of the hands) at the origin and destination and different horizontal distances. There is minimal lift asymmetry for all lifts (i.e. all objects are lifted in front of the body resulting in an asymmetry multiplier of 1,0), and the hand-to-object coupling is poor for all lifts (the coupling multiplier is 0,9). A significant control is present for almost all lifting actions.

Data regarding the geometry characteristics at the origin and destination of the lifts, by weight category, is shown in Table G.4.

Table G.4 — Data regarding load and geometry characteristics

Load characteristics		Origin		Destination		Number of potential sub-tasks derived
Number	Weight	Vertical height above floor	Horizontal distance	Vertical height above floor	Horizontal distance	
494	6 kg	8 levels from 14 cm to 84 cm	35 cm, 45 cm, 55 cm	80 cm	30 cm	24
1 235	8 kg	4 levels from 80 cm to 110 cm	30 cm	8 levels from 14 cm to 84 cm	35 cm, 45 cm, 55 cm	96
123	13 kg	2 levels, at 30 cm and 50 cm	35 cm	80 cm	30 cm	2

In this scenario, it is not possible to use the traditional multitask CLI approach since there would be up to 50 different individual FILI values (or about 122 if one considers both origin and destination). Also, the mean frequency of each type of lift would be very low (about 0,030 to 0,036 lifts per minute).

Since the traditional CLI approach cannot work, the proposed VLI approach (see F.3), using weight and geometries simplifications, should be used to assess the task.

The reference mass for this example was set to 23 kg.

In the presented example we have only three weight categories (6 kg, 8 kg and 13 kg). Each of them can have two simplified variants for height of hands (good; bad) at the origin or destination. In turn, each of them can have one, two or three simplified variants for horizontal distance (near; mid; far). Since different horizontal distances per weight category are clearly identified at origin and at destination, this results in a total of 14 individual subtasks, as shown in Table G.5. Table G.5 also displays the corresponding weights, geometries, partial frequency and frequency multipliers, FILI and STLI values for each of the 14 identified subtasks.

For determining partial frequencies of individual subtasks, a special procedure has been adopted that takes into account, for each weight category, how many times the height of hands starts or ends respectively in a good or bad area, considering small height intervals of 10 cm and then considering how many times each height of hands (good; bad) at the origin or destination corresponds to different variants for horizontal distance (near; mid; far) at both origin and destination.

The resulting frequencies of lifts for the various combinations of vertical height and horizontal reaches (14 in this example) are reported in Table G.5.

Since 14 subtasks is still too many to use in the CLI formula, it is advisable to use the VLI concept and approach.

To apply the VLI approach, subtasks and corresponding data (FILI, frequencies and STLI) are distributed into six LI categories. These six categories are determined according to the distribution of the individual FILI values (in this case 14 values) using preferentially the sextile distributions as key points for grouping (in other terms, the values corresponding to the 16,6th, 33,3rd, 50th, 66,6th, and 83,3rd percentile of the resulting FILI distribution). As a simpler alternative, six key points can be obtained by dividing the range of FILI values (i.e. maximum FILI − minimum FILI) divided by six. However, this simpler option has some disadvantages (i.e. some LI categories can be empty, the distribution of FILI values can be not well represented).

In any case, the original frequencies of individual subtasks (14 in this case) are grouped into the six LI categories. Single (category) LI values can consequently be calculated and used for reordering (from highest to lowest) within the six LI categories.

Within each resulting LI category, a representative FILI value is chosen. In category 1 (the highest LI category), the representative value chosen shall be the highest FILI in that category. The representative values in each of the other five LI categories are the average FILI values. This ensures that the worst-case (least-safe) scenario is included in the analysis.

Tables G.6 and G.7 display details of this procedure according to the previous example.

Table G.5 — Data regarding the 14 resulting subtasks (and corresponding FILI and STLI) by applying the simplifications and the frequency estimation procedures

Subtask	Weight (kg)	Vertical height classification and v_M		Vertical dislocation (d_M = 1, constant)		Horizontal distance classification and h_M		Asimmetry		Type of grasp (c_M = 0,9, constant)		FIRML	FILI	Frequency (rounded)	Duration scenario and FM		STLI
1	6	L/H	0,78	G	1,00	N	0,71	A	1,00	P	0,90	11,5	0,523	0,17	LD	0,850	0,62
2	6	L/H	0,78	G	1,00	M	0,56	A	1,00	P	0,90	9,0	0,664	0,17	LD	0,850	0,78
3	6	L/H	0,78	G	1,00	F	0,40	A	1,00	P	0,90	6,5	0,929	0,17	LD	0,850	1,09
4	6	G	1,00	G	1,00	N	0,71	A	1,00	P	0,90	14,7	0,408	0,33	LD	0,833	0,49
5	6	G	1,00	G	1,00	M	0,56	A	1,00	P	0,90	11,6	0,518	0,16	LD	0,850	0,61
6	6	G	1,00	G	1,00	F	0,40	A	1,00	P	0,90	9,3	0,725	0,16	LD	0,850	0,85
7	8	L/H	0,78	G	1,00	N	0,71	A	1,00	P	0,90	11,5	0,698	0,33	LD	0,833	0,84
8	8	L/H	0,78	G	1,00	M	0,56	A	1,00	P	0,90	9,0	0,885	0,33	LD	0,833	1,06
8	8	L/H	0,78	G	1,00	F	0,40	A	1,00	P	0,90	6,5	1,239	0,33	LD	0,833	1,49
10	8	G	1,00	G	1,00	N	0,71	A	1,00	P	0,90	14,7	0,544	0,98	LD	0,752	0,72
11	8	G	1,00	G	1,00	M	0,56	A	1,00	P	0,90	11,6	0,690	0,49	LD	0,811	0,85

Key

A absent

CM coupling multiplier

DM distance multiplier

F far

FILI frequency independent lift index

FIRML frequency independent recommended mass limit

FM frequency multiplier

G good

HM horizontal multiplier

LD long duration

L/H low or high

M medium

N near

P poor

STLI single task lifting index

VM vertical multiplier

Table G.5 *(continued)*

Subtask	Weight (kg)	Vertical height classification and v_M		Vertical dislocation (d_M = 1, constant)		Horizontal distance classification and h_M		Asimmetry		Type of grasp (c_M = 0,9, constant)		FIRML	FILI	Frequency (rounded)	Duration scenario and FM		STLI
12	8	G	1,00	G	1,00	F	0,40	A	1,00	P	0,90	8,3	0,966	0,49	LD	0,811	1,19
13	13	L/H	0,78	G	1,00	N	0,71	A	1,00	P	0,90	11,5	1,134	0,20	LD	0,850	1,33
14	13	G	1,00	G	1,00	N	0,71	A	1,00	P	0,90	14,7	0,885	0,10	LD	0,850	1,04

Key

A absent

CM coupling multiplier

DM distance multiplier

F far

FILI frequency independent lift index

FIRML frequency independent recommended mass limit

FM frequency multiplier

G good

HM horizontal multiplier

LD long duration

L/H low or high

M medium

N near

P poor

STLI single task lifting index

VM vertical multiplier

Table G.6 — Identification of key points by the sextile approach using the FILI data distribution from Table G.5

	First key point 16,66th percentile	Second key point 33,33th percentile	Third key point 50th percentile or median	Fourth key point 66,66th percentile	Fifth key point 83,33th percentile	Sixth key point Maximum value
Key value	0,527	0,672	0,711	0,885	0,960	($FILI_{max}$) 1,239
LI category range	0,408 to 0,526	0,527 to 0,671	0,672 to 0,710	0,711 to 0,884	0,855 to 0,959	0,960 to 1,239

Key
FILI frequency independent lift index
LI lifting index

Table G.7 — Relevant values for each FILI category using the key points from Table G.6 and the consequent cumulated frequencies derived from Table G.5

Category data	FILI category (<16,66th)	FILI category (16,66th–33,33th)	FILI category (33,33th-50th)	FILI category (50th–66,66th)	FILI category (66,66th-83,33th)	FILI category (>83,33th)
Range of FILI values	0,408 to 0,526	0,527 to 0,671	0,672 to 0,710	0,711 to 0,884	0,855 to 0,959	0,960 to 1,239
Representative category FILI value	0,483	0,604	0,694	0,805	0,907	1,239
Number of subtask in each category	3	2	2	2	2	3
Cumulative frequency (lifts per minute) within the category	0,66	1,15	0,82	0,26	0,50	1,02
FM values (long duration)	0,791	0,735	0,772	0,842	0,810	0,748
STLI (category) value	0,611	0,822	0,899	0,956	1,12	1,656
Order by STLI value	6	5	4	3	2	1

Key
FILI frequency independent lift index
FM frequency multiplier
STLI single task lifting index

Using these data, organized in six FILI categories, it is possible to calculate the VLI by means of the traditional CLI formula.

Based on the data presented for this example, the relevant data for calculating the VLI [with Formula (F.2)] are reported in Table G.8.

Table G.8 — Relevant data for calculating final VLI derived from Table G.7

Connotation of cumulative frequencies by STLI order	Cumulative frequencies of categories (lifts per minute)	Corresponding FM (long duration)	Partial value $[(1/FM_J) - (1/FM_{J-1})]$	FILI	$STLI_1$ and $\Delta FILI_J$
FM_1	1,02	0,748		1,239	**1,656**
$FM_{1,2}$	1,52	0,698	0,096	0,907	**0,087**
$FM_{1,2,3}$	1,78	0,672	0,055	0,805	**0,045**
$FM_{1,2,3,4}$	2,60	0,590	0,207	0,694	**0,144**
$FM_{1,2,3,4,5}$	3,75	0,475	0,410	0,604	**0,248**
$FM_{1,2,3,4,6}$	4,41	0,409	0,340	0,483	**0,164**

Key

FILI frequency independent lift index

FM frequency multiplier

STLI single task lifting index

VLI variable lifting index

Using data reported in Table G.8, the VLI for this job can be calculated with Formula (G.1):

$$VLI = STLI1 + \sum \Delta LI \tag{G.1}$$

$$STLI_1 = 1{,}656$$

$$\Delta FILI_2 = 0{,}907 \times [(1/0{,}698) - (1/0{,}748)]) = 0{,}907 \times (0{,}096) = 0{,}087$$

$$\Delta FILI_3 = 0{,}805 \times [(1/0{,}672) - (1/0{,}698)] = 0{,}805 \times (0{,}055) = 0{,}045$$

$$\Delta FILI_4 = 0{,}694 \times [\ (1/0{,}590) - (1/0{,}672)] = 0{,}694 \times (0{,}207) = 0{,}144$$

$$\Delta FILI_5 = 0{,}604 \times [(1/0{,}475) - (1/0{,}590)] = 0{,}604 \times (0{,}410) = 0{,}248$$

$$\Delta FILI_6 = 0{,}483 \times [(1/0{,}409) - (1/0{,}475)] = 0{,}483 \times (0{,}340) = 0{,}164$$

$$VLI = STLI_1 + \Delta FILI_2 + \Delta FILI_3 + \Delta FILI_4 + \Delta FILI_5 + \Delta FILI_6$$

$$VLI = 1{,}656 + 0{,}087 + 0{,}045 + 0{,}144 + 0{,}248 + 0{,}164 = 2{,}34$$

The final VLI value for the present example is 2,34 (considering a reference mass of 23 kg.).

The exposure level is considered as high.

NOTE The VLI calculation is very difficult to complete manually and is best completed using dedicated software. Free downloadable software is available at various websites[59].

Annex H
(informative)

Carrying

H.1 Reference conditions for carrying limits

The recommended limits for cumulative mass per day and cumulative mass related to distance (steps 4 and 5 in Figure 1 and 4.2.2.1 and 4.2.2.2) assume reference conditions.

Reference conditions include the following:

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

— no stair steps or climbing;

— good coupling with the load;

— no obstructions to movement;

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

— no obstructions to vision.

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

H.2 Correction ratios and multipliers for carrying conditions other than reference conditions

When carrying tasks are performed in conditions other than reference conditions, the threshold values supplied in Table 5 shall be reduced. Correction ratios and multipliers have been established for the influencing factors below that are beyond the reference conditions. These make it possible to adjust the threshold values supplied in Table 5 to non-reference conditions. These correction ratios are presented as multipliers.

— Where there is more than one influencing factor, only the two most unfavourable multipliers (lowest values) shall be used.

— Where carrying is performed with only one hand, the recommended limits for cumulative mass in Table 5 shall first be multiplied by 0,6, and then two of the most unfavourable multipliers (lowest numbers) shall be applied.

Regarding the carrying durations and the load limits in Table 5, the kg per time interval represents the total amount of mass carried within that duration regardless of the number of trips. The amount of mass carried per trip and the number of trips can vary. Given that, in most cases, a carry also involves a lift, the lifted mass is subject to lifting or lowering assessment.

Consider the average or modal carrying distance and apply the multipliers in Table H.1 accordingly.

Table H.1 — Carrying distance correction ratios or multipliers

Carrying distance	CR or multiplier
1 m to 2 m	1
> 2 m to 5 m	0,8
> 5 m to 10 m	0,6
> 10 m to 20 m	0,2

Carrying distances > 20 m are considered to be unacceptable.

When carrying at low or high levels the recommended limits for cumulative mass for carrying in Table 5 shall be reduced according to Table H.2.

Table H.2 — Correction ratios or multipliers for the height at which the carrying (not lifting or lowering) effort is applied (handhold height)

Vertical hand position during carrying	CR or multiplier
Conditions with hand position: > 75 cm to 110 cm	1
Conditions with hand position: 40 cm to 75 cm or > 110 cm to 140 cm	0,8[a]
Exceptional conditions > 140 cm to < 40 cm	0,4[a]

[a] Does not apply to shoulder carries where the weight of the load is borne by the shoulder and not by the hands.

Pick-up, set-down or carrying with hands below 40 cm or beyond 175 cm is considered to be unacceptable.

The conditions considered to be risk-generating are: an object without hand-grips or with unsuitable hand-grips, twisting the trunk, having to reach in > 0,40 m (horizontally), or out of the reach span, one or more postural or body position constraints, unstable object, visibility hindered by the object (see Table H.3).

Table H.3 — Correction ratios or multipliers for conditions in which the tasks are performed

Conditions in which the tasks are performed	CR or multiplier
No risk-generating factor	1
One risk-generating factor	0,8
Two or more risk-generating factors	0,7

The following additional risk factors should also be considered in the general assessment of the task:

— ambient noise, noisy conditions;

— poor atmospheric conditions such as dust, fumes or smoke in the air;

— poor or damaged walking surfaces;

— physical obstacles in the carry path;

— limited head room;

— limited or constrained manoeuvre room;

— strict task pacing;

— multiple tasks being performed;

— quality requirements.

The information presented in this annex has been drawn from studies presented in the French standard NF X35-109 and from German studies on carrying[11],[28],[36],[38].

H.3 Example — Carrying a part from a machine to a shipping container

The operation is performed once a minute using two hands where there are two good handles, 7 h per day and the activity conditions are as follows:

— the part weighs 12 kg;

— machine-to-container distance is 10 m;

— the operative picks and carries the part up at a height of 1,15 m;

— the part is set down at an off-ground height of 0,45 m;

— the horizontal reach-in to set-down is 0,60 m.

In order to use Table 5, the kg per duration shall be calculated. Given that the mass is 12 kg, the work time duration is 7 h per day and the operation is performed once per minute, the cumulative mass is:

12 kg × 1/min × 60 min/h × 7 h = 5 040 kg/7 h

Consider the correction multipliers from the tables above:

— carry distance is 10 m, from Table H.1 the correction multiplier is 0,6;

— carry height is 1,15 m, from Table H.2 the correction multiplier is 0,8;

— the reach-in or horizontal reach for the set down is 0,6 m, from Table H.3 the correction multiplier is 0,8.

Among the multipliers, the two most severe multipliers are 0,6 and 0,8. Therefore, these two numbers are used for calculation of the recommended limit for cumulative mass. The acceptable cumulative mass for 7 h (from Table 5) is 6 000 kg. The resulting recommended cumulative mass for 7 h and with the given conditions is:

6 000 kg × 0,6 × 0,8 = 2 880 kg

The task of carrying a total of 5 040 kg/7 h is not recommended since 2 880 kg is the maximum cumulative mass acceptable in this condition. A number of job changes can eliminate the need for the correction multipliers, such as reducing the carry distance to less than 2 m, changing the carry height and reducing the horizontal reach-in distance. This can bring the acceptable weight to handle closer to the actual weight being carried. However, there is a need to reconsider the job and task organization as suggested in Annex A to reduce the weight to within an acceptable limit.

Consider the same carrying condition but with a reduced duration (e.g. a carry of 12 kg where the carry is performed for 4 h).

In this example, the cumulative mass is:

12 kg × 1/min × 60 min/h × 4 h = 2 880 kg

This is below the limit of 5 000 kg/4 h in Table 5. With the multipliers added, the actual recommended limit is: 5 000 kg × 0,6 × 0,8 kg = 2 400 kg.

The actual accumulated weight is only 480 kg greater than the recommended accumulated carrying under these conditions. Modifications to the task itself (in order to reduce the conditions that can increase risk of injury) eliminate or reduce the multipliers and change the weight recommendations for the new conditions.

Annex I
(informative)

Exposure and risk: the basis for Table D.1

I.1 Exposure versus risk: the difference

The term exposure is defined as the extent to which a person is subject to a change or to specific circumstances (e.g. task conditions including frequency, force, heights or depths reached, duration). The amount of that exposure can be expressed in quantitative terms and can refer to the extent to which a person is subjected to a hazard (potential source of harm) or combination of hazards. In this document, exposure is referred to as the amount of the combined effect of all job-related physical lifting and carrying hazards (i.e. all the variables used in the lifting formulae which can present a risk of harm).

Risk is defined as the combination of the probability of occurrence of harm (e.g. likelihood of having an adverse health outcome such as back pain) and the severity of that harm. The probability can vary depending on many personal factors. In this document, age and sex are included as overall risk variables for a working population. Other individual factors that can affect the risk are not included, such as obesity, prior history of back pain, depression and other psychosocial variables.

As a result of the many different individual factors among people, the same exposure to a hazard (e.g. lifting) for different people does not necessarily present the same degree of risk. The exposure can result in different responses among workers due to many personal factors. The exposure and risk information in Table D.1 is based on the general working population accounting for most personal risk factors.

In this document, the LI variables (LI, CLI, VLI and SLI) are considered to be indicators of the level of exposure to the hazards which are associated with the physical demands of lifting jobs.

I.2 Summary of research on the relationship between LI and low back pain (LBP) risk

I.2.1 Studies on generic LBP

A number of epidemiological studies (Table I.1) have been conducted to investigate the level and strength of the association between LI values and adverse health effects, primarily low-back-pain-related health outcomes in various working populations. In this subclause, some brief remarks on the main results of these studies are synthesized to suggest to what extent the LI can be considered for prevention of various LBP health outcomes.

Table I.1 — Epidemiological studies investigating the relationship between various types of LI and LBP outcomes (in reverse chronological order)

Study	Sample size	Age	Study design	Industry sector	LI/CLI/VLI values	% reporting LBP/symptoms	Main finding
Battevi, Pandolfi, Cortinovis (2016)	3 402	Mean = 43,5	Cross-sectional	Manufacturing, pharmaceutical and food	VLI	N/A	VLI shows an exposure-response relationship when VLI is greater than 1,0
Pandalai, Wheeler, Lu (2016)	138	18 to 64	Prospective	Manufacturing	Bayes factors for max and min CLIs	15 % reported LBP during one-year follow-up	A risk of LBP associated with CLI values > 1,5 exists in the study sample.
Garg et al. (2014)	258	19 to 65	Prospective	Manufacturing and WRT[a]	Mean peak task CLI = 2,8	48 % had self-reported LBP during 4,5-year follow-up	Peak LI and CLI are useful metrics for estimating risk of self-reported LBP
Garg et al. (2014)	258	19 to 65	Prospective	Manufacturing and WRT[a]	Mean peak task CLI = 2,8	9 % reported seeking care for LBP during 4,5-year follow-up	Peak LI and CLI are useful metrics for estimating risk of sickness absence due to LBP
Kapellusch et al. (2014)	258	19 to 65	Prospective	Manufacturing and WRT[a]	Mean peak task CLI = 2,8	14 % reported use of medication for LBP during 4,5-year follow-up	Peak LI and CLI are useful metrics for estimating medication use for LBP
Lu, Waters, Krieg and Werren (2014)	78	Mean = 40	Prospective	Manufacturing	Mean CLI = 1,5	32 % reported LBP during one-year follow-up	The CLI > 2,0 can be useful for predicting LBP
Waters, Lu, Piacitelli, Werren and Deddens (2011)	677	Mean = 36 (19 to 68)	Cross-sectional	Manufacturing	0 to 9,37	20 %	Within a range of LI from 1,0 to 3,0, there is an exposure-response relationship between the LI values and LBP

Key

— Categorical LI data were used

N/A Not available

[a] The number is for jobs not persons.

Table I.1 *(continued)*

Study	Sample size	Age	Study design	Industry sector	LI/CLI/ VLI values	% reporting LBP/symptoms	Main finding
Kucera, Loomis, Lipscomb, Marshall, Mirka and Daniels (2009)	105	Mean = 46	Prospective	Fishing	Range 0 to 5,4	61 %	The LI > 3,0 is associated with LBP
Xiao, Dempsey, Lei, Ma and Liang (2004)	69	Mean = 41	Cross-sectional	Manufacturing	1,9 to 2,4 (median value)	64 %	Lifting repetitiveness and work age contributed to the occurrence of LBP
Yeung, Genaidy, Deddens and Leung (2003)	217	Mean = 39	Cross- Sectional	WRT[a]	N/A	N/A	Workers' perceived effort is significantly associated with RNLE task variables and MSD symptoms
Marras, Fine, Ferguson and Waters (1999)	353[a]	N/A	Cross-sectional	Manufacturing	—	N/A	RNLE identifies high risk jobs well but not low risk jobs
Schneider, Grant, Habes and Bertsche (1997)	19	21 to 46	Cross-sectional	Manufacturing	Range 3,9 to 8,2	47 %	High prevalence of back pain is related to high LI values
Sesek, Gilkey, Drinkaus, Bloswick and Herron (2003)	182[a]	N/A	Retrospective	Manufacturing	—	N/A	OR for back injury were found to be 2,1 and 4,0 for LI values and 1,0 and 3,0 respectively
Wang, Garg, Chang, Shih, Yeh and Lee (1998)	97	17 to 62	Retrospective	Eight industry sectors	—	90 %	The LI is a reliable measure for assessing discomfort rating due to LBP
Waters et al. (1999)	308	Mean = 46	Cross-sectional	Manufacturing	—	30 %	OR for LBP 2,45 for 2 < LI < 3

Key

— Categorical LI data were used

N/A Not available

a The number is for jobs not persons.

In the early published studies on the validity of the NIOSH 1991 equation, Waters et al.[52],[56] found that the increase in risk of reported low back injury was statistically significant with LIs greater than

2,0. The study[56] was conducted at an automotive manufacturing plant. Subsequent and expanded published research utilizing larger worker samples across various industries have used LI and CLI as the only exposure metric and have largely supported the earlier findings of an increase in low back injury for LIs or CLIs over 2,0[40],[54]. The study[54] showed that on the basis of prevalence proportion ratios (a way to take account of the various confounding factors in a cross-sectional study) for the categories of LI ranges, the risk of low back injury in the LI or CLI ranges of 0 to 1 and 1 to 2 were virtually identical. This can be indicative that there is very little difference in the risk associated with an LI or CLI between 0,0 and 2,0 for a variety of lifting tasks.

While the risks associated with the range of LI and CLI have not been unequivocal, a number of studies have identified usable risk "thresholds" for the interpretation of the LI and CLI. In a study looking at the incidence of work-related LBP as related to the LI and CLI of jobs for 750 material handling workers[15], Boda et al. concluded that the LI/CLI design ideal of 1,0 would need to be increased by at least 20 % to reflect the design intent of the original NIOSH publication[57]. In the most comprehensive comparison to date[44], Potvin compared the NIOSH recommended weight limit (RWL, also RML) in 216 lift conditions to the specific biomechanical, physiological and psychophysical criteria used in the development of the NIOSH equation. Potvin found that the RWL (RML) was found to be much more conservative than expected with the average RWL (RML) actually being acceptable to more than 95 % of the female population across a range of moderate lift frequency. This finding was consistent with earlier research. Potvin concluded that, on average, the RWL (RML) would have to be multiplied by 1,68 (a 68 % increase) in order to produce a value that reflects the biomechanical, physiological and psychophysical design criteria overall defined by the original NIOSH publication[57]. Taken together, this suggests that a usable risk threshold between low and intermediate or high risk of LBP would fall somewhere intermediate between CLI of 1,0 and 2,0. Pandalai et al., in a study[43] using prospective data from 138 manufacturing workers and analysing CLI using a Bayesian random threshold approach to estimate the probability of an increase in LBP as a threshold step function, found that a CLI of > 1,5 was associated with the risk of LBP.

I.2.2 2016 Italian study on CLI/VLI and acute low back pain (LBP) outcomes

In a large study performed in Italy by Battevi et al.[14], the health effect variable considered was acute LBP episodes occurred in the previous 12 months. The variable was defined as presence of lumbar pain with or without irradiation, obliging the patient to remain immobile for at least 2 days, or 1 day if medication was taken. These types of episodes involved sick leave from work and served to differentiate chronic LBP from acute LBP. The aim of this study was to evaluate the efficacy of the LI (mainly VLI) in predicting the risk of one or more acute LBP episodes in the past 12 months.

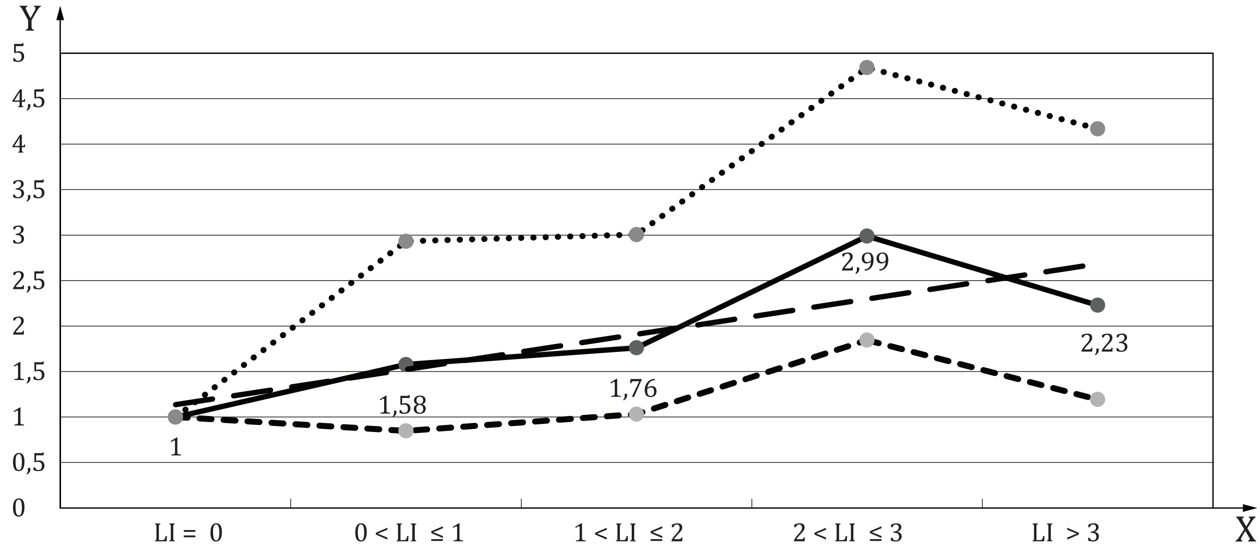
A sample of 3 402 study participants from 16 companies in different industrial sectors was analysed. Of the participants, 2 374 were in the risk exposure group involving manual materials handling (MMH) and 1 028 were in the reference group without MMH. The LI was calculated for each participant in the exposure group. Occupational physicians at the study sites collected LBP information. In particular, a subject was assessed as positive if she or he reported at least one episode of acute LBP in the last year (12 months).

The risk of acute LBP was estimated by calculating the odds ratio (OR) between levels of the risk exposure and the reference group using a logistic regression analysis. Both crude and adjusted ORs for body mass index, gender and age were analysed.

Both crude and adjusted ORs showed a dose-response relationship. As the levels of LI increased, the risk of acute LBP increased. This risk relationship existed when LI was greater than 1. In particular, when considering adjusted ORs and using LI computed starting from a reference mass of 23 kg, the results obtained are summarized in Table I.2 and Figure I.1.

Table I.2 — Association between LI (using a reference mass of 23 kg) and occurrence of acute low-back pain in the previous year; mean odds ratio, upper and lower 95 % confidence limits, adjusted for body mass index, gender and age

LI class	Mean OR	OR lower 95 % CL	OR upper 95 % CL
LI = 0	1	=	=
0 < LI ≤ 1	1,58	0,85	2,93
1 < LI ≤ 2	1,76	1,03	3,01
2 < LI ≤ 3	2,99	1,85	4,84
LI > 3	2,23	1,19	4,17



Key

———	mean
– – –	lower CL
········	upper CL
— — —	odds ratio trend
X	LI range
Y	odds ratio

Figure I.1 — Adjusted OR: LI vs acute LBP

These results and data show that, for a LI greater than 1 and up to 2, a mean OR of 1,76 exists and that the corresponding lower CL (at 95 %) is slightly greater than 1, which stays for a significant difference in the occurrence of acute LBP with respect to non-exposed. The OR is higher in the exposed to LI between 2 and 3. When LI values exceed 3, the OR has a little decline with respect to the 2 > LI ≥ 3 class (probably for a healthy worker effect) but is still high and significant considering the reference group.

These results confirm that, considering the health effect acute LBP, a LI of 1 is a good discriminatory point between a still acceptable and a risky condition across all frequencies of lifting. However, when just looking at frequencies of lift that are > 0,1 (greater than one lift per 10 min, the definition in this document of repetitive lifting), the ORs for the LI is between 0 and 1 and between 1 and 2 show very little difference and support a discriminating point between LI = 1 and LI = 2, such as 1,5.

I.2.3 Summary of German studies on spinal loading and lumbar disc-related injury

In a large two-step investigation performed in Germany, the so-called German Spine Study EPILIFT and EPILIFT2[16],[46], the health effects considered were lumbar-disc herniation (prolapse) and lumbar-disc space narrowing (chondrosis), accompanied by functional deficits, i.e. sensitive and/or motor radix syndrome or local syndrome. The dose-response relation between occupational lifetime lumbar-spine exposure to manual materials handling, intensive-load postures or both, on the one hand[31], and disc-related degenerative diseases of the lumbar spine, on the other, was analysed in a population-based multi-centre case-control study on 915 case subjects with lumbar diseases and 901 control subjects. Adjusted, gender-stratified odds ratios and 95 % confidence intervals were determined applying unconditional logistic regression analysis.

To address the problem of assessing an occupational-life risk induced by a wide variety of postures and manual handling tasks (i.e. object mass, exerted force, action frequency and duration), each potential overloading action was considered (≥5 kg object mass, ≥20 ° trunk inclination) via the induced lumbosacral disc-compressive force. Besides this situational lumbar load, the cumulative lumbar load was characterized by shift dose and lifetime dose as integrative measures. External exposure data (e.g. object mass, postures, frequencies, durations) were gathered in comprehensive individual interviews.

In relation to lifetime doses which were categorized in tertiles, adjusted odds ratios were found up to 3,9 (CI 2,6-6,0) and 3,2 (CI 1,9-5,5) among the male prolapse or chondrosis case groups, whereas the odds ratios amounts up to 2,5 (CI 1,6-3,8) and 3,0 (CI 1,3-6,8) were found among the female cases. In total, positive dose-response relations were found for all four case groups, i.e. for males and females as well as for disc herniation and disc-space narrowing. Specific lag-time analyses showed that even past or early-in-life exposures contribute to the risk of developing lumbar disc-related diseases[45].

As cumulative lumbar-load dose models which are best-fitting the dose-response relations, the following properties or thresholds were identified as best estimates to answer the questions:

— What is a too heavy object?

— What is a too disadvantageous posture?

— What work per day is too intensive?

— What actions are as hard as lifting and carrying?

A threshold value of 3,2 kN among men and 2,5 kN among women with respect to the disc compressive force, 45° of trunk forward inclination for both genders, shift-dose thresholds of 2,0 kNh among men and 0,5 kNh among women and, referring to lifetime doses doubling the risk, about 7 MNh among men and 3 MNh among women. Push and pull activities were included[34],[46],[47].

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