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Ergonomics — Manual handling —

Part 2: Pushing and pulling

Ergonomie — Manutention manuelle —

Partie 2: Actions de pousser et de tirer

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Foreword

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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.

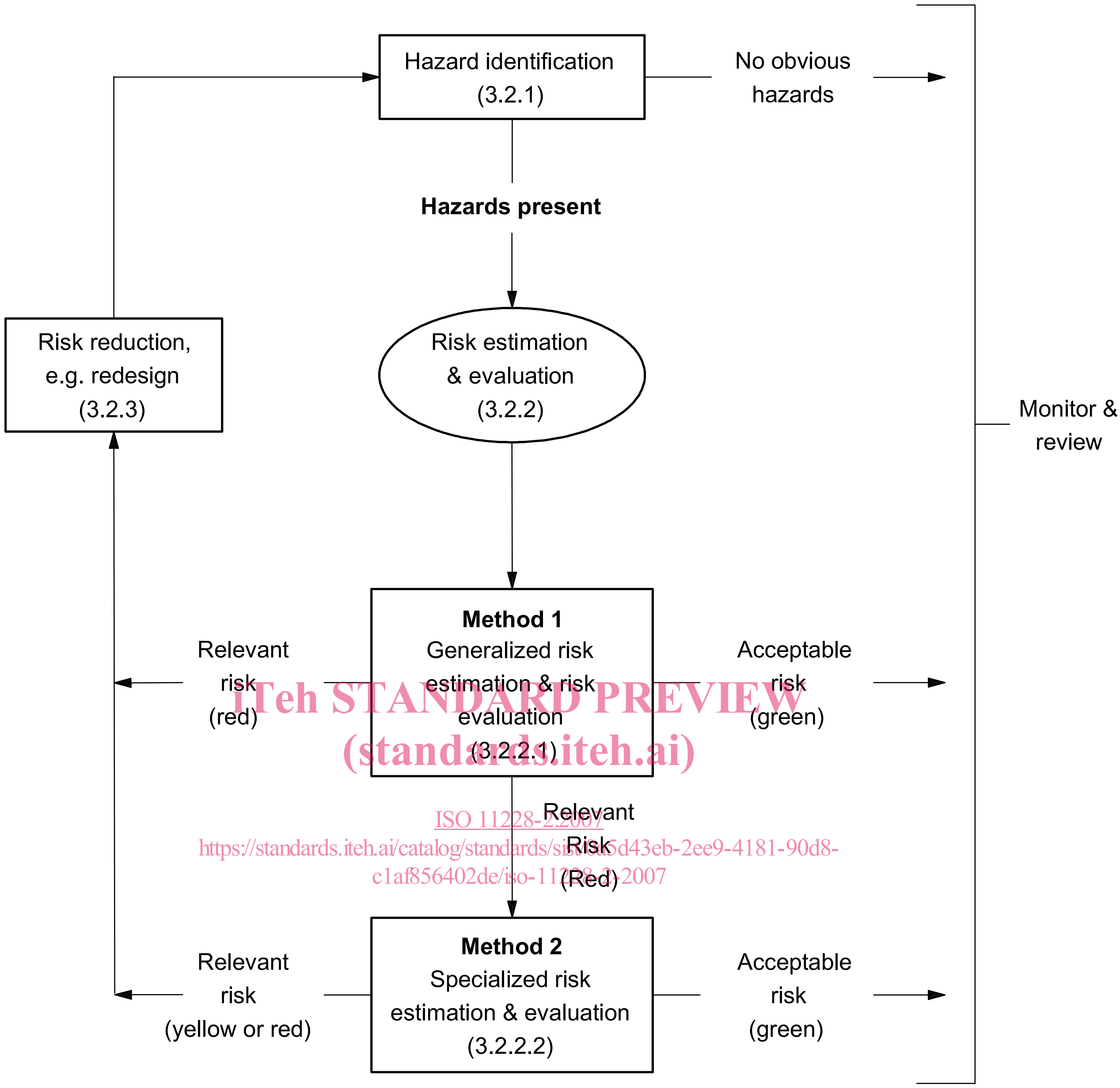

Figure 1 — Risk assessment model

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.

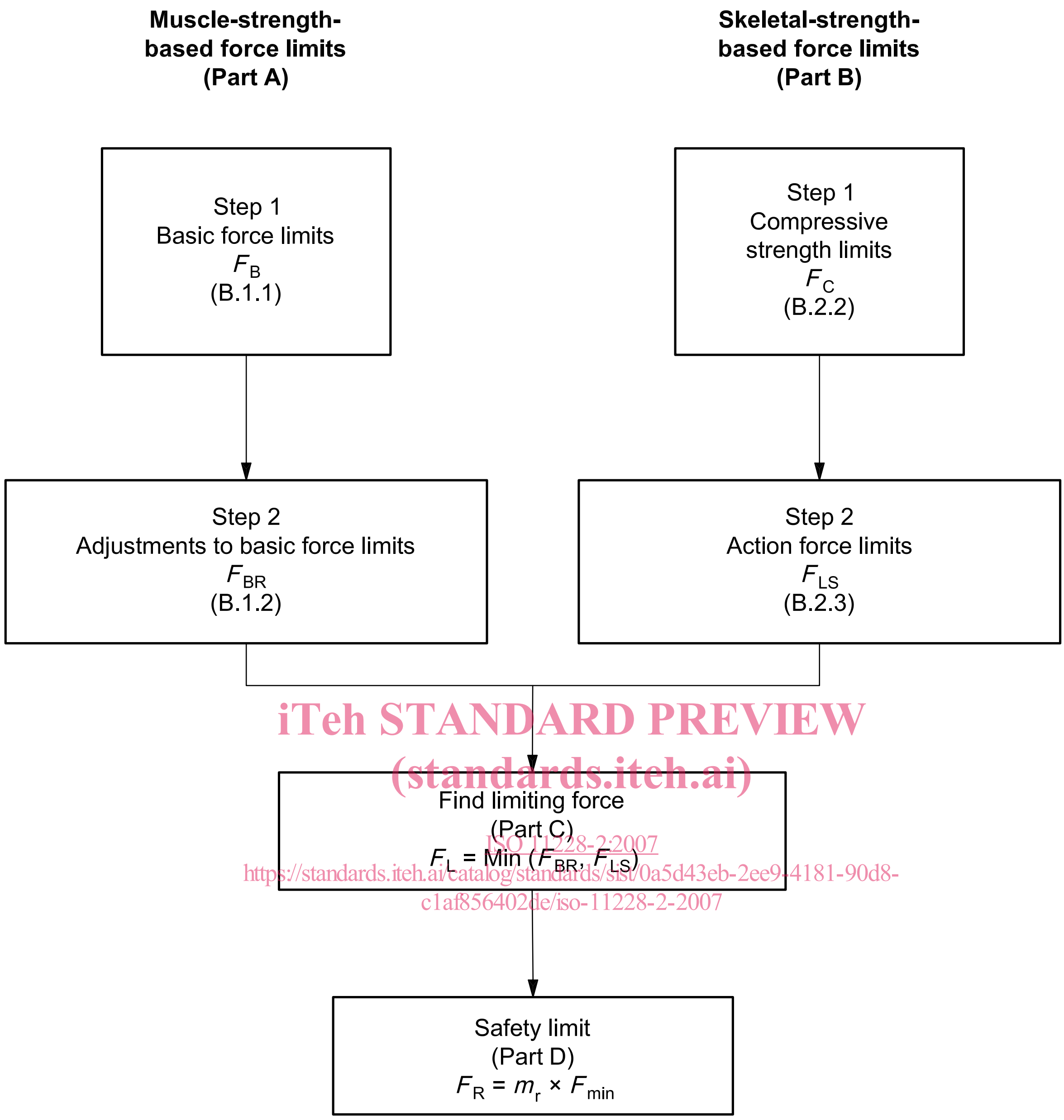

Figure 3 — Specialized risk estimation and assessment — Method 2

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}.

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

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.