INTERNATIONAL STANDARD

ISO 11228-2

First edition
2007-04-01

Ergonomics — Manual handling —

Part 2:
Pushing and pulling

Ergonomie — Manutention manuelle —

Partie 2: Actions de pousser et de tirer

Reference number
ISO 11228-2:2007(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11228-2 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 3, *Anthropometry and biomechanics*.

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

— *Part 1: Lifting and carrying*

— *Part 2: Pushing and pulling*

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

Introduction

Pain, fatigue and disorders of the musculoskeletal system can result from awkward and/or forceful manual handling tasks such as the pushing or pulling of objects. Musculoskeletal pain and fatigue can themselves influence postural control and increase the likelihood of hazardous working practices, leading to an increased risk of injury, as well as a reduction in productivity and the quality of work output. Good ergonomic design can provide an approach for avoiding these adverse effects.

This part of ISO 11228 provides two methods for identifying the potential hazards and risks associated with whole-body pushing and pulling. Its content is based on current knowledge and understanding of the musculoskeletal risk factors associated with these types of handling tasks. In addition to providing an ergonomics approach for the assessment of push/pull tasks, it proposes recommendations for reducing the risk of injury or ill health.

The assessment and control of risks associated with other aspects of manual handling are to be found in ISO 11228-1, ISO 11228-3 and ISO 11226.

Ergonomics — Manual handling —

Part 2:
Pushing and pulling

1 Scope

This part of ISO 11228 gives the recommended limits for whole-body pushing and pulling. It provides guidance on the assessment of risk factors considered important to manual pushing and pulling, allowing the health risks for the working population to be evaluated. The recommendations apply to the healthy adult working population and provide reasonable protection to the majority of this population. These guidelines are based on experimental studies of push/pull tasks and associated levels of musculoskeletal loading, discomfort/pain, and endurance/fatigue.

Pushing and pulling, as defined in this part of ISO 11228, is restricted to the following:

— whole-body force exertions (i.e. while standing/walking);

— actions performed by one person (handling by two or more people is not part of the assessment, but some advice is given in Annex C);

— forces applied by two hands;

— forces used to move or restrain an object;

— forces applied in a smooth and controlled way;

— forces applied without the use of external support(s);

— forces applied on objects located in front of the operator;

— forces applied in an upright position (not sitting).

This part of ISO 11228 is intended to provide information for designers, employers, employees and others involved in the design or redesign of work, tasks, products and work organization.

2 Terms and definitions

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

2.1
initial force
force applied to set an object in motion (i.e. force required to accelerate the object)

2.2
pulling
human physical effort where the motive force is in front of the body and directed towards the body as the body stands or moves backwards

2.3
pushing
human physical effort where the motive force is directed to the front of, and away from, the operator’s body as the operator stands or moves forward

2.4
sustained force
force applied to keep an object in motion (i.e. force required to keep the object at more or less constant velocity)

2.5
stopping force
force applied to bring an object to rest

2.6
unfavourable environmental conditions
conditions that give rise to additional risk of injury

EXAMPLE Hot or cold environments, slippery floors.

3 Recommendations

3.1 Avoiding hazardous manual handling tasks

Hazardous manual handling tasks should be avoided wherever possible. This can be achieved by appropriate workplace or job design, as well as through mechanization or automation. For example, the manual pushing and pulling of heavy objects across a work surface can be avoided by using powered conveyor belts or a gravity-inclined roller track.

3.2 Risk assessment

Risk assessment consists of the following steps: hazard identification, risk estimation, risk evaluation (see ISO/IEC Guide 51).

For the purposes of this part of ISO 11228, the risk assessment model shown in Figure 1 is used.

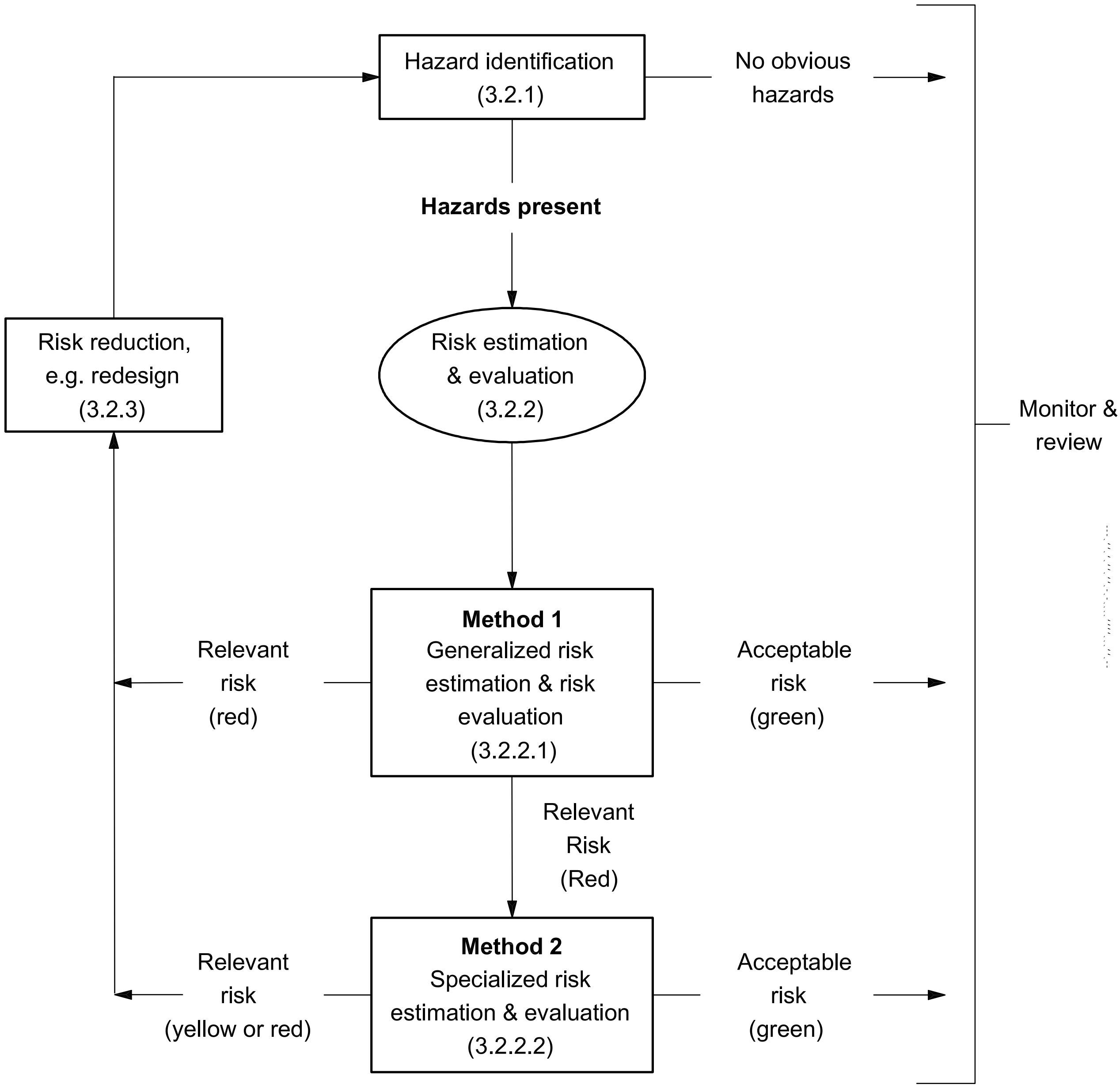


Figure 1 — Risk assessment model

3.2.1 Hazard identification

3.2.1.1 Force

Initial forces are used to overcome the object's inertia, when starting or changing the direction of movement. Sustained forces are those used to maintain the movement of the object. Initial forces are usually higher than sustained forces and should, therefore, be kept to a minimum. Frequent starting, stopping and manoeuvring of the object should be avoided. Smooth continuous force exertions should be applied to the object, avoiding jerky movements and long duration; sustained forces should be avoided, as they increase the risk of muscle or whole-body fatigue.

3.2.1.2 Posture

The ability to exert a force is largely determined by the posture a person adopts. Awkward postures often lead to decreased abilities for force exertions and increased risk of injury from high loads being placed on body joints or segments. The operator should adopt a comfortable and natural posture when applying either initial or sustained push/pull forces. The operator should exert the force with a stable and balanced posture that allows the application of his/her body weight to the load and thus minimizes the forces acting on the back (i.e. spinal compressive loading and sagittal or lateral shear forces) and shoulders. Twisted, lateral bent and flexed trunk postures should be avoided as they increase the risk of injury. The load on the arms and shoulders is influenced by posture in relation to the applied force, which is also influenced by the position of the hands. Therefore, the hand position should not be too high or too low and the hands should not be too close together. Also, the elbows should be kept low.

Whereas lifting, holding and carrying can lead to high compressive loads on the operator's lumbar spine, the compression forces arising from pushing and pulling are generally much lower. Shear forces, on the other hand, tend to be higher. Currently, there is limited knowledge about the possible effects of shear forces on the risk of back injury and only a few guideline figures exist on “safe limits” for shear forces. For these reasons, this part of ISO 11228 focuses on compressive forces only when proposing safety limits for pushing and pulling tasks.

3.2.1.3 Frequency and duration

When pushing and pulling, both the frequency and duration of the applied force should be considered. Long duration force exertions should be avoided (e.g. by means of mechanical aids) in order to limit/avoid the effects of muscle fatigue. High repetitive force exertions will result in more frequent initial forces and should be avoided.

3.2.1.4 Distance

Distances over which operators move objects can vary from several paces (1 m or 2 m) up to many metres. Long distances coupled with high forces and frequent movements may be fatiguing to the operators. The longer the distance, the more fatiguing the movement may be for a given force exertion level. Long distances could involve multiple corrective movements on the part of the operator, altering the path of the object and thus increasing the force demands and the exposure of the operator to any other hazards posed by the work environment.

3.2.1.5 Object characteristics

Manoeuvrability of the object should be optimized. If the object is on wheels/castors, then these should be suitable for the object (i.e. appropriate material and diameter) and well maintained. For objects without wheels or castors, friction should be reduced (e.g. surfaces with low frictional properties or rollers should be considered). The force should be applied against the object in a suitable and secure manner (e.g. handles should be provided where appropriate). An object that restricts an operator's visibility presents special hazards when pushing. In these situations, it may be preferable to pull the object. It is advisable to use long vertical handgrips, where possible, in order to give the users the opportunity to grasp at their preferred height.

3.2.1.6 Environmental conditions

The surface over which the object is moved should be suitable for transporting the object and be well maintained. Slopes, ramps and steps increase the physical effort needed to push or pull an object, thereby increasing the workload on the musculoskeletal system and, consequently, the risk of injury. Wet or contaminated surfaces can present particular hazards to the operator when applying forces. Vibration, inappropriate lighting and hot and cold environments can impose additional hazards on the operator.

3.2.1.7 Individual characteristics

Individual skills and capabilities, the level of training, age, gender and health status are important characteristics to consider when carrying out a risk assessment (see 3.2.2.2). Skill and experience are likely to benefit the operator when performing the task and reduce the risk of injury. Training can increase the level of skill and ability to carry out a task. Shoes worn by the worker should provide adequate support and traction for the environment where the task takes place.

3.2.1.8 Work organization

The overall organization of the work performed by an operator can modify the risk of injury. Physical tasks performed other than pushing and pulling can contribute to operator fatigue and biomechanical loading over the course of the workday. All such tasks deserve their own risk assessment and evaluation.

It must be understood that the hazards posed by the pushing and pulling of objects often result from the combination or interaction of the various risk factors, e.g. high sustained forces over long distances. Furthermore, operators should be trained in how to safely perform each task and how to recognize hazardous workplaces, tasks and equipment conditions. Furthermore, operators should be made aware of the necessary procedures and communication channels through which to report and correct such hazards. Equipment and facilities must be regularly and properly maintained for safe usage and defective or damaged equipment must be removed from use immediately. All involved parties should be aware of safe operating and maintenance procedures. The equipment purchase process should be based upon clear task requirements and thus result in the selection of equipment suitable for the specific workplace and task conditions.

3.2.2 Risk estimation and risk assessment

The risk estimation approach adopts a multidisciplinary approach giving suitable consideration to biomechanical, physiological and psychophysical capabilities. The biomechanical approach considers force exertions in relation to both individual strength capabilities and the risk of injury, e.g. lumbar spine compression is considered in relation to lumbar spine strength for different age populations. The physiological approach takes into consideration energy expenditure and fatigue limits. The psychophysical approach takes into account workers’ perceptions of acceptable effort, forces and discomfort.

The risk assessment procedure identifies two methods by which to assess and evaluate the risks arising from pushing and pulling tasks. Method 1 provides a simple risk assessment checklist and psychophysical tables with which to quickly evaluate a task. The checklist addresses not only the assessment of risk and suggested threshold values, but also the identification of steps to reduce the level of risk. The psychophysical tables provide the means to determine acceptable initial and sustained forces by considering handle height, distance moved and frequency of push/pull tasks for males and females. It may be sufficient to carry out Method 1, taking appropriate action, or adopting practical solutions to ensure that the overall risk of injury is low. If the checklist is insufficient and the situation or population is not addressable by the psychophysical tables of Method 1, then Method 2 should be used.

Whereas Method 2 adopts a three-zone approach to determining the level of risk (green, yellow and red), the overall assessment stemming from Method 1 requires a risk rating based on two levels, either acceptable (green) or not acceptable (red). The three risk zones are defined as follows:

a) **Green zone (acceptable risk)**

   The risk of disease or injury is negligible or is at an acceptably low level for the entire operator population. No action is required.

b) **Yellow zone (conditionally acceptable risk)**

   There is a risk of disease or injury that cannot be neglected for the entire operator population or part of it. The risk shall be further estimated, analysed together with contributory risk factors and followed as soon as possible by redesign. Where redesign is not possible, other measures to control the risk shall be taken.

c) **Red zone (not acceptable)**

   There is a considerable risk of disease or injury that cannot be neglected for the operator population. Immediate action to reduce the risk (e.g. redesign, work organization, worker instruction and training) is necessary.

3.2.2.1 Method 1 — Generalized risk estimation and risk assessment approach

Method 1 (see Figure 2 and Annex A) adopts a checklist approach for identifying and determining the appropriate level of risk for pushing and pulling tasks.

Section A.1 of the checklist is used to record information about the job. Section A.2 provides guidance on acceptable forces based on psychophysical data, in conjunction with an examination of six categories of risk (A.2.1): the task; load characteristics; working environment; individual capability; work organization; and other factors. Based on the overall assessment made in section A.2, section A.3 is used to record a comprehensive assessment of the level of risk (i.e. green/red) arising from the task. When making a judgment as to the overall level of risk, initial consideration should be given to acceptable forces, and when either initial or sustained forces are exceeded for 90 % of the user population the task should be rated as high risk (i.e. RED). If initial and sustained forces are not exceeded, but a number of risk factors are identified from the checklist (A.2.2.), then the level of risk should also be rated as RED. For initial and sustained forces less than those specified and where only a small number of risk factors are present, the task can be considered low risk (i.e. GREEN), although every effort should be made to reduce the level of risk of those factors that remain. Where there is any doubt about the relative importance of risk factors in section A.2.2, or the number of risk factors present, the task should always be evaluated as RED or Method 2 applied.

Not all the questions in each category may be relevant to the task and it is important to realize that risk factors from each of the different categories may be inter-related and could have a great influence when found in combination. Therefore, it is important that each risk factor is not considered in isolation when making an overall judgment on the level of risk.

When the level of risk is considered high, steps should be taken to identify the cause of the problem and to determine what action should be taken to reduce the level of risk. A.4 allows for prioritizing risk reduction measures. Following the implementation of risk reduction measures, the task should be monitored and re-evaluated if the job changes. If the task and/or the working population do not fit the assumptions of the psychophysical tables, Method 2 should be implemented.

METHOD 1, see Annex A

Step 1 — Complete A.1.

Step 2 — Complete the checklist given by Table A.3 and determine the initial and sustained forces according to A.2.2:

a) determine handle height;

b) determine distance pushed or pulled;

c) determine frequency of pushes/pulls, both initial and sustained;

d) determine worker population, i.e. all male (use male limits) or all female or mixed male/female (use female limits);

e) consult Tables A.5 to A.8 to find acceptable initial and sustained forces to accommodate 90 % of the intended user population;

f) determine/measure actual initial and sustained forces (see Annex D).

Step 3 — Compare acceptable (see Tables A.5 to A.8) and measured forces and determine risk factors present from checklist. Rate the overall level of risk (see A.3) as follows:

- If actual forces (initial or sustained) are higher than recommended forces, rate the risk RED.
- If actual forces (initial or sustained) are less than recommended forces, but there is a predominant number of risk factors present, rate the risk RED.
- Otherwise, rate the risk GREEN

Step 4 — Prioritize and take action to reduce the risks (see A.4), or apply Method 2.

Figure 2 — Generalized risk estimation and assessment procedure — Method 1

3.2.2.2 Method 2 — Specialized risk estimation and risk assessment approach

Method 2 (see Annex B) adopts a procedure to determine whole-body pushing and pulling force limits according to specific characteristics of the population and the task. Method 2 is divided into four parts and should be applied according to Figure 3:

a) Part A — Muscle force limits;

b) Part B — Skeletal force limits;

c) Part C — Maximum forces permitted;

d) Part D — Safety limits.

Part A determines force limits based on static strength measurements and adjusts those forces according to population characteristics (i.e. age, gender and stature) and the requirements of the task (i.e. frequency, duration and distance of push/pull task). The procedure adopted in part B takes into account push/pull tasks resulting in high lumbar spinal compressive forces and adjusts push/pull forces according to spinal compression limits for age and gender.

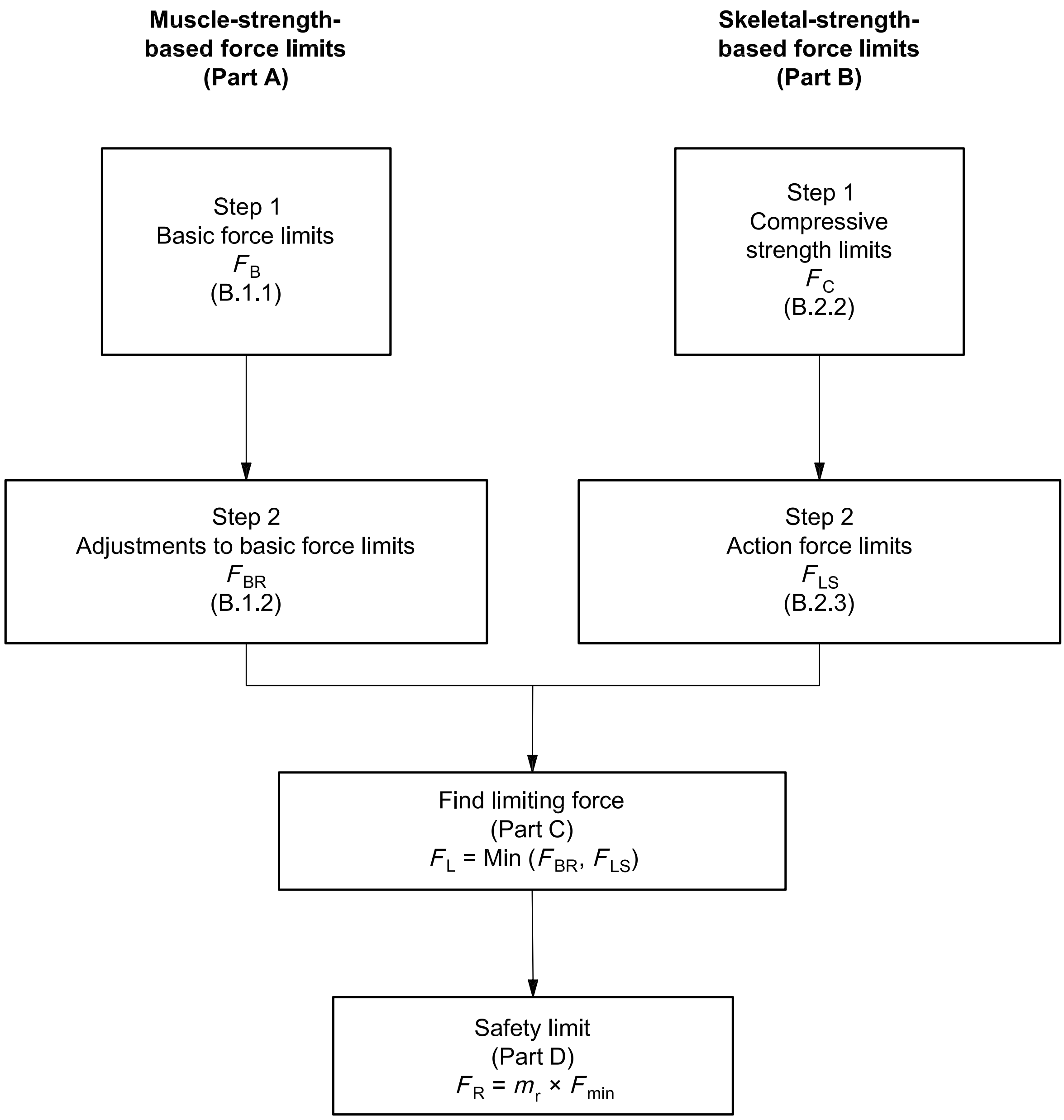


Figure 3 — Specialized risk estimation and assessment — Method 2

3.2.2.2.1 Part A — Muscle-strength-based force limits, F_{Br}

Part A adopts a two-step procedure for determining force limits adjusted to population (step 1) and task characteristics (step 2).

Step 1 — Basic force limits, F_B — Determine maximum static strength exertions for pushing/pulling of the intended user population taking into account age, gender and stature (refer to B.1.1 and B.1.2).

Step 2 — Determine F_{Br} by adjusting the basic force limits, F_B, according to the distance, d, and frequency, f, of the push/pull task (see B.1.3):

$$F_{Br} = F_B\left[1 - m_d(d) - m_f(f)\right]$$

where

F_B is the basic force limit;

m_d is the travel distance multiplier (see Table B.11 or B.12);

d is the travel distance (in metres) of the push/pull task;

m_f is the task frequency multiplier (see Table B.11 or B.12);

f is the frequency (number of times per minute) the task is repeated over the course of a working day.

3.2.2.2.2 Part B — Skeletal-based force limits, F_{LS}

Part B provides force limits based upon compressive strength characteristics of the lumbar spine. The procedure is described in Annex B and adopts a two step approach: 1) estimation of compressive strength limits, F_C, taking into account the age and gender of the user population; and 2) assessing the action force limit, F_{LS}, that corresponds to the compressive strength limit, F_C, of a specific push or pull action in the workplace. F_{LS} should not be exceeded by the actual force measured at the workplace, ensuring that the compressive strength limits of the lumbar spine are not exceeded.

Step 1 — Determine F_C, taking into account age and gender of the intended user population.

Step 2 — Determine the F_{LS} that corresponds with the compressive strength limit, F_C, in a specific push or pull action (using B.2, Figure B.3). Identify the relationship between

— F_{LS}, and

— action forces observed in the workplace.

Action forces measured in the workplace should not exceed the action force limit (F_{LS}).

3.2.2.2.3 Part C — Limiting force, F_L

Part C involves selecting the minimum force from either

a) muscle-based force limits, F_{Br}, or

b) skeletal-based force limits, F_{LS}.

$$F_L = \text{min.}\ (F_{Br}, F_{LS})$$

3.2.2.2.4 Part D — Safety limit, F_R

To evaluate the risk, the actual resultant force is compared with a safety limit, F_R, calculated from the minimum limiting force, F_{min}, and a risk multiplier, m_r, such that

$$F_R = m_r \times F_{min}$$

where

$m_r = 0{,}85$ represents the upper limit of the “green” zone;

$m_r = 1{,}0$ represents the upper limit of the “yellow” zone.

Then compare the actual force with F_R for the final evaluation. Use the actual initial force if the pushing or pulling distance of the task is less than, or equal to, 5 m and use the actual sustained force if the distance is greater than 5 m.

Note that pushing and pulling activities can induce high shear forces on the lumbar spine. Compared to spinal compressive forces, little is known about “safe limits” for spinal shear forces. Therefore, this part of ISO 11228 addresses spinal compressive forces and muscular strength only when evaluating limits for pushing and pulling.

3.2.3 Risk reduction

Risk reduction can be achieved by minimizing or excluding hazards which result from the task, the object(s) handled, the workplace, the work organization or the environmental conditions, examples of which are given in Annex C.

Annex A
(informative)

Method 1 — Pushing and pulling: general assessment checklist

A.1 Step 1

Complete Table A.1 and then, if the response is “Yes”, Table A.2.

Table A.1

Job description:	Is an assessment needed? (i.e. is there a potential risk of injury, and are the factors beyond the limits of the guidelines?) Yes/No [a]
[a] Circle as appropriate.	

Table A.2

Operations covered by this assessment (detailed description): Locations: Personnel involved: Date of assessment:	Diagrams (other information):

A.2 Step 2 — Assessment of potential risk factors

A.2.1 Check list

Complete the check list of Table A.3.

Table A.3

Questions to consider	**YES** (= risk)	**NO**	**Risks and potential problems** (make rough notes in this column in preparation for the possible remedial action to be taken)	**Suggestions/possible remedial action** (possible changes to be made to system/task, load, workplace/space, environment, communication needed)
Task evaluation — Are there... • High-accelerated motions to start, stop or manoeuvre the load? • Handles/couplings outside of the hip to elbow vertical height range of the user population? • Movements at high speed (over 1,2 m/s)? Hands used to hold a low load behind the body is outside the scope of this part of ISO 11228 and should be avoided				
The load or object to be moved... • Does it lack good handholds/coupling? • Is the load unstable? • Is vision over/around the load restricted? **If on casters/wheels...** • Does the load exceed the casters/wheels rating? • Is the floor surface in poor condition or does the floor otherwise create problems for caster/wheel operation? • Are swivel casters inappropriate/unsuitable for proper manoeuvrability? • Are brakes necessary to safely stop the movement of the load? (if brakes provided – no risk) • If brakes are used, are they effective?				

Table A.3 (*continued*)

Questions to consider	**YES** (= risk)	**NO**	**Risks and potential problems** (make rough notes in this column in preparation for the possible remedial action to be taken)	**Suggestions/possible remedial action** (possible changes to be made to system/task, load, workplace/space, environment, communication needed)
The working environment — Are there... • Confined spaces/narrow doorways? • Inadequate space provided for turning/manoeuvring? • One or more constraints on body posture/positioning? • Rutted/damaged/slippery floors? • Ramps/slopes/uneven surfaces? • Tripping hazards? • Poor lighting conditions? • Hot/cold/humid conditions? • Strong air movements?				
Individual capability — Does the job... • Require unusual capabilities? • Hazard those with a health problem? • Hazard those who are pregnant? • Call for special information/training?				
Other factors • Is movement or posture hindered by clothing or personal protective equipment?				

Table A.3 (*continued*)

Work organization	**Yes** (= risk)	**No**	**Where might the problems stem from?** (Make rough notes in this column in preparation for the possible remedial action to be taken)	**Possible remedial action** (possible changes to be made to management and organizational issues, communication needed)
Management and organizational issues — Is there... • Poor maintenance/cleaning of trolleys/carts/floor surfaces? • Poor general awareness of operating/maintenance procedures? • Poor communication between users of equipment and purchasers?				

A.2.2 Determining initial and sustained forces

Determine the following:

a) handle height;

b) distance pushed or pulled;

c) frequency of push/pull actions, both initial and sustained;

d) worker population, i.e. all male (use male limits) or all female or mixed male/female (use female limits);

e) by consulting Tables A.5 to A.8, find the acceptable initial and sustained forces to accommodate 90 % of the intended user population;

f) determine/measure the initial and sustained forces (see Annex D).

A.3 Step 3

Rate the overall risk of injury, RED/GREEN (see Figure 2, step 3). As a guide to rating the overall risk of injury, compare the acceptable forces (see Tables A.5 to A.8) with the measured forces:

a) if the actual forces are higher than the recommended forces, rate the risk as RED;

b) if the actual forces are less than the recommended forces, but there is a predominant number of risk factors present, rate the risk as RED;

c) otherwise, rate the risk as GREEN.

If, following remedial action, the overall assessment is RED or the level of risk is difficult to determine, take measures to reduce the risk or implement Method 2.

A.4 Step 4

Determine the risk reduction measures to be taken, using Table A.4.

Table A.4

Risk reduction measures that should be taken, in order of priority: 1 2 3 4 5		Date by which action should be taken:
Date for reassessment:		
Assessor's name:	Signature:	

Take action and verify that it has the desired effect.

A.5 Maximum acceptable forces

See Tables A.5 to A.8.

Table A.5

Handle height		Two-handed *pushing* — Maximum acceptable *initial* force — 90 % of population N															
		Frequency of pushing															
		10/min		5/min		4/min		2,5/min		1/min		1/2min		1/5min		1/8h	
cm		0,1667 Hz		0,0833 Hz		0,0667 Hz		0,042 Hz		0,0167 Hz		0,0083 Hz		0,0033 Hz		$3{,}5 \times 10^{-5}$ Hz	
m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f
		2 m pushing distance															
144	135	200	140	220	150					250	170			260	200	310	220
95	89	210	140	240	150					260	170			280	200	340	220
64	57	190	110	220	120					240	140			250	160	310	180
		8 m pushing distance															
144	135					140	150			210	160			220	180	260	200
95	89					160	140			230	160			250	190	300	210
64	57					130	110			200	140			210	160	260	170
		15 m pushing distance															
144	135							160	120	190	140			200	150	250	170
95	89							180	110	220	140			230	160	280	170
64	57							150	90	190	120			200	130	240	150
		30 m pushing distance															
144	135									150	120			190	140	240	170
95	89									170	120			220	150	270	180
64	57									140	110			190	120	230	150
		45 m pushing distance															
144	135									130	120			160	140	200	170
95	89									140	120			190	150	230	180
64	57									120	110			160	120	200	150
		60 m pushing distance															
144	135											120	120	140	130	180	150
95	89											140	120	160	130	200	160
64	57											120	100	140	110	170	130

m male

f female

For a worker population of all males, use male limits; for an all-female or mixed male/female population, use female limits. The low handle heights are not recommended.

Table A.6

Handle height		Two-handed *pushing* — Maximum acceptable *sustained* force — 90 % of population N															
		Frequency of pushing															
		10/min		5/min		4/min		2,5/min		1/min		1/2min		1/5min		1/8h	
cm		0,1667 Hz		0,0833 Hz		0,0667 Hz		0,042 Hz		0,0167 Hz		0,0083 Hz		0,0033 Hz		$3,5 \times 10^{-5}$ Hz	
m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f
		2 m pushing distance															
144	135	100	50	130	80					150	100			180	110	220	140
95	89	100	50	130	70					160	90			190	100	230	130
64	57	100	40	130	60					160	80			180	90	230	120
		8 m pushing distance															
144	135					60	50			130	70			150	80	180	110
95	89					60	50			130	80			150	90	180	110
64	57					60	50			120	70			140	80	180	110
		15 m pushing distance															
144	135							60	40	110	40			130	70	160	90
95	89							60	40	110	40			130	70	160	100
64	57							60	40	110	40			120	70	150	90
		30 m pushing distance															
144	135									60	40			120	60	160	80
95	89									60	40			120	60	160	90
64	57									60	40			110	60	150	80
		45 m pushing distance															
144	135									50	40			100	50	130	80
95	89									50	40			90	60	130	80
64	57									50	40			90	50	130	70
		60 m pushing distance															
144	135											70	30	80	40	110	60
95	89											70	30	80	40	110	60
64	57											70	30	80	40	100	60

m male

f female

For a worker population of all males, use male limits; for an all-female or mixed male/female population, use female limits. The low handle heights are not recommended.

Table A.7

Handle height		Two-handed *pulling* — Maximum acceptable *initial* force — 90 % of population N															
		Frequency of pulling															
		10/min		5/min		4/min		2,5/min		1/min		1/2min		1/5min		1/8h	
cm		0,1667 Hz		0,0833 Hz		0,0667 Hz		0,042 Hz		0,0167 Hz		0,0083 Hz		0,0033 Hz		$3{,}5 \times 10^{-5}$ Hz	
m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f
		2 m pulling distance															
144	135	140	130	160	160					180	170			190	190	230	220
95	89	190	140	220	160					250	180			270	210	320	230
64	57	220	150	250	170					280	190			300	220	360	240
		8 m pulling distance															
144	135					110	110			160	160			170	170	210	200
95	89					150	140			230	160			240	190	290	210
64	57					180	150			260	170			270	200	330	220
		15 m pulling distance															
144	135							130	100	150	130			160	150	200	170
95	89							180	100	210	140			230	160	280	180
64	57							200	110	240	150			260	170	310	190
		30 m pulling distance															
144	135									120	120			150	140	190	170
95	89									160	130			210	150	260	180
64	57									180	130			240	150	300	190
		45 m pulling distance															
144	135									100	100			130	140	160	160
95	89									140	130			180	150	230	180
64	57									160	130			210	150	260	190
		60 m pulling distance															
144	135											100	100	110	110	140	140
95	89											130	120	160	130	190	160
64	57											150	130	180	140	220	170

m male

f female

For a worker population of all males, use male limits; for an all-female or mixed male/female population, use female limits. The low handle heights are not recommended.

Table A.8

Handle height		Two-handed *pulling* — Maximum acceptable *sustained* force — 90 % of population N															
		Frequency of pulling															
		10/min		5/min		4/min		2,5/min		1/min		1/2min		1/5min		1/8h	
cm		0,1667 Hz		0,0833 Hz		0,0667 Hz		0,042 Hz		0,0167 Hz		0,0083 Hz		0,0033 Hz		$3{,}5 \times 10^{-5}$ Hz	
m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f
		2 m pulling distance															
144	135	80	50	100	80					120	100			150	110	180	150
95	89	100	50	130	80					160	100			190	110	240	140
64	57	110	40	140	80					170	90			200	100	250	130
		8 m pulling distance															
144	135					60	60			100	90			120	100	150	130
95	89					60	60			130	90			160	100	190	130
64	57					70	50			140	80			170	90	200	120
		15 m pulling distance															
144	135							60	40	90	60			100	80	130	110
95	89							70	40	120	60			140	80	170	110
64	57							70	40	120	60			150	70	180	100
		30 m pulling distance															
144	135									70	50			90	70	130	100
95	89									70	50			120	70	170	100
64	57									70	50			130	60	180	90
		45 m pulling distance															
144	135									50	50			80	70	100	90
95	89									60	40			100	60	140	90
64	57									60	40			110	60	150	80
		60 m pulling distance															
144	135											60	40	60	50	90	70
95	89											70	40	90	50	120	70
64	57											80	30	90	50	120	60

m male

f female

For a worker population of all males, use male limits; for an all-female or mixed male/female population, use female limits. The low handle heights are not recommended.

Annex B
(informative)

Method 2 — Specialized risk estimation and risk evaluation

Method 2 can be used to calculate basic force limits when pushing or pulling and accounts for both the demographic and anthropometric characteristics of the intended user population.

In particular, these characteristics include distributions of

— age,

— gender, and

— stature.

Basically, Method 2 is used to calculate force limits when pushing or pulling

a) at selected absolute handle heights,

b) for specified target populations.

Method 2 involves the following step-by-step approach.

B.1 Part A — Determining muscle-strength-based force limits

B.1.1 Step 1 — Calculating basic force limits

B.1.1.1 Summary of procedure

The procedure for calculating the basic force limits, F_B, is as follows:

a) collect input data (see B.1.1.2);

b) adjust the force data to age and gender distributions of the target population (see B.1.1.3);

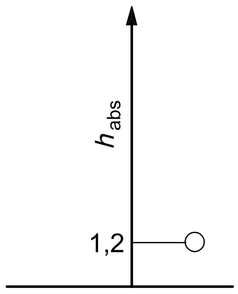
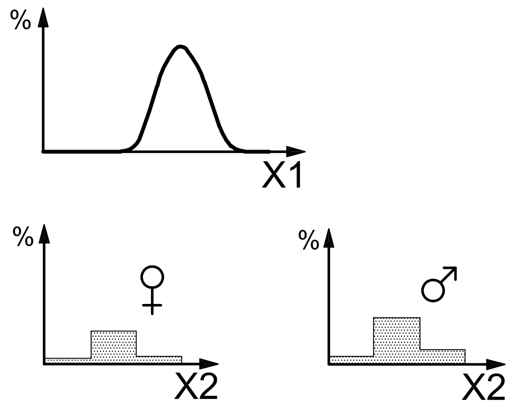
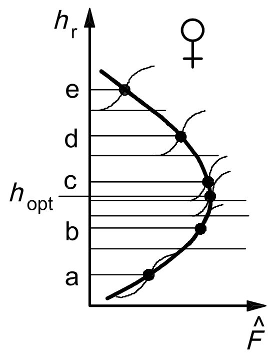
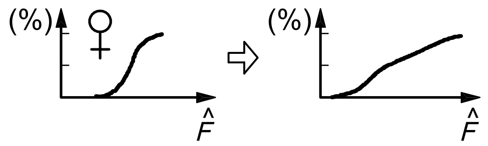
c) adjust the force data to stature distributions of the target population (see B.1.1.4);

d) determine F_B (see B.1.1.5).

B.1.1.2 Collecting input data

See Table B.1.

Table B.1 — Collecting input data

Input		Description	Graphical examples
1	Determine absolute handle height, h_{abs}.	For example, 1,2 m	
2	Determine target group characteristics.	Target group characteristics: — stature distribution — distributions of age and gender	
3	Determine strength distributions of reference group based on experimental findings. See Figure B.1.	Strength distributions of reference group: — i.e. young females — when pushing or pulling — at selected relative handle heights, h_r (a – e)	
4	Apply "synthetic distribution procedure" as described in Annex F.	Demographic fitting leads to synthetic distributions according to Annex F.	 a) Young women b) Target population

X1 stature

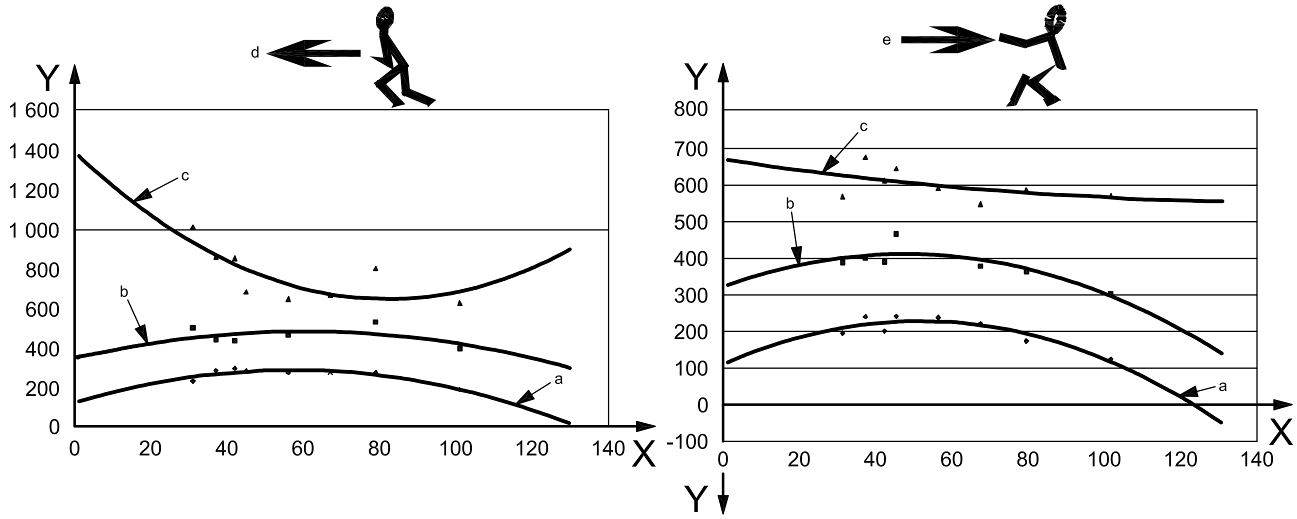
X2 age

$\hat{F}$ physical strength, N

h_{abs} absolute height, m

h_{opt} optimal relative working height

h_r relative handle height, %



a) Pushing **b) Pulling**

Key

X relative working height, %

Y strength, N

a 5th percentile.

b 50th percentile.

c 95th percentile.

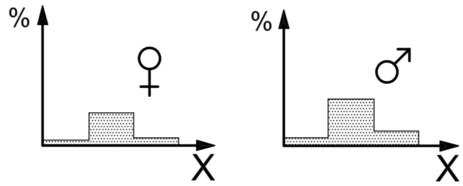
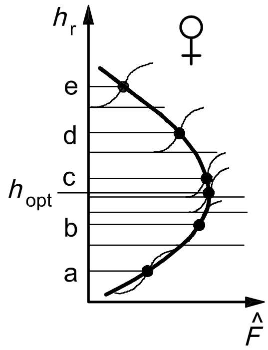
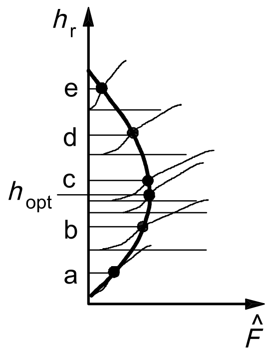
Figure B.1 — Strength percentiles depending on relative working heights (see Reference [7])

B.1.1.3 Adjusting forces to age and gender of intended users

Adjust the strength distributions of the reference group (females) to the characteristics of the intended user population. This transformation applies to strength distributions at all relative working heights and yields a set of new strength distributions, modified in position and shape, i.e. normal distribution no longer applies. Resulting distributions are made up by a combination of weighted normal distributions, with each reflecting its subgroup in age and gender.

This procedure, referred to as the “synthetic distributions procedure” is presented in Annex F. Generally, this procedure involves three basic actions as summarized in Table B.2.

Table B.2 — Adjusting strength to age and gender

<table>
<tr><th colspan="2">Action</th><th>Description</th><th>Graphical examples</th></tr>
<tr><td>1</td><td>Determine target population.</td><td>The demographic profile of a target population is given by its distribution of age and gender.</td><td>
</td></tr>
<tr><td>2</td><td>Select strength distributions of reference group.</td><td>Strength distributions of reference group:
— i.e. young females
— when pushing or pulling
— at selected relative handle heights, h_r (a – e)</td><td>
</td></tr>
<tr><td>3</td><td>Apply “synthetic distribution procedure” in accordance with Annex F.</td><td>This procedure yields a set of strength distributions at selected relative handle heights, h_r, adjusted to the target population.</td><td>
</td></tr>
<tr><td colspan="4">X age
$\hat{F}$ physical strength, N
h_{opt} optimal relative working height
h_r relative handle height, %</td></tr>
</table>

B.1.1.4 Adjusting strength to stature distributions

Strength distributions should reflect the effects of stature as well as age and gender. Adjust the strength distributions derived in B.1.1.3 to particular stature distributions of specific user populations, i.e. pushing strength will change when shifting from tall to medium-sized or shorter populations.

This is described in Table B.3.

Table B.3 — Adjusting strength to stature distribution

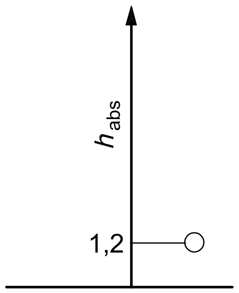
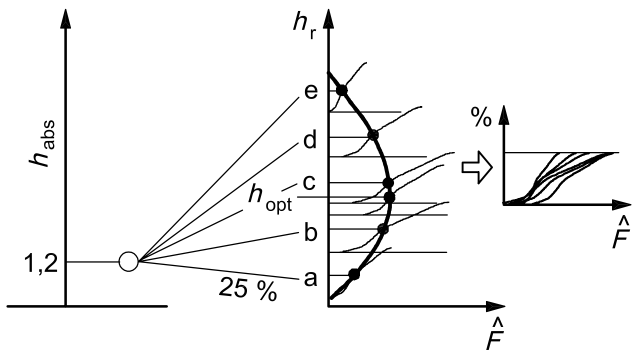
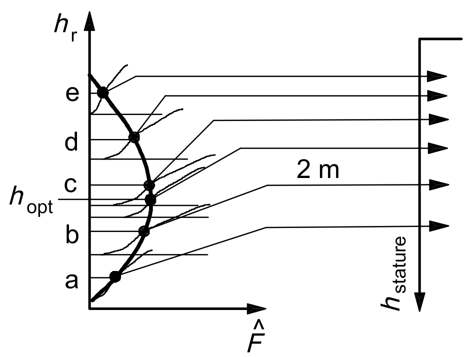
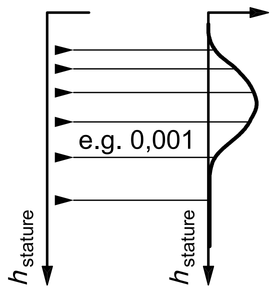
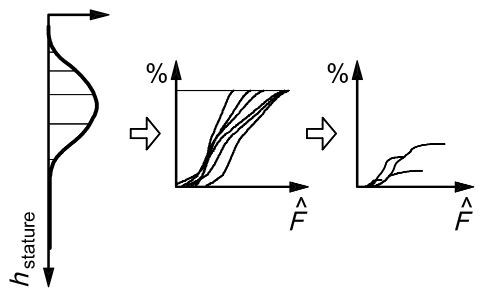
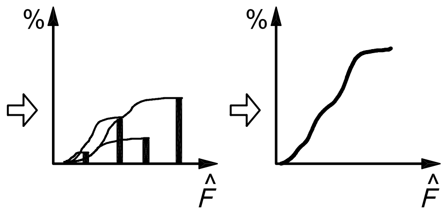
	Action	Description	Graphical examples
1	Select absolute handle height.	Select absolute handle height of interest, e.g. 1,2 m above ground.	
2	Rearrange strength distributions obtained in Table B.2.	Go to selected relative handle heights. Pick up all the adjusted strength distributions at all relative heights and combine them in a single chart. a – e: optional relative working heights	
3	Predict statures.	Predict statures for each relative working height, i.e.: — when working at h_{abs} = 0,5 m above ground — at a relative working height h_r = 25 % — then stature (or a 100 %) results in $h_{stature}$ = 2 m	
4	Determine weighting multipliers from stature distributions.	Find frequencies of all predicted statures — e.g. the probability of meeting a 2 m tall person might be 0,001. This probability is the weighting factor applicable to the corresponding strength distribution.	
5	Weight strength distributions.	Multiply each strength distribution by its stature probability. This yields a set of weighted distributions.	

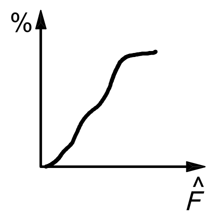
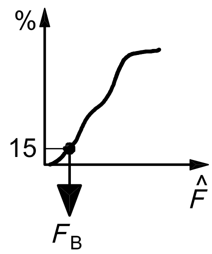
Table B.3 (*continued*)

Action		Description	Graphical examples
6	Calculate a combined distribution function.	Add up all of the weighted distributions. This yields a combined distribution function.	
$\hat{F}$ physical strength, N h_{abs} absolute height, m h_{opt} optimal relative working height h_r relative handle height, % $h_{stature}$ stature, m; $h_{stature} = 100\ (h_{abs}/h_r)$ m			

B.1.1.5 Determining force limits

Force limits may be found by taking a percentile approach as described in EN 1005-3[11]. An outline of the procedure is given in Table B.4.

Table B.4 — Determining basic force limits, F_B

Action		Description	Graphical examples
1	Refer to results from Table B.3.	Continue with the combined distribution function:	
2	Find basic force limit, F_B.	Determine a percentile limit that includes force capacities of a defined majority (85 %) of the intended user population.	
$\hat{F}$ physical strength, N F_B basic force limit			

B.1.1.6 Example demonstrating effects of muscle-based force limits

a) Scenario

1) Activity: pushing

2) Population:

i) American (A)

ii) Japanese (B)

3) Absolute working height: 1,5 m

b) Assumptions

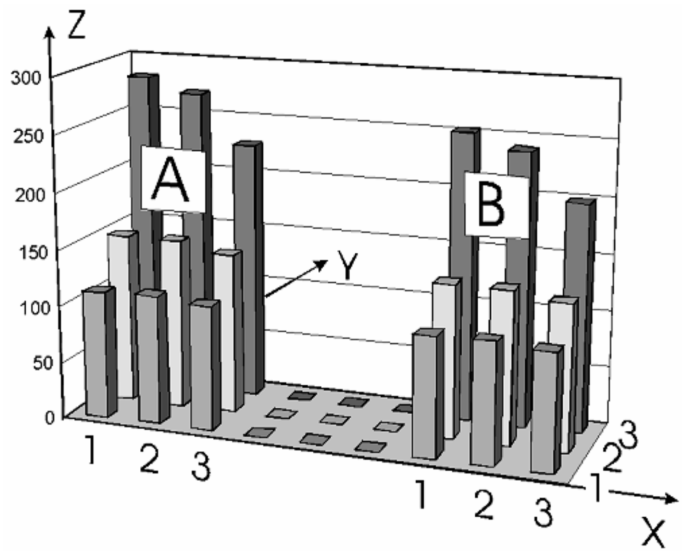
1) Physical strength: identical strength distributions in both nationalities

2) Load limits: 15th percentile

This example calculates basic force limits, F_B, when pushing. These limits refer to American and Japanese populations which differ widely in stature distributions. Strength distributions of both nations were assumed to be identical.

Each of the two nationalities encloses a variety of predefined subpopulations specified in particular by a mix of age and gender.

See Figure B.2.



Key

A American

B Japanese

X age mixes 1 junior
2 all ages
3 senior

Y gender mixes 1 mix 1
2 mix 2
3 mix 3

Z basic force limits, F_B, N

NOTE See d) for an explanation of the mixes.

Figure B.2 — Adaptive muscle-based force limits varying within a user population and between two different user populations

c) Age mixes

This example identifies three age mixes, grouping the general working population:

1) junior — population clusters in age group 1 (age $<$ 20 years);

2) all ages — equal distributions in all three age groups (age $<$ 20 years, 20 years $\leqslant$ age $<$ 50 years, and 50 years $\leqslant$ age $<$ 65 years);

3) senior — population clusters in age group 3 (50 years $<$ age $\leqslant$ 65 years).

d) Gender mixes

Each of the above age mixes realizes three different ratios between males and females:

1) mix 1: males to females = 0:100 %;

2) mix 2: males to females = 50:50 %;

3) mix 3: males to females = 100:0 %.

A combination of the above mixes in age and gender further yields a 3 $\times$ 3 array as shown in Figure B.2.

e) Calculation of basic force limits, F_B

1) at the position of each element in the array, and

2) for both American and Japanese populations.

f) Interpretations

The results shown by Figure B.2 quantitatively demonstrate the wide adaptivity of this kind of force limit. The limits not only reflect given demographic profiles, but account for variations in stature distributions as well.

As for demographic profiles, strength limits in both nations decrease with

1) increasing age, and

2) increasing female representation.

Figure B.2 demonstrates clearly the way in which the two nationalities shape force limits as an effect of differing stature distributions.

B.1.2 Precalculated force limits

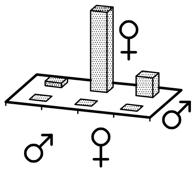
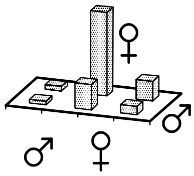
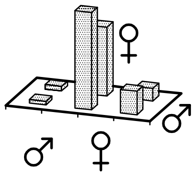
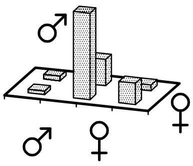
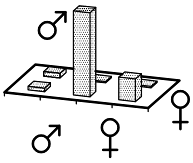
This subclause provides a set of basic force limits, F_B, that can be used to bypass the procedure given in B.1.1. Selected examples refer to standard situations when pushing or pulling.

Precalculated basic force limits, F_B, may be found as follows:

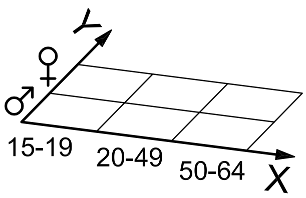
a) first, select the subgroup from Tables B.5 and B.6 that best approximates the target population;

b) then find precalculated force limits in Tables B.7 to B.10.

Table B.5 — Population subgroup profiles varying in age and gender and reflecting all ages of adult working population

Gender distribution male to female ratio %	Visualization [a]	Population subgroup no.
0:100	 0 % : 100 %	1
25:75	 25 % : 75 %	2
59:41 Natural distribution	 59 % : 41 %	3
75:25	 75 % : 25 %	4
100:0	 100 % : 0 %	5

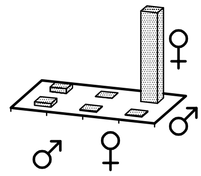
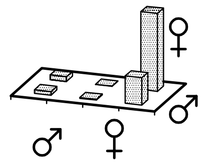
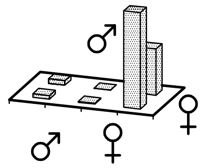
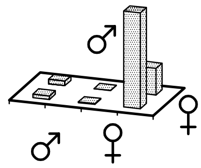
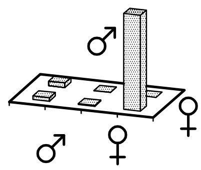
a



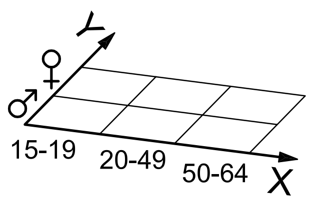
X age

Y sex

Table B.6 — Population subgroup profiles varying in age and gender and reflecting elderly working population (50–64 years)

Gender distribution male to female ratio %	Visualization [a]	Population subgroup no.
0:100	 0 % : 100 %	6
25:75	 25 % : 75 %	7
59:41 Natural distribution	 59 % : 41 %	8
75:25	 75 % : 25 %	9
100:0	 100 % : 0 %	10

a



X age

Y sex

Table B.7 — Basic force limits, F_B, when PUSHING, accounting for absolute working height, h_w, and population subgroup — Central European working population, PROFESSIONAL users

Absolute working height, h_w m	Basic force limits, F_B N									
	Population subgroup no.[a]									
	1	2	3	4	5	6	7	8	9	10
2,05	40	54	87	111	165	35	46	71	81	110
1,9	72	87	120	146	205	66	78	104	114	146
1,75	93	108	142	171	239	87	98	127	139	176
1,6	111	125	159	190	266	103	115	146	159	201
1,45	125	138	172	204	287	117	128	160	174	220
1,3	135	147	180	214	301	126	138	170	185	234
1,15	141	153	185	218	310	133	144	176	192	242
1,0	144	156	187	221	312	136	146	178	194	244
0,85	144	155	185	218	308	135	145	176	191	241
0,7	139	150	180	213	299	131	141	171	186	233
0,55	132	142	172	203	282	123	133	161	175	218
0,4	120	131	160	189	260	113	122	148	160	198
0,25	106	116	144	171	232	99	107	131	141	173

NOTE 1 Age and gender distribution according to the Europe of the 12 members states, 1993.

NOTE 2 Stature distribution according to Reference [8].

NOTE 3 Strength distribution according to DIN 33411-5 [7].

NOTE 4 Technical solutions could possibly completely transform the task or at least improve the condition for it.

NOTE 5 Although these data are presented, it is not advisable to work above shoulder height.

NOTE 6 These data are not recommended force limits.

a Refer to Tables B.5 and B.6.

Table B.8 — Basic force limits, F_B, when PULLING, accounting for absolute working height, h_w, and population subgroup — Central European working population, PROFESSIONAL users

Absolute working height, h_w m	Basic force limits, F_B N									
	Population subgroup no. [a]									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2,05	14	22	42	57	91	11	17	32	38	56
1,9	40	50	74	92	132	36	44	62	70	92
1,75	61	72	98	119	167	56	65	86	95	122
1,6	78	90	117	141	197	73	82	106	116	147
1,45	93	104	132	158	221	87	97	122	133	168
1,3	105	116	143	171	240	98	108	134	146	184
1,15	113	123	151	180	252	106	115	142	155	195
1,0	118	128	156	185	259	111	120	147	160	201
0,85	120	130	158	187	261	113	122	148	161	202
0,7	119	129	156	185	257	111	120	146	159	198
0,55	114	124	152	179	247	107	116	141	153	189
0,4	107	116	143	169	231	100	108	131	142	175
0,25	96	106	132	156	212	89	97	119	128	157

NOTE 1 Age and gender distribution according to the Europe of the 12 member states, 1993.

NOTE 2 Stature distribution according to Reference [8].

NOTE 3 Strength distribution according to DIN 33411-5 [7].

NOTE 4 Technical solutions could possibly completely transform the task or at least improve the condition for it.

NOTE 5 Although these data are presented, it is not advisable to work above shoulder height.

NOTE 6 These data are not recommended force limits.

[a] Refer to Tables B.5 and B.6.

Table B.9 — Basic force limits, F_B, when PUSHING, accounting for absolute working height, h_w, and population subgroup — Central European working population, DOMESTIC users

Absolute working height, h_w m	Basic force limits, F_B N									
	Population subgroup no. [a]									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2,05	N/A	N/A	N/A	1	54	N/A	N/A	1	1	31
1,9	24	28	38	47	84	20	24	33	38	55
1,75	39	44	55	65	112	35	39	51	56	78
1,6	54	59	70	80	136	49	53	65	71	99
1,45	66	71	82	92	156	61	65	77	83	117
1,3	76	81	91	101	170	70	74	86	92	130
1,15	83	87	97	106	179	77	81	92	98	139
1,0	86	90	100	108	182	80	83	94	100	141
0,85	86	90	99	107	179	80	83	93	99	139
0,7	82	86	94	103	171	76	79	89	95	132
0,55	75	78	86	94	157	69	72	81	86	119
0,4	66	68	76	83	137	60	63	71	75	101
0,25	53	56	63	69	114	48	51	58	62	81

NOTE 1 Age and gender distribution according to the Europe of the 12 member states, 1993.

NOTE 2 Stature distribution according to Reference [8].

NOTE 3 Strength distribution according to DIN 33411-5 [7].

NOTE 4 Domestic users include younger and elderly non-working population.

NOTE 5 Technical solutions could possibly completely transform the task or at least improve the condition for it.

NOTE 6 Although these data are presented, it is not advisable to work above shoulder height.

NOTE 7 These data are not recommended force limits.

[a] Refer to Tables B.5 and B.6.

Table B.10 — Basic force limits, F_B, when PULLING, accounting for absolute working height, h_w, and population subgroup — Central European working population, DOMESTIC users

Absolute working height, h_w m	Basic force limits, F_B N									
	Population subgroup no. [a]									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2,05	N/A	N/A	N/A	1	22	N/A	N/A	N/A	1	10
1,9	9	12	18	24	48	8	10	15	18	30
1,75	23	26	35	42	74	20	23	31	35	50
1,6	36	40	49	56	97	32	36	45	49	69
1,45	47	51	60	68	116	43	47	56	61	85
1,3	57	61	70	77	131	52	56	65	70	98
1,15	64	67	76	83	140	58	62	71	76	107
1,0	68	71	79	87	145	62	66	75	80	111
0,85	69	72	80	87	146	63	66	75	80	111
0,7	67	70	78	85	142	62	65	73	78	107
0,55	63	66	73	80	133	58	60	68	73	99
0,4	56	59	66	72	119	51	54	61	65	87
0,25	47	49	56	62	102	42	45	51	55	72

NOTE 1 Age and gender distribution according to the Europe of the 12 member states, 1993.

NOTE 2 Stature distribution according to Reference [8].

NOTE 3 Strength distribution according to DIN 33411-5 [7].

NOTE 4 Domestic users include younger and elderly non-working population.

NOTE 5 Technical solutions could possibly completely transform the task or at least improve the condition for it.

NOTE 6 Although these data are presented, it is not advisable to work above shoulder height.

NOTE 7 These data are not recommended force limits.

a Refer to Tables B.5 and B.6.

B.1.3 Step 2 — Adjusting basic force limits

B.1.3.1 General

Adjustments to the basic force limits, F_B, should be carried out in accordance with the actual workplace task to be performed. This is achieved using the following procedure.

a) Determine the travel distance, d, in metres, over which the object is pushed or pulled.

b) Identify the task frequency, f, (push/min or pull/min) over the course of the working day.

c) Adjust F_B as follows:

$$F_{Br} = F_B\left[1 - m_d(d) - m_f(f)\right] = F_B m(d,f)$$

where

F_B is the basic force limit;

m_d is the travel distance multiplier (see Table B.11 or Table B.12);

d is the travel distance (m) of the push/pull task;

m_f is the task frequency multiplier (see Table B.11 or Table B.12);

f is the frequency (times/min) with which the task is repeated over the course of a working day.

The resulting capacity limits, F_{Br},

— reflect demographic and anthropometric characteristics of the envisaged user population (see B.1.1 or B.1.2),

— are adjusted to actual workplace requirements.

B.1.3.2 Multiplier, $\overline{m}$, for mixed populations

If the target population includes a mix of males and females, an average multiplier, $\overline{m}$, applies:

$$\overline{m} = \frac{1}{100}\left(p_m \cdot m_m + p_f \cdot m_f\right)$$

where

p_m is the percentage of males;

m_m is the male multiplier;

p_f is the percentage of females;

m_f is the female multiplier.

Table B.11 — Multipliers for travel distance < 5 m (use for evaluation of initial forces)
(adapted from Reference [9])

Distance m	m_d	
	Males	**Females**
< 5	0,3	0,23

Frequency times/min (Hz)	m_f
0,2 (0,0033)	0,15
0,5 (0,0083)	0,20
1 (0,01667)	0,25
2,5 (0,042)	0,30
4 (0,0667)	0,33

Table B.12 — Multipliers for travel distance ⩾ 5 m (use for evaluation of sustained forces)
(adapted from Reference [9])

Distance m	m_d	
	Males	Females
5	0,18	0,27
10	0,26	0,39
15	0,31	0,46
20	0,34	0,51
25	0,36	0,55
30	0,38	0,58
35	0,40	0,61
40	0,42	0,63
45	0,43	0,65
50	0,44	0,67
55	0,45	0,68
60	0,46	0,70
65	0,47	0,71

Frequency	m_f
10/min (0,16667 Hz)	0,49
5/min (0,0833 Hz)	0,48
4/min (0,0667 Hz)	0,47
2,4/min (0,04 Hz)	0,43
1/min (0,01667 Hz)	0,36
1/2 min (0,0083 Hz)	0,30
1/5 min (0,0033 Hz)	0,22
1/10 min (0,001667 Hz)	0,18
1/20 min (0,000833 Hz)	0,14
1/40 min (0,000417 Hz)	0,11
1/60 min (0,000278 Hz)	0,09
1/120 min (0,000139 Hz)	0,07
1/240 min (0,000069 Hz)	0,05
1/360 min (0,000035 Hz)	0,04

B.2 Part B — Skeletal-strength-based force limits

B.2.1 General

In addition to the muscle-based force limits, F_B and F_{Br}, the approach of this part of ISO 11228 takes into consideration spinal compressive force limits. This approach involves two steps:

a) estimating compressive force limits of lumbar spine;

b) finding action force limits.

B.2.2 Step 1 — Estimate compressive-strength-based force limits

Human spinal strength depends upon age and gender (see Figure B.3). Therefore, spinal limits should depend on demographic profiles. For this purpose, the demographic approach is comparable with that of the muscle force limits (see Clause B.1).

The lumbar spine limits change with different user populations. Table B.13 provides a variety of precalculated lumbar spine limits generated for a set of preselected situations, including:

— two different age groups — USA “physically active” adult population and “physically active” USA-seniors;

— a set of specified ratios between males and females.

Precalculated limits in Table B.13 change in a “natural” way with varying profiles of target populations.

Refer to Table B.13 for precalculated lumbar spine limits or use the following procedure to calculate them:

— start with the compressive strength data from Figure B.3 or other validated data;

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

— introduce age classes;

— calculate distribution parameters (percentiles or average and standard deviation) of compressive strength in each age class;

— generate log-distributions of compressive strength in all age classes;

— obtain a demographic profile of target population using above age intervals;

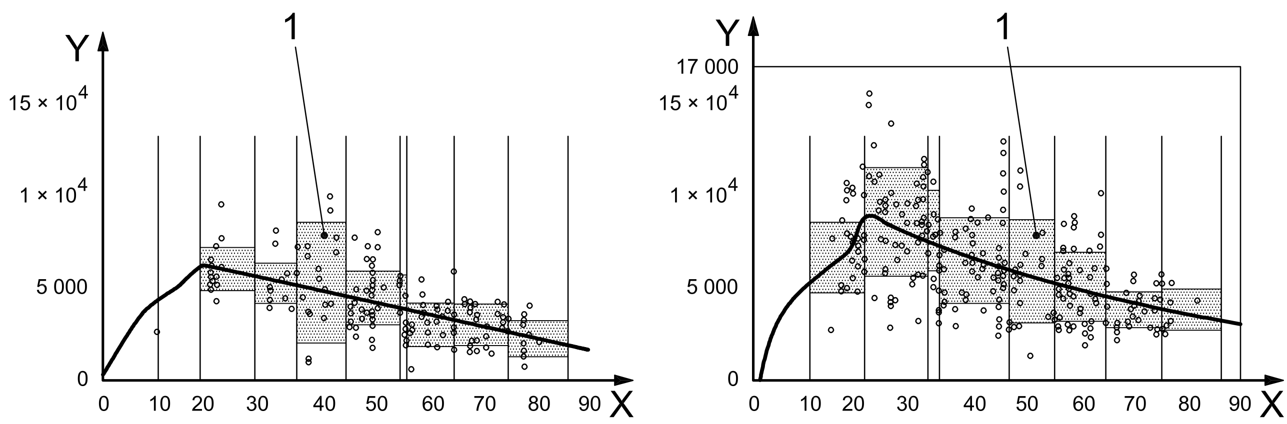
— find weighting multipliers accounting for the demographic weight of each age class;

— multiply each age class distribution by its “own” weighting multiplier;

— sum up all weighted age class distributions to get total spinal strength distributions in both males and females;

— integrate total strength distributions with increasing strength to find total strength distribution functions of males and females;

— determine the 15th percentile to find compressive strength limits of the lumbar spine.



a) Females

b) Males

Key

X age, years

Y compressive strength, N

1 percentile intervals: 15th to 85th percentiles

Figure B.3 — Compressive strength of lumbar spine (including regressions and distribution parameters of age classes) [1], [6]

Table B.13 — Precalculated compressive-strength-based force limits varying with selected user populations

Ratio males:females %	Compressive force limits of lumbar spine [a]	
	Active adults males: 20–64 years females: 18–64 years	**Active seniors** males and females: 56–64 years
0:100	2,8	2,0
25:75	3,0	2,1
Natural	3,3	2,3
75:25	3,6	2,6
100:0	3,9	3,1

[a] Target population: USA, 2 000.

B.2.3 Step 2 — Determine action force limits

A second step determines limitations of externally applied forces in such a way that the compressive force limits of the lumbar spine will not be exceeded.

At the time of publication of this part of ISO 11228, the procedure given in Table B.14 is valid.

Table B.14 — Procedure for determining action force limits

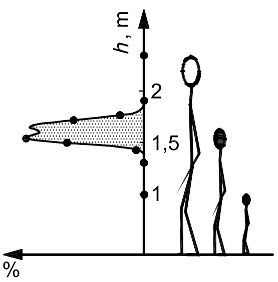
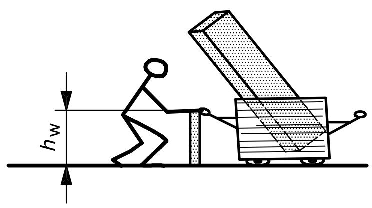
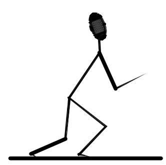
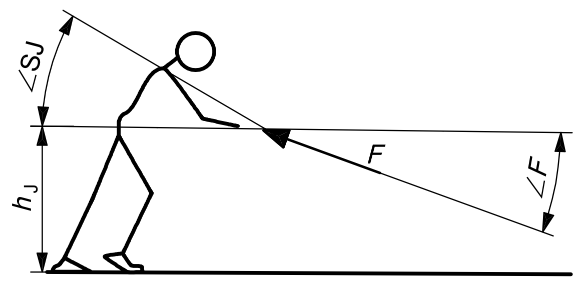
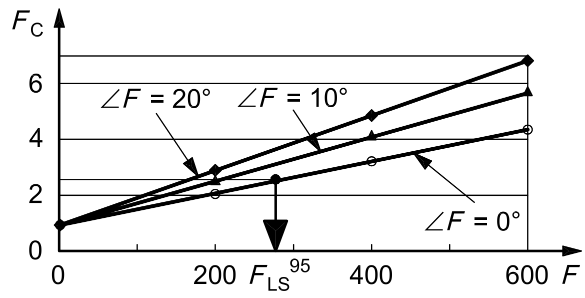
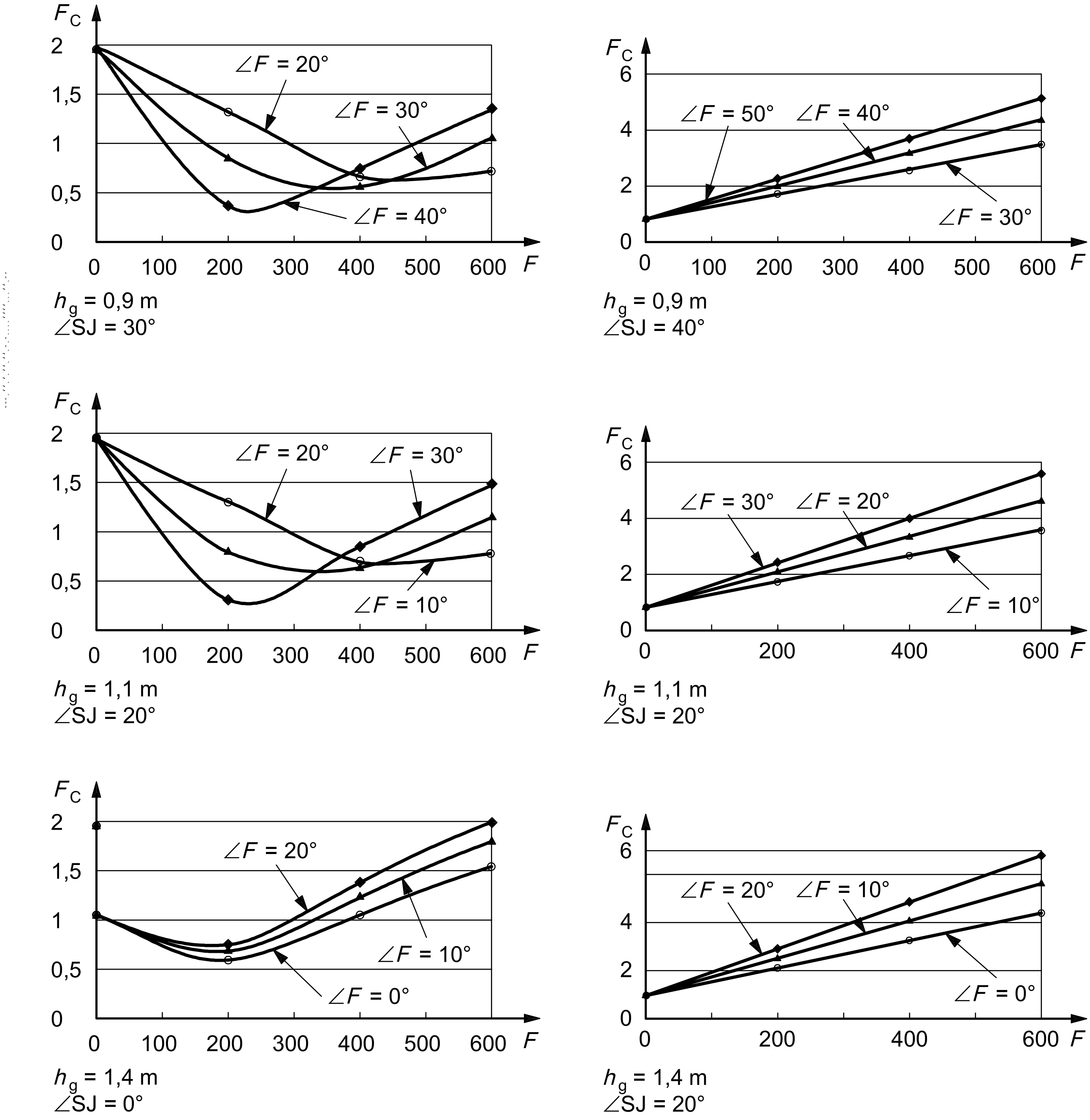
Determine the stature of the 5th, 50th and 95th percentile of the envisaged user population.	EXAMPLE 
Select or measure the absolute working height, h_w.	EXAMPLE 
Predict or observe the most common working posture for the three selected percentiles.	EXAMPLE 

Table B.14 (*continued*)

Derive the shoulder joint angle, ∠ SJ, for the three selected percentiles. Find the force angle, ∠ F, for the three selected percentiles.	EXAMPLE 
Select appropriate charts for the three selected percentiles relating compressive loads of lumbar spine to actual workplace activities.	See Figure B.4
Determine action force limits, F_{LS}, using the chart selected for the three selected percentiles. Find the minimum value of F_{LS}: $F_{LS} = \text{min.}\left(F_{LS}^{15}, \bar{F}_{LS}, F_{LS}^{95}\right)$	EXAMPLE  h_g = 1,4 m ∠SJ = 20°

Y	stature, m
h_g	grip height, m
h_w	absolute working height, m
F	action force, N
∠ F	force angle, degrees
F_C	compressive load, kN
F_{LS}	action force limits, N
∠ SJ	shoulder joint angle, degrees



a) Pushing **b) Pulling**

Key

F action force, N

F_C compressive load on L5/S1, kN

Figure B.4 — Compressive loads of lumber spine depending upon action forces at selected pushing or pulling activities [2]

Annex C
(informative)

Risk reduction methods

C.1 Introduction

Scientific knowledge stresses the importance of an ergonomic approach in removing or reducing the risks associated with pushing or pulling. Ergonomics focuses on the design of work and its accommodation of human physical and mental capacities (see ISO 6385 [21]). An ergonomic approach considers tasks in their entirety, taking into account a range of relevant factors, including the nature of the task, the characteristics of the object handled, the working environment and individual’s limitations and capabilities.

C.2 Repetitive handling

In seeking to avoid injury from pushing or pulling, it is pertinent to ask whether these tasks can be eliminated altogether. A mechanical handling system rather than a manual system should be considered when push/pull tasks are hazardous and engineering improvements to the manual system are limited.

However, the introduction of automation or mechanization may create new risks. All equipment should be well maintained, compatible with the rest of the work system, effective, appropriately designed and easily operated. Workers should be properly trained to use the equipment safely and effectively. Operating instructions and safety concerns should be indicated on the equipment.

C.3 Design of work — Task, workplace and work organization

C.3.1 Task

C.3.1.1 General

The physical load placed on the back and shoulders when pushing and pulling may increase owing to any one or more of the following:

- increased forces;
- use of awkward postures (twisted, lateral bent or flexed trunk postures);
- long distances of movement;
- long work durations;
- high movement frequencies.

The task should therefore be designed in such a way that these risk factors are avoided. Activities for pushing/pulling tasks should also be varied so as to allow adequate recovery time.

C.3.1.2 Impact of posture and force direction on maximum pushing and pulling forces

Force exertions should always be considered in relation to posture. Unsuitable postures may increase the required force as they increase the postural workload or decrease postural stability (e.g. pushing an object while the trunk is bent forward increases the compressive load on the lumbar spine and decreases postural stability). Altering the posture to suit the intended force application (i.e. making use of the position and mass distribution of body segments) can decrease the force needed (e.g. upright postures while pushing an object will often lead to higher force demands and decreased stability when compared to leaning forward).

Ideally, the handle height and configuration of the object pushed or pulled should minimize vertical force components and provide for a nearly complete horizontal force exertion. Safe floor conditions and good coupling between the shoe of the worker and the floor is also necessary to allow the worker to adapt and maintain an effective posture.

High forces or inappropriate handle heights, however, will result in increasing vertical force components. For this reason, for the application of Method 2, the input initial and sustained forces are the measured resultant forces required to push or pull the object in question (see Annex E).

C.3.2 Workplace

The workplace should be designed in such a way that it contains no risks for pushing and pulling tasks [12].

— The working areas should be large enough to allow adequate room to manoeuvre. Sufficient space is a prerequisite for carrying out work efficiently and in appropriate working postures.

— Floor or ground surfaces should be level, clean, dry and unbroken, to avoid potential slipping or tripping accidents.

— Slopes or ramps should be of a low gradient to avoid accidents or high forces.

— Stacking heights should be restricted to improve visibility.

— Doors should be opened automatically instead of manually to reduce the frequency of initial pushes and pulls.

C.3.3 Work organization

The work should be organized in such a way that

— the composition, frequency and duration of the task allow adequate physiological recovery time for the worker, and

— the worker has some degree of autonomy in how he/she can organize the task.

The above concerns for push/pull tasks are embedded in the psychophysical force limits presented in Annex A. Additional tasks performed by the worker may also need to be evaluated and the metabolic demands and recovery requirements, if necessary, assessed overall for all tasks. Job enrichment, job enlargement and job rotation may have a key role to play providing recovery, variety and maintaining levels of production output. These tasks should involve the use of a different muscle groups.

The worker should be able to adjust the rate or pace of his/her work to his/her own capabilities. Work with a strictly fixed rate or pace is not recommended. To reduce the distance of loads to be pushed or pulled, it is recommended that storage areas be positioned close to production areas. The amount of work undertaken in fixed postures is also an important consideration. Recommendations concerning working postures are made in ISO 11226 [23].

C.4 Design of object, tool or material handled

The object to be handled may constitute a hazard because of its size or shape. In determining whether the object represents a risk, proper account must also be made of the way and circumstances in which the object 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.

In addition, there may be physical or chemical hazards which should also be indicated, e.g. the object could have sharp edges, be too hot or too cold to touch or be contaminated, or could contain materials or substances which are hazardous if spilled.

C.4.1 Coupling and hand holds

A good hand grip or coupling with the object being pushed or pulled is essential if accidents with respect to handling are to be avoided and it is often determined by the characteristics of the object. The handles should be positioned at a suitable height and distance apart. For example, trolley handles should be positioned between hip and elbow height (between 90 cm and 115 cm), see (Reference [12]). The size of hand grips should suit the size of the hand of both women and men — preferably between 3,0 cm and 4,5 cm in diameter. The handle or handhold should be of adequate length to allow variation in grasp for manoeuvring and manipulation of the load. At least 6 cm of free space around the handhold should be provided to allow adequate clearance for a lightly gloved hand. The design should enable a safe range of body postures or joint angles.

The operating mechanism should minimize static load (duration of the holding of a posture for a sustained period of time), should optimize the amount of force needed and should enable the worker sufficient recovery periods. Therefore, the necessity of pressing or holding controls for a sustained period should be avoided.

In most cases, the health risks associated with pushing an object are lower than the risks from pulling an object. The operator should wear appropriate footwear to protect the foot and to achieve adequate coupling with the floor surface. Footwear and proper maintenance and cleaning of the floor surface should reduce slipping risks.

C.4.2 Wheels and castors

Trolleys and other wheeled equipment should be provided with suitable wheels or castors (e.g. having the proper size and composition). The selection of castors for wheeled equipment such as trolleys and carts is one of the more critical factors in ensuring acceptable forces and safe handling conditions. The castors/wheels should be rated for the load. Swivel castors should be located on the push end of the load for proper manoeuvrability. The equipment should be regularly lubricated and adequately maintained according to the manufacturer's specifications. Good bearings, larger wheel diameter, wheel material, width and profile suitable for the surface over which it will travel can all help to reduce push/pull forces.

C.4.3 Handling by two or more people

Handling by two or more people may make possible an operation that is beyond the capability of one person, or reduce the risk of the operation to that person. The load that a team can handle safely is less than the sum of the loads that the team members could cope with individually. Handling by two or more workers requires that each person have adequate coupling, vision and physical space for his/her feet and body around the object and along the path of travel. Mechanized movement should be considered for multiple-person handling situations that do not meet the above conditions.

C.5 Design of working environment

General environmental conditions, including illumination, noise and climate should be within tolerable levels. It is recommended that ISO 7730 [3] be applied 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 may 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. Nevertheless, 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 worker to see clearly what he/she is doing and also prevent poor working postures. High noise levels may lead to the inability to hear warnings and to increased work stress.

For out-of-door work, account needs to be taken of the effects of changing weather conditions. Wet, icy or slippery conditions can present particular hazards for push/pull tasks.

C.6 Worker capabilities

Work should be adapted to the worker's physical and mental capabilities. The worker should be made aware of possible risks that are involved in the work and of his/her own possibilities and responsibilities to reduce these risks. For more demanding tasks, the worker should be supported by appropriate education and training, and, if needed, medical monitoring and technical aids.

Annex D
(informative)

Suggested approach for measuring push/pull forces

This approach applies only to carts, trolleys or dollies that are pulled or pushed by human operators in industrial situations. The procedure described gives the steps for taking correct force measurements. Pull forces will generally be the same as push forces. Measure pull forces if the dolly, trolley or cart is designed to be pulled.

a) Use a mechanical or electronic force gauge in order to take the measurements. Follow the manufacturer's instructions for using the gauge. Make sure that the forces measured will not exceed the gauge's capacity. Preferably, forces should be measured in all three directions simultaneously. When forces are measured in only the one direction (i.e. primary motive force), then the angle of the force application should also be recorded.

b) Load the dolly, trolley or cart with the maximum weight that it will carry under normal conditions. Make sure that the load condition is safe. The load must not shift or fall when the dolly, trolley or cart is moved.

c) Take the measurements by pushing and pulling on the handle of the dolly, trolley or cart. Select a measurement point on the handle. Determine whether a pushing or a pulling measurement will be easier and more accurate to take. This will depend upon the nature of the handle and the surfaces against which the gauge will react. The push or pull forces should be the same. If the handle is horizontal, locate the measurement point at the midpoint of the handle. If handles are vertical, locate a measurement point on the chassis midway between the handles. Select a gauge attachment that will give a stable push point on the handle. If the push surface is not stable, attach a push plate to the handle or to the chassis. The push surface must not deform when pushed against with the gauge. Use a hook attachment for pull force measurements.

d) Take both the *initial* push force measurements and the *sustained* push force measurements. The initial force is the minimum force required to start the dolly, trolley or cart in motion. The sustained force is the minimum force required to maintain the dolly, trolley or cart in motion.

e) Take two conditions for the *initial force*. Position the swivel casters in line with the direction of motion of the dolly, trolley or cart for the first condition. Position the swivel casters at right angles to the direction of motion for the second condition. The push force must straighten out the casters to move the dolly, trolley or cart. The right angle condition will produce higher forces compared to the in-line condition.

   Workers may first straighten out the swivel casters by giving a quick pull or push sideways on the dolly before pushing it to its destination. The initial sideways force required to straighten the swivel casters may be measured instead of the straight-on push force with the casters at right angles.

f) Hold the gauge firmly against the handle or push plate. Do not jerk the gauge. Pull or push the dolly, trolley or cart at least 1 m in 3 s for the sustained force measurement. This speed equates to a slow walk. Take 2 s or 3 s to reach this speed when measuring initial force. Read the force from the gauge as the dolly, trolley or cart starts to move. Do not push or pull faster than 1 m/10 s. If necessary, mark off a distance of 1 m or more on the floor and time the measurement with a stopwatch in order to be accurate. Repeat the measurement process until you have made at least three consistent measurements. Five to seven measurements are preferred. Consistent measurements should not differ from each other by more than about 15 %. Record the measurements. Take the peak or maximum force measurement of the consistent initial force measurements.

g) Position the swivel casters in the in-line direction to measure the *sustained force*. Set the dolly, trolley or cart in motion and apply the minimum sustained force to keep it in motion. Repeat the measurement process until two consistent measurements have been made. Record the measurements. Compute an average of the consistent sustained force measurements.

Annex E
(informative)

Application examples for Methods 1 and 2

This annex provides examples for the application of the two methods.

Figure E.1 illustrates the pushing movement involved.

Figure E.1 — Pushing four-wheeled cage over 10 m distance symmetrically with two hands

E.1 Example 1

E.1.1 Method 1

E.1.1.1 Input data

- Measured peak initial exerted force: 125 N
- Measured average sustained force: 30 N
- Measured peak stopping force: –90 N
- Absolute handle height: 1,45 m

— Gender distribution: 25 % male, 75 % female

— Travel distance: 10 m

— Working frequency: 1/min (and action time > 3 s)

E.1.1.2 Application

a) Find the appropriate tables in Annex A that fit the input data given above for the handle height (1,45 m), travel distance (10 m) and working frequency (1/min). Use the female population as the limiting population.

   — Handle height = 1,45 m: use 1,44 m handle height.

   — Distance moved = 10 m: in the tables, look at 8 m and 15 m distances; interpolate if necessary.

   — Work frequency = 1/min.

b) Refer to Table A.5 for initial forces accommodating 90 % of the female population:

   — for 8 m pushing distance, the force limit is 160 N;

   — for 15 m pushing distance, the force limit is 140 N.

c) Refer to Table A.6 for sustained forces accommodating 90 % of the female population:

   — for 8 m pushing distance, the force limit is 70 N;

   — for 15 m pushing distance, the force limit is 40 N.

Using the more protective 15 m distance and comparing with the measured forces of 125 N for the peak initial force and 30 N for the averaged sustained force, the actual initial force of 125 N is less than the capability of 90 % of females to produce an initial force of 140 N, and the actual sustained force of 30 N is less than the capability of 90 % of the females to produce a sustained force of 40 N. As a consequence, the risk is rated GREEN.

E.1.2 Method 2

E.1.2.1 Input data

a) Part A — Muscle-strength-based force limits

1) Step 1 — Basic force limits, F_B (see B.1.1)

   — Absolute handle height: 1,45 m

   — Ages: all under 50

   — Gender distribution: 25 % male, 75 % female

2) Step 2 — Adjustments to basic force limits, F_{Br} (see B.1.3)

   — Travel distance: 10 m

   — Working frequency: 1/min (and action time > 3 s)

b) Part B — Skeletal-strength-based force limits

1) Step 1 — Compressive-strength-based force limits, F_C (see B.2.1)

— Ages (same as above)

— Gender distribution (same as above)

2) Step 2 — Action force limits, F_{LS} (see B.2.2)

— Shoulder joint angle (∠SJ): 0°

— Force angle (∠F): 10°

c) Part C — Not applicable

d) Part D — Safety limits (see 3.2.2.2.4)

— Measured peak initial exerted force: 125 N

— Measured average sustained force: 30 N

— Measured peak stopping force: –90 N

E.1.2.2 Procedure

a) Part A — Muscle-strength-based force limits

1) Step 1 — Basic force limits, F_B

The maximum static strength exertions for pushing/pulling of the intended user population is determined taking into account age, gender and stature (see to B.1.2).

Using the population subgroups in Tables B.5 and B.6, and the precalculated force limits in Tables B.7 to B.10, the basic force limit, F_B, for the given population and handle height can be found (from Table B.7) to be 138 N.

2) Step 2 — Adjustments to basic force limits, F_{Br}

The muscle-based force limits, F_{Br}, are determined by adjusting the basic force limits, F_B, according to the distance, d, and frequency, f, of the push/pull task (see to B.1.3).

With the input data, it can be found from Table B.12 (for a pushing distance of more than 5 m) that

m_f (task frequency multiplier) = 0,36, and

m_d (travel distance multiplier) = 25 % × 0,26 + 75 % × 0,39 = 0,36.

Using the formula

$$F_{Br} = F_B\left[1 - m_d(d) - m_f(f)\right]$$

it can be calculated that in this case example the adjusted force limit is

$$F_{Br} = 138(1 - 0{,}36 - 0{,}36) \approx 39 \text{ N}$$

b) Part B — Skeletal-strength-based force limits

1) Step 1 — Compressive-strength-based force limits, F_C

Determine compressive strength limits taking into account the age and gender of the intended user population. With the input data, it can be found from Table B.13 that the compressive force limit, F_C, is 3,0 kN.

2) Step 2 — Action force limits, F_{LS}

Determine the action forces observed in the workplace. F_{LS} should not exceed F_C of the lumbar spine.

From observations, we know $\angle$SJ to be 0° and $\angle F$ to be 10°. In Figure B.4 we read that, for pushing with an F_C of 3,0 kN, F_{LS} would be *more than 600 N*.

c) Part C — Limiting force

The muscle-strength-based force limit (F_{Br} = 38,6 N) is smaller than the skeletal-strength-based force limit ($F_{LS} > 600$ N), so $F_L \approx 39$ N.

d) Part D — Safety limit

A safety limit, F_R, is calculated from the minimum limiting force, F_{min}, and a risk multiplier, m_r, such that

$$F_R = m_r \times F_{min}$$

where

$m_r = 0{,}85$ represents the upper limit of the "green" zone;

$m_r = 1{,}0$ represents the upper limit of the "yellow" zone;

$m_r > 1{,}0$ represents the "red" zone.

Thus, the red/yellow limit in this case is 39 N, and the yellow/green limit is 33 N.

Since the pushing distance is more than 5 m, the actual sustained force is to be used for the evaluation (and not the initial force). In this case, the evaluation is green, since the actual sustained force (30 N) is smaller than the yellow/green limit of 33 N.

E.2 Example 2 — Standard and advanced applications — Method 2

E.2.1 General

On airliners trolleys have to be pushed and pulled in the aisles of an aircraft during meal services. On short-distance flights the service may occur while the aircraft is ascending or descending.

For the pushing of a 90 kg full-size trolley at a slope of 5°, an action force of 230 N was measured. Determine if this force is acceptable for the likely airline flight attendant population at a rate of 80 pushes per day.

E.2.2 Input data

a) Part A — Muscle-strength-based force limits

1) Step 1 — Basic force limits, F_B (see B.1.1)

— Absolute handle height: 1,02 m

— Ages: all under 50

— Gender distribution: 20 % male, 80 % female

2) Step 2 — Adjustments to basic force limits, F_{Br} (see B.1.2)

— Travel distance: < 5 m

— Working frequency: 80 pushes/8 h = 0,17/min

b) Part B — Skeletal-strength-based force limits

1) Step 1 — Compressive-strength-based force limits, F_C (see B.2.1)

— Ages (same as above)

— Gender distribution (same as above)

2) Step 2 — Action force limits, F_{LS} (see B.2.2)

— Shoulder joint angle ($\angle$SJ): 20°

— Force angle ($\angle F$): 20° – 30°

c) Part C — Not applicable

d) Part D — Safety limits (see 3.2.2.2.4)

Measured peak initial exerted force: 230 N

E.2.3 Application of Method 2 using input from precalculated tables

Two examples of Method 2 are presented. The first utilizes the precalculated force limits from the tables given in Annex B. The second applies the detailed calculation procedures given in B.1.1 and B.2. The resulting force limits reflect the specific demographic and anthropometric profile of the intended flight attendant population.

a) Part A — Muscle-strength-based force limits

1) Step 1 — Basic force limits, F_B

The maximum static strength exertions for pushing/pulling of the intended user population is determined taking into account age, gender and stature (see to B.1.1).

The population subgroups in Table B.5 for professional use leads to subgroup 2 as being closest to the real condition. For a working height of 1,0 m (case closest to the actual task), the precalculated force limits in Table B.7 (pushes, professional use) yields an F_B of 156 N.

Applying the detailed calculation procedure given in B.1 yields an F_B of 157 N, which reflects the real population demographic situation.

2) Step 2 — Adjustments to basic force limits, F_{Br}

F_{Br} is determined by adjusting F_B according to the distance (d) and frequency (f) of the push/pull task (see to B.1.3).

With the input data, it can be found from Table B.11 (for a pushing distance of less than 5 m) that

m_f (task frequency multiplier) = 0,15

m_d (travel distance multiplier) = 20 % × 0,3 + 80 % × 0,23 = 0,24

Using the formula

$$F_{Br} = F_B \left[1 - m_d(d) - m_f(f) \right]$$

it can be calculated that in this case example the adjusted force limit is

$$F_{Br} = 156(1 - 0{,}24 - 0{,}15) = 95 \text{ N}$$

b) Part B — Skeletal-strength-based force limits

1) Step 1 — Compressive-strength-based force limits, F_C

Determine compressive strength limits taking into account the age and gender of the intended user population. Given the input data, Table B.13 yields F_C = 3,0 kN.

Calculating F_C by the detailed procedure in B.2 yields F_C = 3,9 kN. The detailed calculation procedure here reflects better the demographics of flight attendants around 25 years of age.

2) Step 2 — Action force limits, F_{LS}

Determine the action forces observed in the workplace. F_{LS} should not exceed F_C of the lumbar spine.

From task observations, determine $\angle$ SJ to be 20° and $\angle F$ to be 20° to 30°. From Figure B.4 we read that, for pushing with an F_C of 3,0 kN, F_{LS} would be *more than 600 N*.

c) Part C — Limiting force

The muscle-strength-based force limit (F_{Br} = 95 N) is smaller than the skeletal-strength-based force limit ($F_{LS} > 600$ N), so $F_L = 95$ N.

d) Part D — Safety limit

The safety limit, F_R, is calculated from the minimum limiting force, F_{min}, and a risk multiplier, m_r, such that

$$F_R = m_r \times F_{min}$$

where

m_r = 0,85 represents the upper limit of the "green" zone;

m_r = 1,0 represents the upper limit of the "yellow" zone;

$m_r > 1{,}0$ represents the "red" zone.

Thus, the red/yellow limit in this case is 95 N, and the yellow/green limit is 80 N.

In this case, the evaluation is RED, since the actual force (230 N) exceeds the red/yellow limit of 95 N.

E.2.4 Application of method 2 using input from specific force measurements

a) Part A — Muscle-strength-based force limits

1) Step 1 — Basic force limits, F_B

Maximum static strength capabilities for trolley pushing (using a test group of 440 females and 80 males) [10].

As the distribution of age and gender differs between the test group and the two airlines (see Figure E.2), a synthetic force distribution for the two airlines was computed (see Figure E.3) using the approach given in EN 1005-3:2002, Annex B [11].

The synthetic distribution shows a maximum pushing force of 215 N for the 15th percentile of airlines 1 and 2.

2) Step 2 — Adjustments to basic force limits, F_{Br}

F_{Br} is determined by adjusting F_B according to the distance (d) and frequency (f) of the push/pull task (see to B.1.3).

With the input data, it can be found from Table B.11 (for a pushing distance of less than 5 m) that

m_f (task frequency multiplier) = 0,15

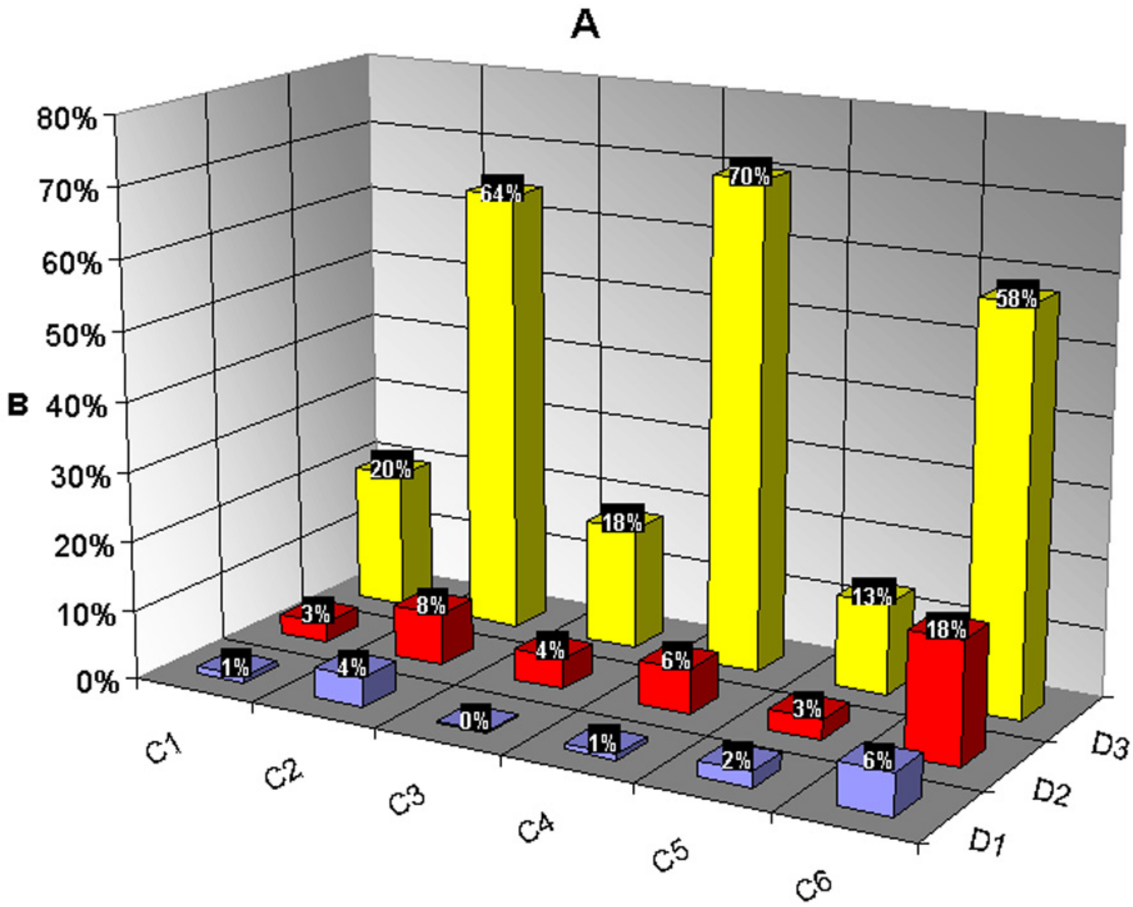
m_d (travel distance multiplier) = 20 % × 0,3 + 80 % × 0,23 = 0,24

Using the formula

$$F_{Br} = F_B\left[1 - m_d(d) - m_f(f)\right]$$

it can be calculated that in this case example the adjusted force limit is

$$F_{Br} = 215\left(1 - 0{,}23 - 0{,}15\right) = 131\,\text{N}$$



Key

A distribution of age and gender

B frequency, %

C1 male 5 × 4 airline 1

C2 female 5 × 4 airline 1

C3 male 5 × 4 airline 2

C4 female 5 × 4 airline 2

C5 male test group

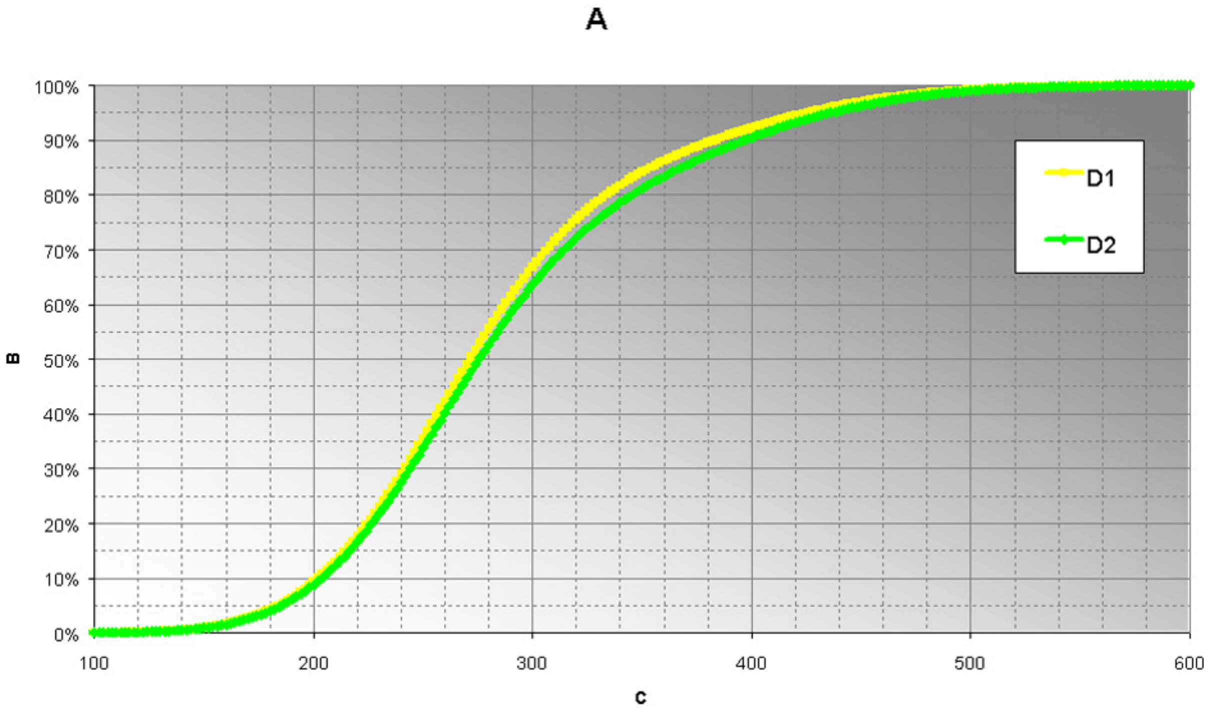
C6 female test group

D1 young (< 25 years)

D2 elderly (> 40 years)

D3 medium (25–40 years)

Figure E.2 — Distribution of age and gender within two airlines and a group of test persons



Key

A maximum push forces at trolley handle height

B cumulated frequency, %

C force, N

D1 airline 1

D2 airline 2

Figure E.3 — Synthetic cumulative frequency of maximal action forces of two airlines

b) Part B — Skeletal-strength-based force limits

1) Step 1 — Compressive-strength-based force limits, F_C

Determine compressive strength limits taking into account the age and gender of the intended user population. Given the input data, Table B.13 yields F_C = 3,0 kN.

2) Step 2 — Action force limits, F_{LS}

Determine the action forces observed in the workplace. F_{LS} should not exceed F_C of the lumbar spine.

From observations we know $\angle$SJ to be 20° and $\angle F$ to be 20° to 30°. From Figure B.4 we read that, for pushing with an F_C of 3,0 kN, F_{LS} would be *more than 600 N*.

c) Part C — Limiting force

The muscle-strength-based force limit (F_{Br} = 131 N) is smaller than the skeletal-strength-based force limit ($F_{LS} > 600$ N), so $F_L = 131$ N.

d) Part D — Safety limit

The safety limit, F_R, is calculated from the minimum limiting force, F_{min}, and a risk multiplier, m_r, such that

$$F_R = m_r \times F_{min}$$

where

$m_r = 0,85$ represents the upper limit of the "green" zone;

$m_r = 1,0$ represents the upper limit of the "yellow" zone;

$m_r > 1,0$ represents the "red" zone.

Thus the red/yellow limit in this case is 131 N and the yellow/green limit is 111 N.

In this case, the evaluation is red, since the actual force (230 N) exceeds the red/yellow limit of 131 N.

Annex F
(informative)

Method for determining combined strength distribution for a particular reference group

Method 2 as described in 3.2.2.2 and B.1.1.3 adopts a special procedure for synthesizing strength distributions of any optional user population using the reference strength distributions of young females. This procedure modifies in particular the complete set of reference strength distributions provided at all relative working heights. An example is given here, demonstrating these modifications for a selected reference distribution. This procedure follows closely the original “synthetic distribution method” according to EN 1005-3 [11]. Its calculation scheme includes two major steps that are described in detail.

F.1 Input parameters

F.1.1 Force

The procedure first requires distribution parameters of maximum isometric forces as observed at a particular reference group (see Figure F.1).

a) Reference group:

— females;

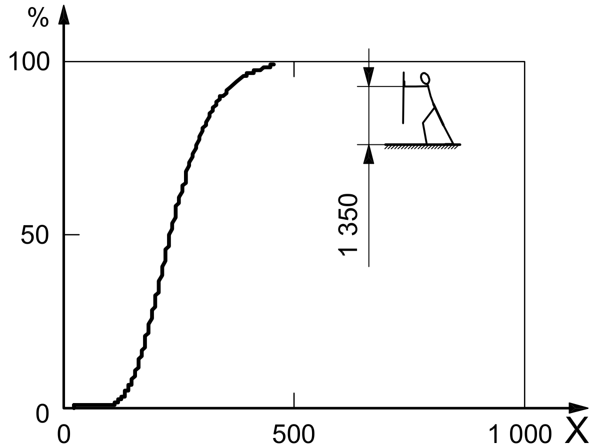
— 20 years $\leqslant$ age $\leqslant$ 30 years.

b) Distribution parameters:

— force average, $\overline{F}$;

— standard deviation of reference group, σ.

Generally, each reference group should be part of the same target population for which limits are calculated — e.g. European, North American, world or some combined grouping. Reference forces may be measured directly, or may be found in the literature or in Table F.1.



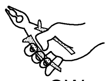
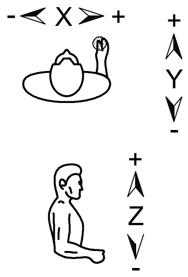
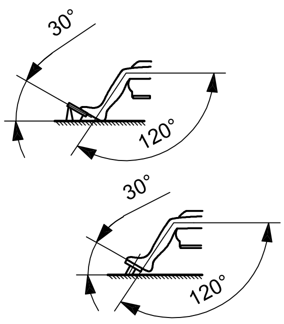
Key

X strength, N

Pushing: $\bar{F} = 228{,}0$ N; $\sigma = 84{,}8$ N

Figure F.1 — Example of distribution parameters

Table F.1 — Maximum strength distribution parameters of young females (German) aged 20–30 years

Activity		$\bar{F}$ N	σ N
 OW = 10 %	Hand work — one-hand power grip	270,0	54,1
	Arm work — sitting, one arm:		
	upwards (+z)	56,0	18,4
	downwards (−z)	86,0	33,2
	outwards (+x)	63,5	26,2
	inwards (−x)	83,4	24,6
	pushing (+y)		
	with backrest	303,0	81,0
	without backrest	75,5	42,7
	pulling (−y)		
	with backrest	242,0	44,9
	without backrest	65,7	33,5
	Whole-body work — standing:		
	pushing	228,0	84,8
	pulling	161,0	45,7
	Pedal work — sitting, with backrest:		
	ankle action	282,0	96,5
	leg action	528,5	157,6
Approximation: If no data of the reference group is available, distribution parameters of the adult female population may be used as an alternative.			

F.1.2 User demography

Further, the intended user population should be analyzed. This analysis concentrates on subgroups as specified by age and gender according to the following categories.

a) females

n_{f1}: age $<$ 20 years

n_{f2}: 20 $\leqslant$ age $\leqslant$ 50 years

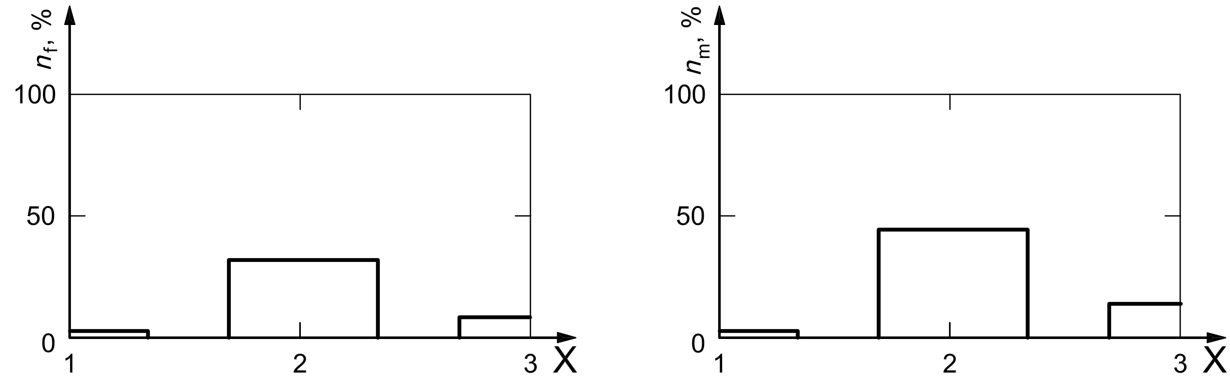
n_{f3}: age $>$ 50 years

b) males

n_{m1}: age < 20 years

n_{m2}: 20 ⩽ age ⩽ 50 years

n_{m3}: age > 50 years



a) **Females** b) **Males**

Key

X age group

n_{fi}, n_{mi} representations of subgroups reflecting the demographic profile of the intended user population

n_{f1} = 1,6 %; n_{f2} = 31,6 %; n_{f3} = 7,6 %

n_{m1} = 2,0 %; n_{m2} = 43,8 %; n_{m3} = 13,4 %

Check that all n_{fi} and n_{mi} sum up to 100 %.

NOTE Population: EC (12 member countries).

Figure F.2 — Example of analysis of intended user population

F.2 Procedure

In a second step, a special procedure calculates force limits in particular adjusted to the user populations specified in F.1. The procedure is given in F.2.1 to F.2.4.

F.2.1 Synthetical distribution parameters of subgroups

Force averages and standard deviations of all other subgroups, i, are defined by the reference parameters ($\overline{F}$, σ) introduced in F.1 and some appropriate multipliers (α_{xx}, s_{xx}) expressing relations between age and gender (see Table F.2 for an example and Table F.3.).

a) Females

— force average: $\overline{F}_{fi} = \overline{F} \times \alpha_{fi}$

— standard deviation: $\sigma_{fi} = \sigma \times s_{fi}$

b) Males

— force average: $\overline{F}_{mi} = \overline{F} \times \alpha_{mi}$

— standard deviation: $\sigma_{mi} = \sigma \times s_{mi}$

where

i = 1, 2, 3 is the age group;

α_{xx}, s_{xx} are the subgroup multipliers;

$\overline{F}$, σ are the force average and standard deviation of the reference group, as specified in F.1.

Table F.2 — Example of determination of force averages and standard deviations

Age group	1	2	3
$\overline{F}_{fi}$	172,8	180,0	167,4
σ_{fi}	61,8	60,0	57,6
$\overline{F}_{mi}$	351,0	388,8	306,0
σ_{mi}	94,2	99,0	108,0

f female
m male
i age group 1, 2 or 3
$\overline{F}$ force average
σ standard deviation

Table F.3 — Subgroup multipliers synthesizing subgroup strength distributions

	Force average α_{xx}		
Age group	**1**	**2**	**3**
Females, α_{fi}	0,96	1,00	0,93
Males, α_{mi}	1,95	2,16	1,70

	Standard deviation s_{xx}		
Age group	**1**	**2**	**3**
Females, s_{fi}	1,03	1,00	0,96
Males, s_{mi}	1,57	1,65	1,81

F.2.2 Logarithmic distributions

At lower force levels (e.g. $\overline{F}$ = 63,5 N, σ = 26,2 N) any approximation to normal yields increasingly poor results at lower percentiles (1 %). In this case logarithmic distributions are more realistic. An easy transformation provides a new set of logarithmic distribution parameters.

a) females $\overline{F}_{fi} = \ln\left(\overline{F}_{fi}\right)$ $\sigma_{fi} = \ln \frac{\overline{F}_{fi} + \sigma_{fi}}{\overline{F}_{fi}}$

b) males $\overline{F}_{mi} = \ln\left(\overline{F}_{mi}\right)$ $\sigma_{mi} = \ln \frac{\overline{F}_{mi} + \sigma_{mi}}{\overline{F}_{mi}}$

c) variable force $x = e^{x}$

The following steps apply to the above parameters in the same way as they do to linear normal distributions.

F.2.3 Generation of new distribution functions of male and female subgroups

a) Females:

$$DF_{\mathrm{f}i}\left(x\right) = \frac{1}{\sigma_{\mathrm{f}i}\sqrt{2\pi}}\int_{-\infty}^{x} \mathrm{e}^{-0,5 z_{\mathrm{f}i}^{2}} \mathrm{d}z$$

where

$$z_{\mathrm{f}i} = \frac{x - \overline{F}_{\mathrm{f}i}}{\sigma_{\mathrm{f}i}}$$

x is the variable force

b) Males:

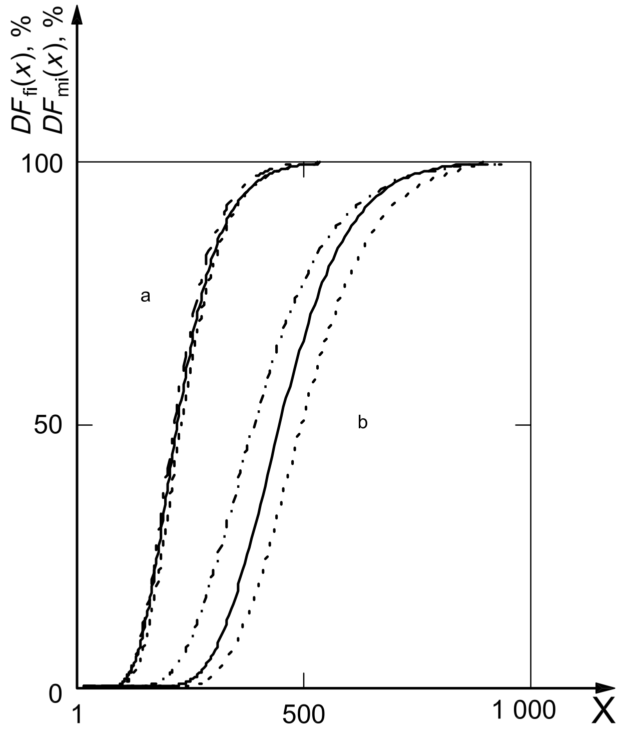
$$DF_{\mathrm{m}i}\left(x\right) = \frac{1}{\sigma_{\mathrm{m}i}\sqrt{2\pi}}\int_{-\infty}^{x} \mathrm{e}^{-0,5 z_{\mathrm{m}i}^{2}} \mathrm{d}z$$

where

$$z_{\mathrm{m}i} = \frac{x - \overline{F}_{\mathrm{m}i}}{\sigma_{\mathrm{m}i}}$$

x is the variable force

See Figure F.3 for an example.



Key

X force, N

a Females.

b Males.

Figure F.3 — Example of generation of new distribution functions

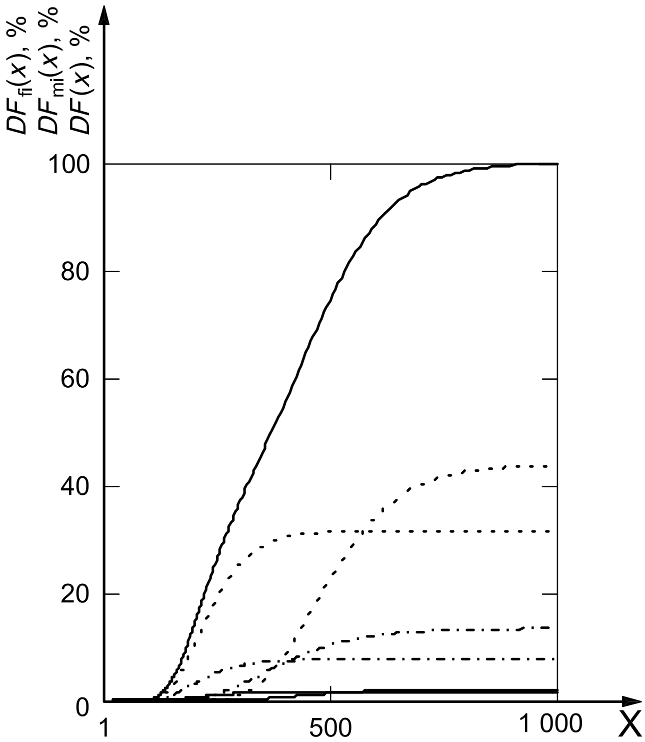
F.2.4 Weighting and combining of all subgroup distributions

This is expressed by the equation

$$DF(x) = \sum_{j} \frac{n_{fi} DF_{fi}(x) + n_{mi} DF_{mi}(x)}{100}$$

where n_{fi}, n_{mi} are the percentages of all the subgroups.

See Figure F.4 for an example.



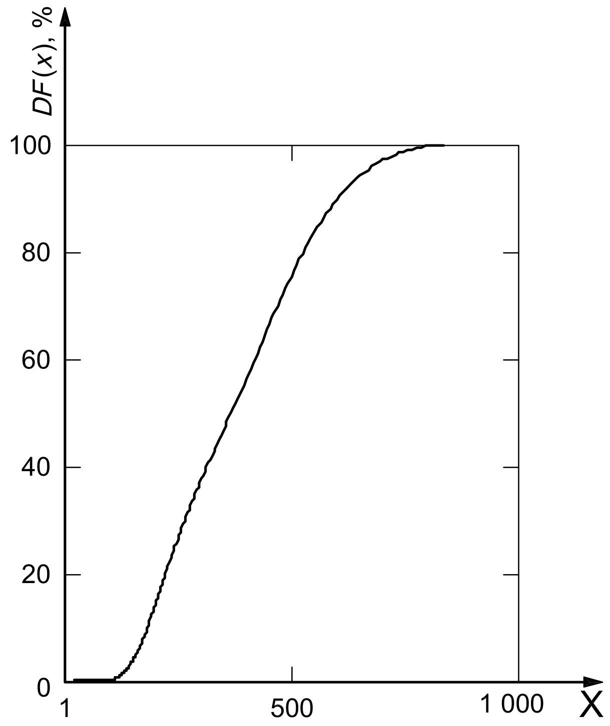
Key

X force, N

Figure F.4 — Example of generation of new distribution functions

F.3 Results

$DF(x)$ is the combined strength distribution function of all the subgroups depending on force x. Its shape closely reflects the demographic profile of any particular target population. Generally these synthetic distribution functions substitute the original female reference distributions in all other method 2 calculation steps.



Key

X force, N

Figure F.5 — Example of result

Bibliography

[1] JÄGER, M. Belastung und Belastbarkeit der Lendenwirbelsäule im Berufsalltag — Ein interdisziplinärer Ansatz für eine ergonomische Arbeitsgestaltung; *Fortschrittberichte VDI*, Reihe 17, Nr. 208, VDI-Verlag, Düsseldorf, 2001

[2] JÄGER, M., JORDAN, C., THEILMEIER, A. and LUTTMANN, A. Dortmunder Lumbalbelastungsstudie 2: Ermittlung und Beurteilung vergleichbarer Tätigkeiten hinsichtlich der Körperhaltung und der Wirbelsäulenbelastung bei verschiedenen beruflichen Tätigkeiten; Hauptverband der gewerblichen Berufsgenossenschaften, St. Augustin, 2001

[3] ISO 7730, *Ergonomics of the thermal environment — Analytical determination and interpretation of themal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*

[4] SNOOK, S.H. and CIRIELLO, V.M. The design of manual handling tasks: revised tables of maximum acceptable weights and forces, *Ergonomics* 1991, vol 34, no. 9, 1197-1213

[5] SCHAEFER, P., BOOCOCK M., KAPITANIAK, B., SCHAUB K.H., MEYER F. Push & Pull by ISO 11228/2 — Force Limits Adjustable to Age, Gender and Stature Distributions, *International Ergonomics Association Conference*, CDROM 00905.pdf, Seoul, 2003

[6] ROSENBERG, S. *Human Lumbar Spine — Structural Stabilities and Load Limits*, PHD Thesis (under publication), Inst. of Ergonomics, TU München, Boltzmannstr. 15, 85747 Garching, Germany, 2004

[7] DIN 33411-5, *Physical strength of man — Part 5: Maximale isometric action forces, values*

[8] JÜRGENS, H.W., AUNE, I.A., PIEPER, U. (1989): Internationaler anthropometrischer Datenatlas. *Schriftenreihe der Bundesanstalt für Arbeitsschutz* Feb. 587. Dortmund: Bundesanstalt für Arbeitsschutz

[9] MITAL, A., NICHOLSON, A.S., AYOUB, M.M. *A Guide to Manual Materials Handling*, 2nd edition, Taylor and Francis London, Washington, DC, 1997

[10] GLITSCH, U., OTTERSBACH, H.-J., ELLEGAST, R., HERMANNS, I., FELDGES, W., SCHAUB, K.-H., BERG, K., WINTER, G., SAWATZKI, K., VOSS, J., GÖLLNER, R., JÄGER, M., FRANZ, G. *Untersuchung der Belastung von Flugbegleiterinnen und Flugbegleitern beim Schieben und Ziehen von Trolleys in Flugzeugen*, BIA-Report, St. Augustin, 2004

[11] EN 1005-3:2002, *Safety of machinery — Human physical performance — Part 3: Recommended force limits for machinery operation*

[12] Eastman Kodak Company, *Kodak's Ergonomic Design for People at Work*, Second Edition, John Wiley & Sons, Inc., Hoboken, NJ, 2004, pp. 240, 553-557

[13] International Data on Anthropometry. *Occupational Safety and Health Series # 65*, ILO, Geneva, 1990, 113 pp. ISBN 92-2-106449-2

[14] JÄGER, M. and LUTTMANN, A. The load on the lumbar spine during asymmetrical bi-manual materials handling. Ergonomic, 1992, Vol. 35, 7/8, 783-805

[15] JÄGER, M., LUTTMANN, A. and LAURIG, W. Lumbar load during one-handed bricklaying. *International Journal of Industrial Ergonomics*, 8 (1991) 261-277

[16] For PC-tools for the work with synthetic distributions see the *IAD-Toolbox* körperliche Arbeit (physical workload) German page: http://www.arbeitswissenschaft.de/Institut/info_produkte.htm

[17] HOOZEMANS M.J.M., KUIJER P.P.F.M., KINGMA I., VAN DIEEN, J.H., DE VRIES, W.H.K., VAN DER WOUDE, L.H.V. et al. Mechanical loading of the low back and shoulders during pushing and pulling activities. *Ergonomics* 2004, 47(1):1-18.)

[18] EN 614-2:2000, *Safety of machinery — Ergonomic design principles — Part 2: Interactions between the design of machinery and work tasks*

[19] ISO 14121:1999, *Safety of machinery — Principles of risk assessment*

[20] ISO/IEC Guide 51: 1999, *Safety aspects — Guidelines for their inclusion in standards*

[21] ISO 6385, *Ergonomic principles in the design of work systems*

[22] ISO 7250, *Basic human body measurements for technical design*

[23] ISO 11226, *Ergonomics — Evaluation of static working postures*

ICS 13.180

Price based on 65 pages