
Ergonomics — Recovery model for cyclical industrial work

*Ergonomie — Modèle de récupération pour les activités cycliques
dans l'industrie*

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

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Foreword

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

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

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

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

Introduction

0.1 General

The literature contains numerous methodologies for measuring physical stress in manual work. Studies from different disciplines and research groups have concentrated on diverse external factors, workplaces, and jobs. Factors most often cited include forceful exertions, repetitive motions, sustained postures, strong vibration and cold temperatures.

The ISO 11228 series, ISO 11226 and ISO TR 12295 establish ergonomic recommendations for different manual handling tasks, repetitive movements and working postures. They apply to occupational and non-occupational activities and provide information for designers, employers, employees and others involved in work, job and product design, such as occupational health and safety professionals.

- The ISO 11228 series relates to manual handling, including lifting and carrying, pushing and pulling and the handling of low loads at high frequency.
- ISO 11226 gives recommended limits for static working postures with no or minimal external force exertion, while taking into account body angles and duration.
- ISO TR 12295 serves as an application guide of the ISO 11228 series and ISO 11226 and offers a simple risk assessment methodology for small and medium enterprises and for non-professional activities. ISO/TR 12295:2014, C.5, is very relevant for this document, since there is a reference to the EAWS system, which is extensively described in [Annex A](#), being the first available ergonomic tool meeting the requirements of the EWA model.

This document can be used by industrial engineers for the application of ergonomic work allowances as a means to determine the correct quantity of cyclical work assigned to a worker in a manufacturing plant in order to meet the definition of a fair day's work. A fair day's work is that length of working day, and that intensity of actual work, which expends one day's full working power of the worker without encroaching upon his or her capacity for the same amount of work for the next and following days^[26]. In the old-fashioned production systems (piecework-based) the fair day's work concept was used in connection with the fair day's wage. In this document, the studies about the definition of the fair day's work become fundamental to connect work-study with the most recent knowledge about biomechanical load (occupational health and safety), with a special focus on the product-process design phase.

0.2 Recovery

In the field of ergonomics there is a special interest in predicting fatigue dependent on the intensity, duration and composition of stress factors and to determine the necessary recovery time. [Table 1](#) shows those different activity levels and consideration periods, possible reasons for fatigue and different possibilities of recovery.

Table 1 — Fatigue and recovery dependent on activity levels

Level of activity	Period	Fatigue from	Recovery by
Work life	Decades	Overexertion for decades	Retirement
Phases of work life	Years	Overexertion for years	Holidays
Sequences of work shifts	Months or weeks	Unfavourable shift regimes	Weekend, free days
One work shift	One day	Stress above endurance limits	Free time, rest periods
Tasks	Hours	Stress above endurance limits	Rest period
Part of a task	Minutes	Stress above endurance limits	Change of stress factors

In ergonomic analysis of stress and fatigue for determining the necessary recovery time, considering the period of one working day is the most important. In this document, this type of recovery is named “recovery external to the work cycle” and is defined in ISO 11228-3.

In case of cyclical industrial work, where awkward static body postures are relevant, a strategy to reduce the stress level is to allow short recovery periods within each work cycle. This type of recovery is named “recovery within the work cycle”.

The proposed model concerns the quantification of recovery periods within the work cycle and considers recovery periods outside the cycle (normally defined as pauses) as an exogenous variable, evaluated within the factors characterizing the work organization.

0.3 Purpose and justification

The industrial sector is one of the sectors with the highest global employment rate (22,5 % of total employment). Despite this, the most recent research efforts about the definition of a fair day’s work date back to the 1980s. In the last 20 years a lot of research has been carried out on the biomechanical load and many new standards have been created.

This document is a first bridge between two different fields of knowledge: work study (industrial engineering) and occupational health and safety (ergonomics). The objective is to improve the work study tools by leveraging the knowledge made available by the most recent studies about work-related musculoskeletal disorders (WMSDs).

This document provides a methodological reference for the procedures to determine the fair quantity of work within a working day in industrial operations with repetitive manual work cycles.

The goal of the model is to guide industrial engineers to keep the biomechanical load or local muscle fatigue generated by the planned cyclical work within the limits defined in the ISO 11228 series and ISO 11226.

This document proposes neither new work measurement techniques nor new ergonomic techniques or standards. Rather, it aims at merging the best available knowledge (industrial engineering and ergonomics) about human capacity of accomplishing a manual task, following a pre-defined work cycle (method description and related standard time) without generating an excess of biomechanical load (fatigue).

Present issues:

- Ergonomic allowance is neglected or assigned based on a partial evaluation of the physical load (usually body postures and forces). The calculation is not influenced by:
 - load duration (action frequency and duration of static actions);
 - work organization (shift duration, duration and distribution of the break periods) and work measurement.
- Lack of a well-recognized standard work performance to measure manual work.
- Available ergonomic evaluation systems work on different measurement scales and the difficulty of assessing the overall physical stress.
- The ergonomic approach tends to be used reactively in the industry rather than proactively (preventive ergonomics).

0.4 Expected benefits

- Support the adoption of the ISO 11228 series and ISO 11226 in the industrial manufacturing sectors.
- Support the definition of a standard work performance to standardize the work measurement.
- Improve working conditions, safety and ergonomics of workers in manufacturing industries.

- Complement the traditional set of experts' capabilities on time and motion with the ergonomic skills necessary to design safe and efficient work stations and sustain continuous improvements in productivity and ergonomics during the entire product life cycle.
- Support the ergonomic evaluation in the earliest stages of product or process development, when changes are still feasible and the cost of such changes is affordable (preventive ergonomics).
- Link ergonomic improvements with labour cost reduction (improve ergonomics – reduce costs – justify investments in ergonomic improvements).
- Reduce cost and deviation of the ergonomic risk-mapping process by linking the biomechanical load measurement with work measurement and organization.
- Be an objective reference for employers and unions when setting up gainsharing contracts based on labour productivity (industrial relations).

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Ergonomics — Recovery model for cyclical industrial work

1 Scope

This document establishes an ergonomic model for any cyclical human work planned and executed in an industrial competitive environment. It also covers the process of measuring work based on the concept of normal work performance and of the assessment of risk factors commonly associated with body postures, body or hand forces, manual material handling of loads and handling low loads at high frequency.

This document applies to the adult working population and is intended to give reasonable protection for nearly all healthy adults. Those areas concerning health risks and control measures are mainly based on experimental studies regarding musculoskeletal loading, discomfort or pain and endurance or fatigue related to work organization and methods.

The scope of this document is any cyclical human work planned and executed in an industrial competitive environment. The most typical cases are within industries where there is the need to define an expected output (products or services) based on the optimization of the trade-off between labour productivity and health and safety.

The most sensitive organizations to this proposal are those within labour-intensive manufacturing industries with series and batch production systems:

- automotive (original equipment manufacturer and tier 1 and 2 suppliers);
- industrial automotive (trucks, buses, agricultural and mining equipment);
- industrial manufacturing (small domestic and industrial equipment or machinery);
- domestic appliances and consumer goods (white goods);
- plastic and rubber products (tires, doors, windows, shoes);
- consumer electronics (PCs, televisions, printers, radios, hi-fis, alarm systems);
- furniture;
- textiles and apparel;
- food preparation;
- packaging;
- aerospace and defence;
- rail and shipping;
- large domestic and industrial equipment or machinery;
- logistics.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 basic motion

manual motion performed with fingers, hands, arms, eyes, feet, legs or body, no longer decomposable as regards to content time

3.2 technical action

elementary manual action to complete operations within the cycle basic motion in which a segment of the upper limb (shoulder, elbow, wrist or finger) is involved to reach a target or to hold an object or a posture

EXAMPLE Grasp, reach, move, turn, apply pressure, hold, turn, push or cut.

3.3 real action

combination of basic motions (technical actions) performed to achieve a finite and planned state of an object

EXAMPLE Get and place an object, place a tool, activate (reach and press a button), micro finger cycle as fastening a screw with fingers.

3.4 standard work

work with the most efficient method to produce a product (or perform a service) at a balanced flow to achieve a desired output rate

3.5 standard working method

method to break down of the work into elements (operations), which are sequenced, organized and repeatedly followed

Note 1 to entry: Standard conditions as part presentation, distances, geometries, weights or tools and equipment are clearly described.

3.6 work measurement

application of techniques designed to define the time for a qualified worker to carry out a specified job at a defined level of performance

3.7 standard work performance

effort level that could be easily maintained year in, year out, by a worker with average physical capabilities, without drawing upon his or her reserves of energy

Note 1 to entry: Working at standard performance brings the worker to the end of the fair day's work without an excess of physical stress.

3.8**time allowance**

time added to the basic time

Note 1 to entry: The amount of the allowance depends on the nature of the work and the working environment, and it is often assessed using an agreed set of guidelines and scales.

Note 2 to entry: Time allowances are used to cover personal needs, technical and organizational planned losses and learning effect. This document refers to time allowances meaning the additional time to recover from an excess of fatigue generated by the work cycle.

3.9**basic time**

time set through a given work analysis system

Note 1 to entry: Predetermined time measuring systems (e.g. methods-time measurement) provide basic times of manual elementary motions (e.g. reach, grasp, move).

Note 2 to entry: Basic time does not include any allowance.

3.10**standard time**

time required by an average skilled operator, working at a normal pace, to perform a specified task using a prescribed method

Note 1 to entry: The difference between standard time and basic time is that basic time is the time when work should be done without any delays. Standard time is the time taken by the worker to complete the work with some unavoidable and therefore planned delays (time allowances).

Note 2 to entry: Standard time includes time allowances.

3.11**methods-time measurement****MTM**

procedure which analyses any manual operation or method into the basic motions required to perform it and assigns to each motion a basic predetermined time, which is determined by the influencing factors under which it is made

Note 1 to entry: Examples include reach or move distance, type of grasp, object weight.

3.12**cycle time**

time available at each workstation to accomplish the tasks assigned for each unit of output

Note 1 to entry: Cycle time corresponds to the pace at which an assembly line delivers its output.

Note 2 to entry: In the case of a single workstation, cycle time and standard time coincide, since there is no idle time caused by the imperfect synchronization of a sequence of workstations (balancing losses).

Note 3 to entry: Cycle time is expressed as the sum of standard time and idle time.

3.13**task assignment****line balancing**

manufacturing-engineering technique, in which the production line operations are divided into tasks, which are assigned to the minimum number of workstations

Note 1 to entry: A production line is said to be in balance when every worker's task takes approximately the same amount of standard time. Well-balanced lines minimize labour idleness and improve productivity.

3.14 work organization

way that tasks are distributed among the individuals in an organization and the ways in which these are then coordinated to achieve the final product or service

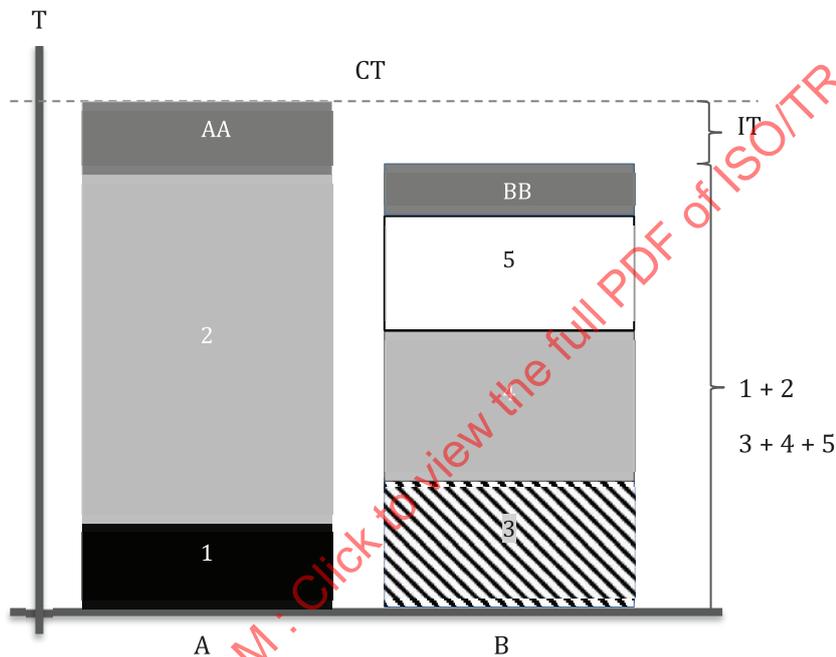
Note 1 to entry: Work organization typically encompasses the total shift duration, the quantity and distribution of the breaks, the type of man-machine interface and the level of allowed flexibility.

3.15 worker saturation

percentage of non-idle time within a cycle time

Note 1 to entry: Worker saturation is expressed as the fraction of standard time and cycle time.

Note 2 to entry: See [Figure 1](#).



Key

- CT cycle time
- T time
- A, B workstation A, B
- 1,2,3,4,5 operation 1,2,3,4,5 (basic time)
- AA, BB allowance A, B
- IT idle time (unsaturation)
- 1 + 2 task assigned to work station A (standard time)
- 3 + 4 + 5 task assigned to work station B (standard time)

Figure 1 — Industrial engineering terminology

3.16 biomechanical load

physical stress acting on the body or on anatomical structures within the body

Note 1 to entry: Loads originate from the external environment (e.g. the force generated by a power hand tool) or are the possible result of voluntary or involuntary actions of the individual (e.g. lifting objects).

EXAMPLE Kinetic (motion), kinematic (force), oscillatory (vibration) stress and thermal (temperature) energy sources.

3.17

transition time

duration of the movements for changing from one body posture to another

3.18

overall load index

OLI

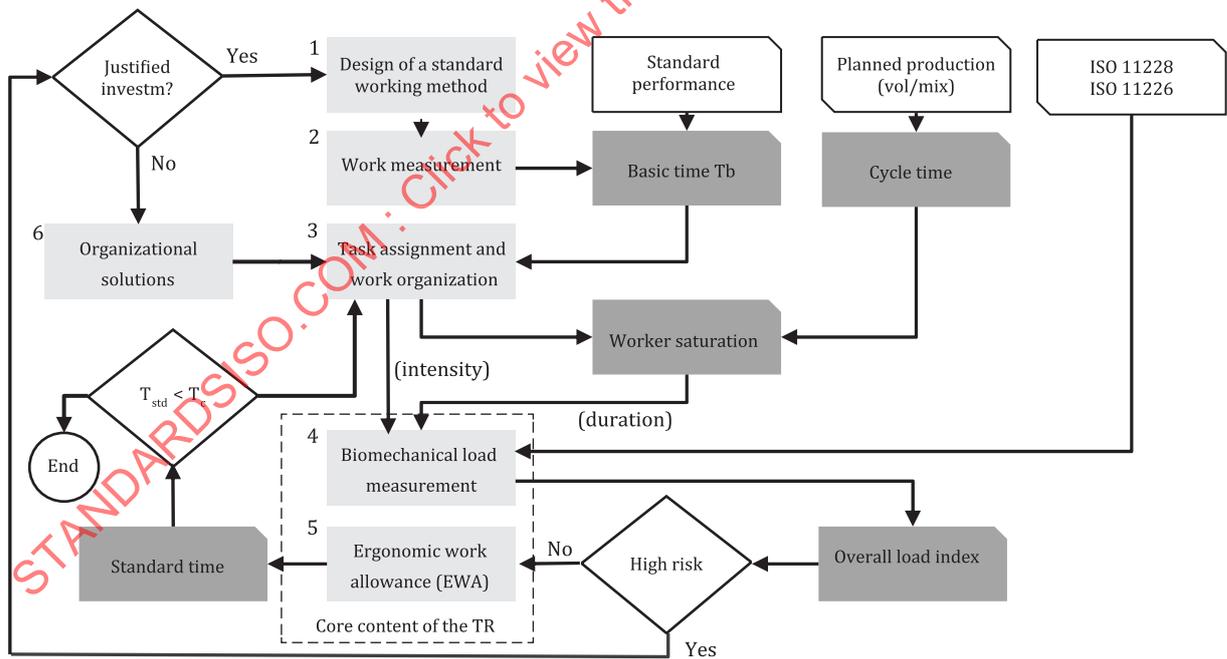
index compounding the overall biomechanical load generated by the different types of physical stress

4 Proposed approach

4.1 The correct work content

The determination of the correct work content for a given activity is a fundamental task for a company in order to be competitive on the market, as well as to safeguard workers' health and to guarantee a proper quality of the performed activity. The setting of a standard time of a manual task is based on the following steps (see Figure 2; T_c is the cycle time and T_{std} is used to indicate the standard time):

- a) design of a standard working method;
- b) work measurement;
- c) task assignment and work organization;
- d) biomechanical load measurement;
- e) ergonomic work allowance calculation (applying the model).



Key

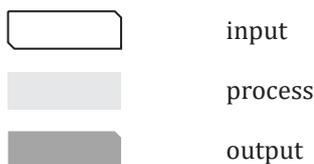


Figure 2 — Standard time setting process

4.2 Design of a standard working method

The design of a standard working method is the key driver to achieve operational excellence in levels of productivity and safety. This task is one of the main responsibilities for industrial engineers, who have to blend wisely several fields of knowledge to coordinate humans, machines and materials to attain a desired output rate with the optimum utilization of energy, knowledge, money and time. It employs key techniques (such as floor layouts, personnel organization, time standards, wage rates, incentive payment plans, production scheduling) and technologies (ICT, digital devices, data and analytics) to control the quantity and quality of goods and services produced. The design and planning of a working system largely determines the ergonomic conditions of the worker and therefore it is fundamental to bring the ergonomic knowledge into the earliest stages of the product and process development process and the ergonomic constraints into the planning process (see [Figure 3](#)).

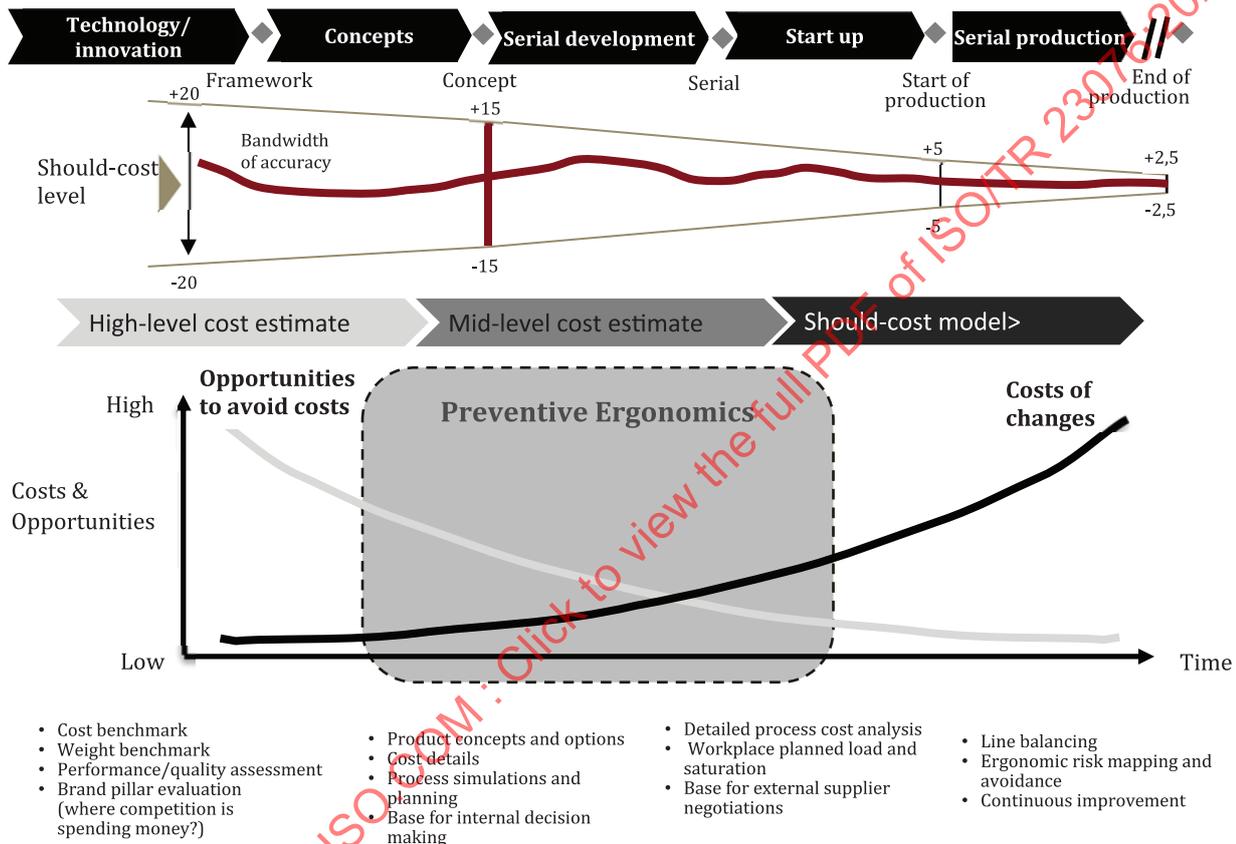


Figure 3 – Preventive ergonomics in the new product development process

To achieve such a sophisticated level of product or process development and planning process, the most advanced industrial companies use a predetermined motion-time system (PMTS). A PMTS is a set of data of elementary human motions, of which a basic time is predetermined, which is used as a reliable language to design, plan and measure a manual task.

The last developments among available PMTSs aim at creating specific tools for designing work systems in the earliest stages of product and process development, rather than simply measuring them once they are up and running. In this way, it is possible to find the most efficient and ergonomic solutions when it is still feasible to make product and process changes and the cost of such change is still affordable (metal has not yet been cut). Indeed, in the early phases of product or process development, investments in tools and equipment have usually not yet been released and changing a CAD file or a design is not too expensive. Standard times play a key role in setting transformation process costs and purchasing costs of goods and services.

World class companies' purchasing departments monitor direct purchasing or outsourced service costs thanks to an analytical calculation based on the most appropriate PMTSs. As far as ergonomics is

concerned, if there is a tool to pre-calculate the biomechanical load based on a planned working method, it becomes economical and effective to preventively reduce the risk due to an excessive workload.

4.3 Work measurement

4.3.1 General

The definition of the basic time (T_b , Step 2 in [Figure 2](#)) is built on the concept of standard work performance^[23], strictly related to the fair day's work. As mentioned previously, the standard work performance represents an effort level that could be easily maintained year in, year out by a worker with average physical capabilities without in any way asking him or her to draw upon his or her reserves of energy. Working at standard performance allows the worker to get to the end of the fair day's work without an excess of physical stress.

Most accurate work measurement techniques (stopwatch and PMTS) make use of performance rating to ensure that times calculated or derived are times for "an average qualified worker" to carry out the work being measured. Since this average qualified worker is not actually observed, performance rating is used to modify what is observed and thus convert it to basic time (see [Figure 4](#)).

Stop-watch procedure	EXAMPLE
Stop watched time T_{sw}	Stop watched time $T_{sw} = 100$
Rated Performance \bar{P}	Rated Performance $P = 90 \%$
Standard performance P	Standard performance $\bar{P} = 100 \%$
Basic time $T_b = T_{sw} \times (P/\bar{P})$	Basic time $T_b = 100 \times (90/100) = 90$

Figure 4 — Stopwatch procedure to set a basic time

Some measurement techniques, such as the PMTS, are not based on the observer to rate the worker's performance. PMTS developers use performance rating in the derivation of the original data to calculate the basic times of each single elementary motion. Therefore, PMTSs, once the method has been set (sequence of elementary motions), directly provide the basic times, without the need to rate the operator's working performance and, even more important, without the need to observe. This is the reason why PMTSs are strongly recommended for designing and planning a new work system, making a preventive approach to ergonomics possible.

Currently, there are a number of different performance rating systems and scales available and in use (no reference standard is defined) and this makes it difficult to define a standard norm performance. Using different performance scales leads to setting different basic times for the same quantity of work, causing critical deviations in the ergonomic evaluation of the work load (e.g. a different basic time per motion would generate different motion frequencies in a cycle).

4.3.2 Standard work performance

Due to increasing globalization, many organizations are currently using several different work measurement techniques in different geographies of the organization. This happens because different techniques have gained a greater degree of usage in specific countries. Global organizations are willing to set comparable standard times of the same piece of work to simplify planning and control processes and to manage properly their manufacturing footprint and production allocation. That's why it is important to support the definition of a global work performance reference, exploiting the large quantity of knowledge about ergonomics, which became available mainly in the last 20 to 25 years (while the most common definitions of standard work performance date back to the 1940s).

Each of the rating systems or scales starts from a different conceptual viewpoint. For example, the Bedaux System assumed that 'normal' performance was 60 'minutes of work' per hour, that 80 'minutes of work' per hour was incentive performance and that 100 was the theoretical maximum.

All work measurement systems use time units to represent work content – the quantity of work involved in carrying out a particular task, operation or job. Thus, the unit, such as 'standard minute', is an expression of quantity of work, rather than of time. It only converts to an equivalent time by assuming that the operator works at standard performance (with reference to the performance rating scale in use) and takes the agreed level of allowances built into the work content value (standard time). Different rating systems claim to rate different factors – commonly these are some combinations of speed, effort, skill, dexterity, consistency and conditions.

One of the common problems of rating is that it is often linked to remuneration, through setting 'daywork' rates or through graduated incentive payment schemes. This results in pressure from employees and unions on work study practitioners to 'slacken' their ratings to give 'looser' time values for jobs.

Thus, even though the same rating system and scale is in use in different organizations, there is no guarantee that the concepts of normal and incentive performance are the same in each one of them – this is especially true if the organizations carry out no rating validation through rating clinics.

In some countries or organizations, trade unions have a right to observe time studies or to carry out parallel studies to check on the times produced by industrial engineers. Where incentive payment schemes are involved there is understandably a desire to challenge ratings and allowances used by the practitioner – since most rating systems are based on subjective judgment, this debate is difficult to resolve in the absence of some means to validate ratings.

The choice of a well-known level of standard performance is crucial for the process of designing safe and ergonomic work systems, especially as far as the upper limbs risk evaluation is concerned. Indeed, a higher level of standard performance would bring to shorter basic times for each elementary motion and consequently an expected increase in action frequency of the upper limbs planned motions. When most of the work measurement systems were developed, there were no ergonomic standards available and the good ergonomic solutions were left to the individual experience of the industrial engineers. Nowadays, the correlation between biomechanical load and the probability of incurring a work-related musculoskeletal disorder is proved and relevant ISO and CEN documents set clear references.

One objective of this document is to take a formal position against the use of the different standard performance levels to set basic times in the industries. The availability of different performance rating scales is not an issue. When measuring a temperature, regardless of the scale used, if the water starts boiling, the value read on each scale is different but well known and equivalent (100 °C or 212 °F or 373,15 °K indicate the same level of heat). In the same way, it is important to establish a fair reference level of work performance, which keeps the biomechanical load under given limits. Several tests have been run by the technical committee of the International MTM Directorate, using the MTM scale as a reference, and the results are summarized in Annex A.4.

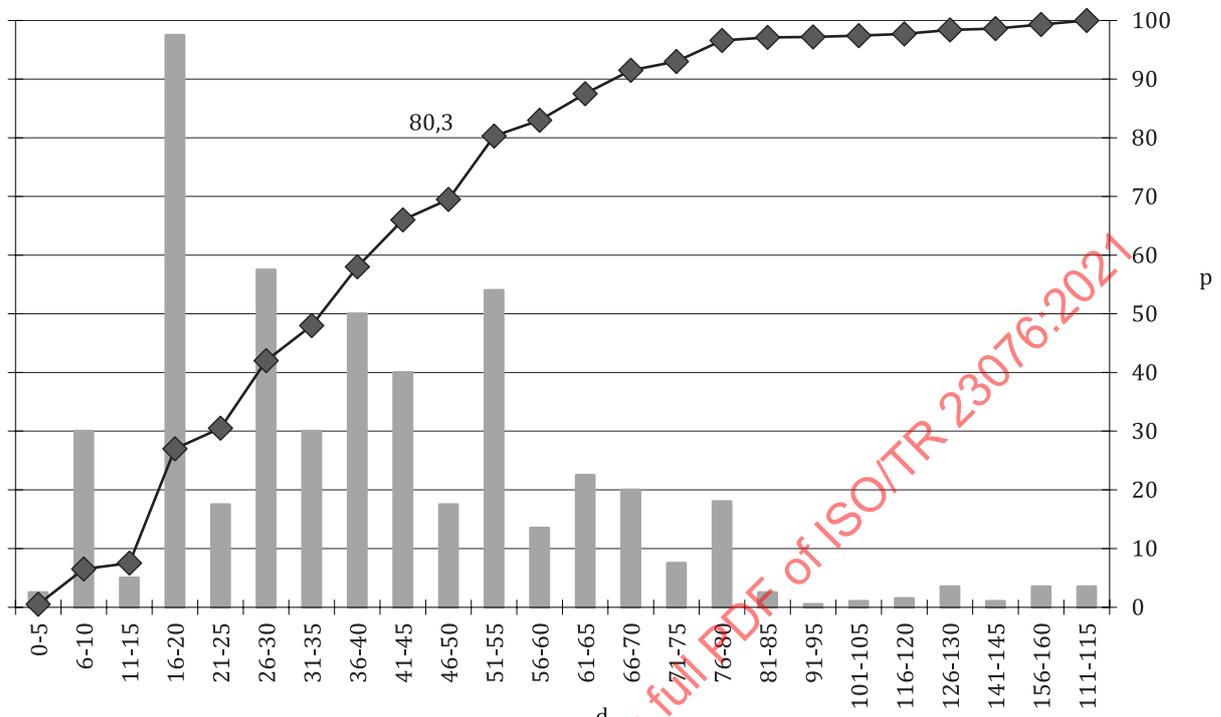
4.3.3 Real action

A real action (RA) is a combined movement of the upper limb (fingers, hand, wrist, elbow or shoulder) aimed at achieving a planned state (e.g. get and place an object to a specific destination). The exact definition of the RA is based on the movement definitions of the building blocks of MTM-UAS^[24].

ISO 11228-3 sets the maximum number of actions at 70 technical actions per minute, equivalent to 40 real actions per minute^[19]. Considering the durations shown in [Figure 5](#), the average duration of one action is in the range of 31–35 TMU (time measurement units) (100 000 TMU = 1 hour), equivalent to 1,2 s and generating a frequency of 50 real actions per minute (equivalent to c. 87 technical actions/min).

In a real workplace, consider that there is usually a distribution of motions between the two upper limbs (left and right) and some body motions and visual controls, which do not generate any real action and therefore dilute the frequency of actions. Consequently, there is a good chance that, adopting

the MTM standard work performance, the resulting frequencies of action will not cause an excessive biomechanical load. Of course, to obtain a complete load evaluation, further influencing factors have to be considered (e.g. force levels, weights, postures).



Key

d duration range of real actions (TMU)

p percentile

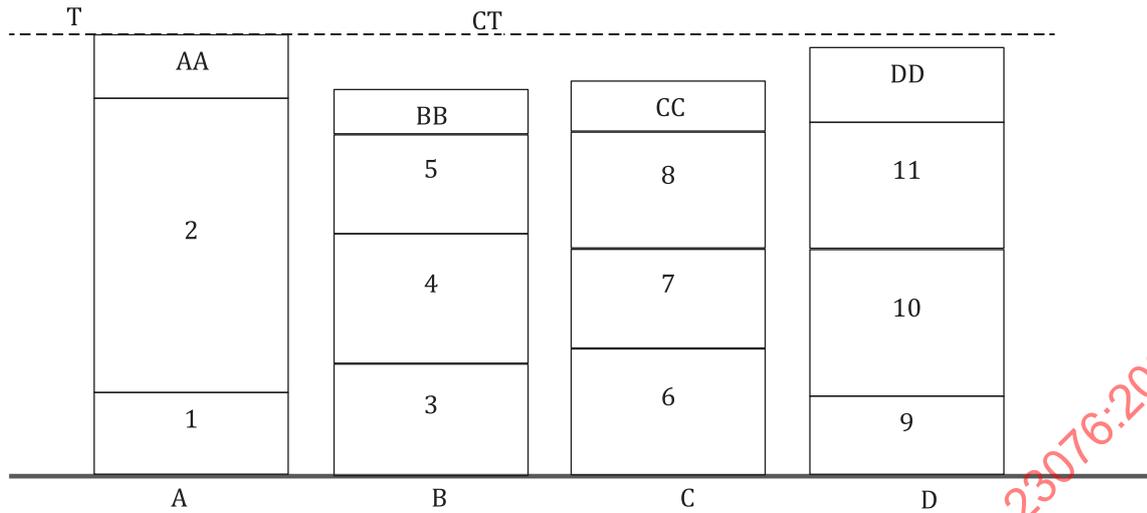
NOTE 1 Histogram bars represent the frequency.

NOTE 2 Points in the line represent the percentile.

Figure 5 — Distribution of real actions duration

4.4 Task assignment and work organization

Task assignment in the manufacturing industry is very important, especially when dealing with assembly lines (line balancing, see [Figure 6](#)). Indeed, once the total work content is calculated (total basic time of all the actions necessary to accomplish the complete task), given a targeted quantity of units to produce and the net working time available in a shift (shift duration minus breaks and non-productive time), it is possible to set the pace of our production flow (cycle time, T_c). Cycle time then becomes the maximum capacity of each workstation along the flow if the operators are to work at a controlled performance and to produce the planned output. T_c is like the capacity of a glass, the water poured into it is the set of tasks assigned to a workstation and T_{std} (standard time) is the quantity of litres of water poured into the glass. Without an accurate work measurement, it would not be possible to balance the line evenly and production would not flow smoothly along the line. Consequently, there would be lower productivity levels and an uneven distribution of work among the workers, forcing the most saturated workers to work harder and faster to cope with the line pace (T_c).



Key
 CT cycle time
 T time
 A, B, C, D workstation A, B, C, D
 1,2,3,4,5 ... operation 1,2,3,4,5... (basic time)
 AA, BB, CC, allowance a, b, c, d
 DD

Figure 6 — Line balancing

Once the tasks are assigned to a workstation and the T_c is set, the duration of each action (times per minute in the case of dynamic actions or seconds of duration per minute in the case of static actions) is determined and the calculation of the workload results accurately accomplished.

4.5 Biomechanical load measurement

Load results from the intensity and the duration of the work and from the working conditions in which it is carried out. A load describes the objective demand of work, which is to be fulfilled in a period of time. It is independent from the individual who performs the activity.

At present, several ergonomic analysis systems are available to measure the workload. Each system was designed to deal with a specific risk area and it works with its own measurement scale (e.g. NIOSH Lifting Index, OCRA Index, ACGIH TLV, HAL, RULA, Strain Index). To apply the EWA model, it is necessary to compound all type of loads (postures, forces, manual material handling of loads, vibrations and repetitive upper limb motions) on a unique scale. In [Figure 7](#) a comprehensive approach is represented. [Clause 6](#) provides a first available solution (EAWS), which meets all the rules of the application of the EWA model.

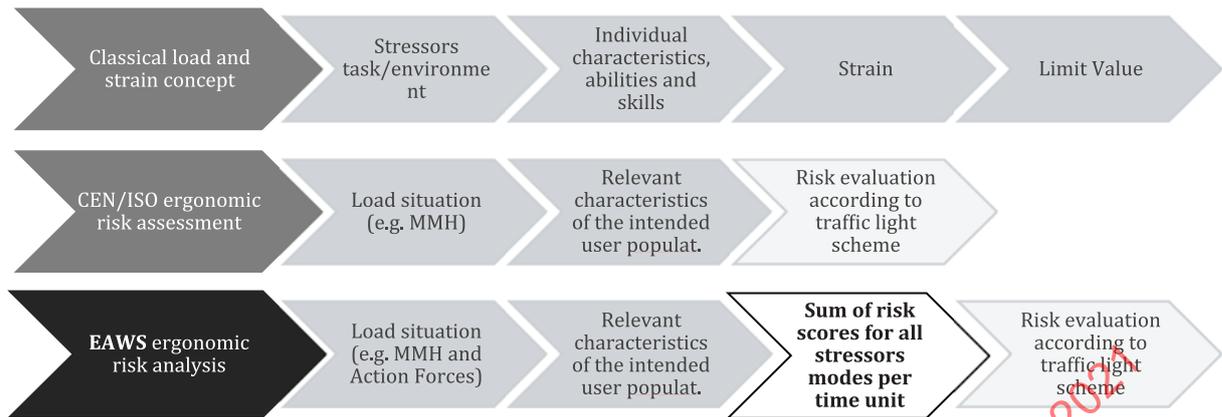


Figure 7 — Approach to an overall load index assessment

The required ergonomic measurement tool provides an overall load evaluation that includes all biomechanical risks to which an operator can be exposed during a cyclical work task. All loads are measured and compounded on a unique scale and the resulting load expressed through a final index, the overall load index (OLI), which is then used in the EWA model to determine a proper allowance factor.

The load is given by the result of the following formula:

$$\text{Load} = \text{Intensity} \times \text{Duration}$$

Intensity is mainly driven by the awkwardness of postures (body, upper limb and grip), intensity of forces (force exertion and manual material handling) and vibrations.

Duration is driven by the action frequency (dynamic actions) and action duration (static actions).

ISO 11226 and ISO 11228 offer models to assess the level of exposure to ergonomic risk by providing a measure of the biomechanical load. These provide a means of measuring loads that are not simple to measure given the numerous and related influencing factors (e.g. the intensity of an upper limb motion depends on the force level with respect to the type of grip used to get the control over the object being moved and to the direction of the movement).

The requirements of the EWA model are even higher, since it needs in input the measurement of the total load generated by the composition of all types of load.

4.6 Ergonomic work allowance (EWA)

4.6.1 General

An allowance is the adjustment of the basic time to obtain the standard time for the purpose of covering the time spent for personal needs, recover from fatigue and unavoidable delays. By providing a small increase in the basic time for each cycle, the “non-productive” time becomes planned and a worker can still be able to complete the work assigned to him or her.

There are two types of interruption: (1) interruption related to the work; (2) interruption not related to the work. For example, a machine breakdown, rest break to overcome fatigue, and receiving instructions from the manager are the interruptions related to the work, but personal needs and lunch breaks are interruptions not related to the work. However, the two types of interruption are both essential for the worker because it is almost impossible to work in a continuous manner during a regular shift.

Fatigue allowance is intended to cover the time given to the worker to overcome fatigue due to work-related stress and conditions. There are three factors that cause fatigue: (1) physical factors, like standing and the use of force; (2) mental and cognitive factors, like mental strain and eye strain; and (3) environmental and work factors, like poor lighting, noise and heat.

This document deals only with (1) physical factors and partially with (2) mental and cognitive factors for workers assigned to cyclical manual tasks in an industrial manufacturing environment. Specifically, EWA means the allowance coping with physical factors. A few mental and cognitive factors of manual repetitive tasks are only evaluated in the most advanced work measurement techniques in the definition of basic time (high-precision motions require visual and mental control and, for this reason, are given more time). Most of the mental and cognitive factors are not dealt with in this document (fatigue related to psychosocial issues, which the worker faces and deals with either in the workplace or otherwise).

The EWA model does not include any coverage of interruptions not related to the work. Specifically, EWA does not include any physiological need allowance, which is a constant value independent from the type of work and typically ranges from 4 % to 5 % of the shift time (equivalent approximately to two breaks of about 10 minutes each, distributed within a typical shift of 8 hours).

Since the definition of basic time T_b assumes there is no physical stress in the accomplishment of a daily task, if the working task generates stress, industrial engineering practices recommend the allowance of a recovery time sufficient to compensate the extra effort. The objective is to level physical effort (biomechanical load) within the standard limits referenced by the work performance, thus reducing the likelihood of incurring work-related musculoskeletal disorders. In other words, the EWA allows more time to execute a task (diluting the basic time), thus reducing the demand for the worker's performance.

The basic time T_b is determined based on the standard work performance. In this subclause the MTM standard performance has been selected as the reference, since, if there are no other risk factors present in the work task (e.g. awkward postures and forces), it leads to having an action frequency which is likely to conform with ISO 11228-3. However, what if those additional risk factors are present?

4.6.2 Traditional approach

In the best traditional industrial engineering practices, ergonomic work allowances (often named rest or fatigue factor) are determined and applied on each single motion. This type of model is named "single-motion work allowance". In the eventuality that a detailed motion-time study is not available, the ergonomic work allowance is often applied as a constant percentage on all workstations, regardless of the type of task carried out (usually the percentage is based on old company agreements). In worst-case scenarios (unfortunately quite common in the real life), no ergonomic allowance is applied.

Table 2 gives some examples of the rest allowance table adopted by the Fiat group from the 1960s until their global adoption of the EWA model in 2008.

Table 2 — FCA old rest allowance model

Basic body Postures		Trunk and upper limbs posture	Force exertion or weight						
			L 0 kg to 2 kg	M 2 kg to 10 kg	P 10 kg to 20 kg	PP 20 kg to 25 kg			
						Allowance in %			
1		A Trunk and upper limbs in normal posture Stationary trunk	5	6 to 7	-	-			
Sitting		B Trunk and upper limbs in awkward posture; Stationary trunk	7	8 to 10	-	-			

NOTE Percentages in this table do not include any allowance for physiological needs (4 %).

Table 2 (continued)

Basic body Postures		Trunk and upper limbs posture	Force exertion or weight			
			L 0 kg to 2 kg	M 2 kg to 10 kg	P 10 kg to 20 kg	PP 20 kg to 25 kg
Allowance in %						
2		A Trunk and upper limbs in normal posture; stationary trunk	7	8 to 9	10 to 12	13 to 17
Standing		B Trunk and upper limbs in normal posture; moving trunk	9	10 to 12	13 to 15	16 to 20
		C Trunk and upper limbs in awkward posture; Stationary trunk	11	12 to 14	15 to 18	19 to 23
		D Trunk and upper limbs in awkward posture; moving trunk	13	14 to 16	17 to 20	21 to 25
3		A Trunk and upper limbs in normal posture; stationary trunk	8	9 to 10	11 to 13	-
Kneeling		B Trunk and upper limbs in awkward posture Stationary trunk	12	13 to 15	16 to 19	-
4		A Trunk and upper limbs in normal posture; stationary trunk	10	11 to 13	-	-
Laying		B Trunk and upper limbs in awkward posture Stationary trunk	14	15 to 18	-	-
5		A Flat surface, with or without load	10	11 to 14	15 to 19	20 to 24
Walking		B Sloped surface, with or without load	13	14 to 17	18 to 22	23 to 27
		C Pushing/pulling trolleys or carts on a flat surface	11	12 to 15	16 to 20	21 to 25

NOTE Percentages in this table do not include any allowance for physiological needs (4 %).

The weaknesses of the traditional model are as follows:

- Despite the wide of range of allowance values (1 % to 23 %) in the table, the resultant average value of the allowance on a workplace is fairly constant (in automotive assembly lines there are values in the range 5,5 % to 6,5 %).
- Single motion models do not consider the frequency of actions, which is one of the key drivers in the ISO 11228 series.
- Single motion models do not consider the sequence of actions and therefore tend to neglect or underestimate the duration of static actions (average motion duration ranges from 1 s to 2 s).

4.6.3 Proposed approach: EWA

The first study which drew attention to the weakness of the correlation between the ergonomic work allowance, assigned with the single motion models, and the overall physical stress (fatigue) was carried out in the Fiat Mirafiori plant (Turin), on the trim line of the vehicle models Musa, Punto and Idea in 2005. The objective of that project was to test the effects of the introduction of the work measurement system MTM-UAS and of the newly developed comprehensive ergonomic tool ergonomic assessment worksheet (EAWS).

The results of that study were as follows:

- Step 1

Same line balancing (unchanged task allocation), work measured using MTM-UAS and calculation of the ergonomic factor using the traditional method (single motion model).

Looking at Figure 8, it is quite evident (especially for workstations 18 and 19 where the EAWS index reaches the highest values) that the correlation between EAWS index and the applied allowance (almost constant around the value of 6 %) is very poor.

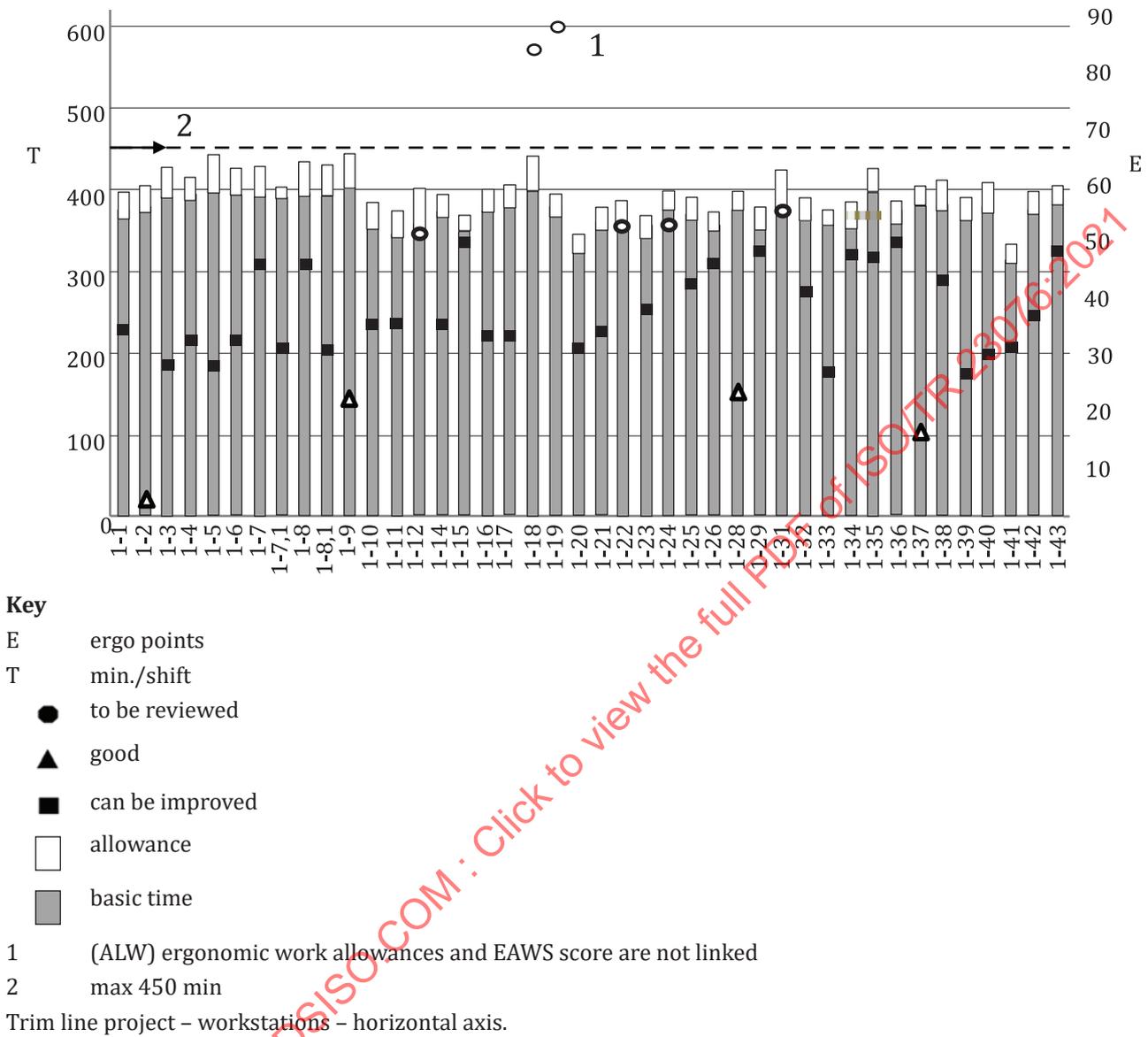
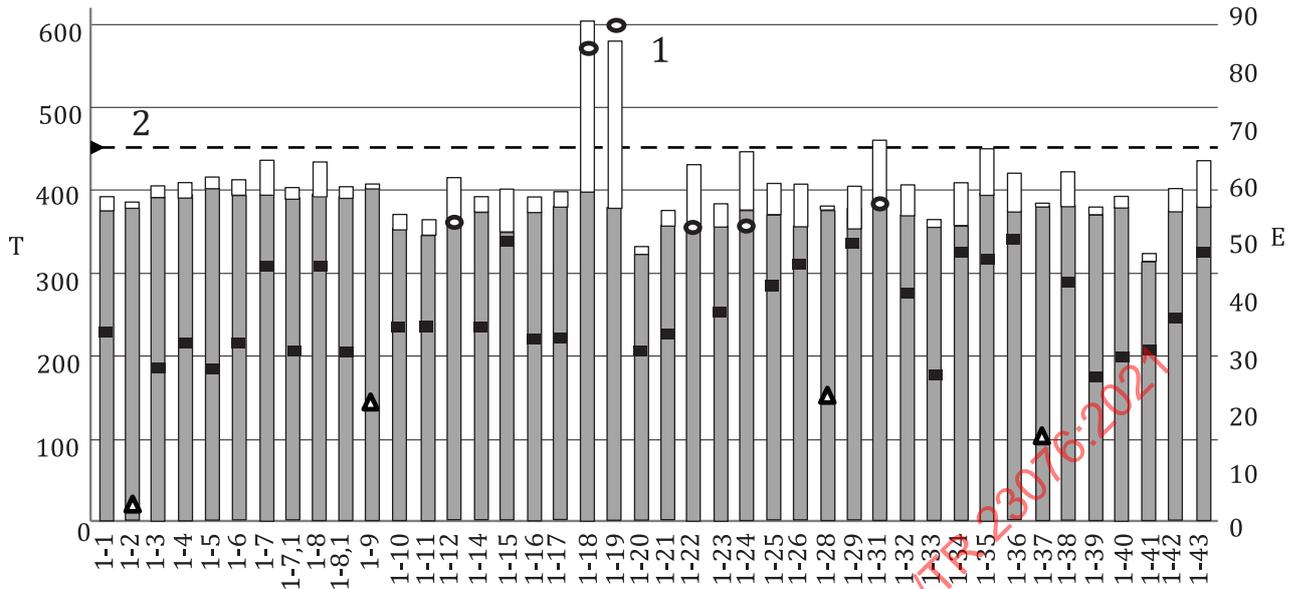


Figure 8 — Mirafiori project, step 1

— Step 2

Same line balancing but calculating the ergonomic allowances using the EWA model.



Key

- E ergo points:
- T min./shift
- to be reviewed
- ▲ good
- can be improved
- allowance
- basic time

- 1 (ALW) ergonomic work allowances and EAWS score are linked by the ERGO-MTM model
- 2 max 450 min

Trim line project – workstations – horizontal axis.

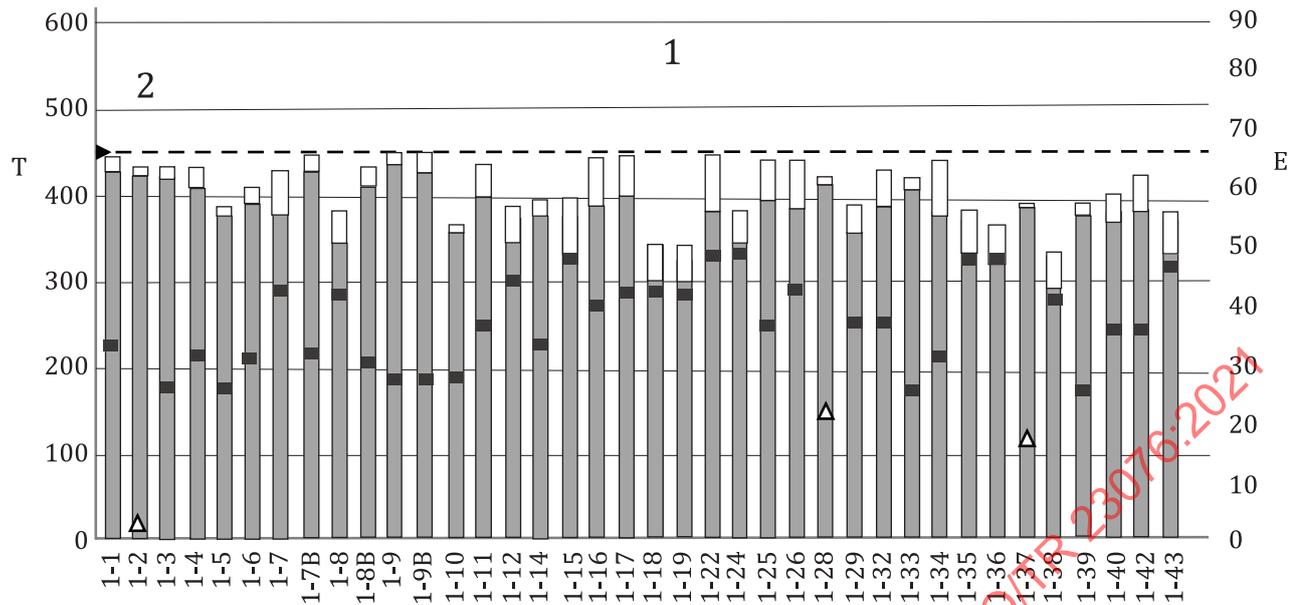
Figure 9 — Mirafiori project, step 2

The ergonomic work allowance model was designed with the main objective of calculating an allowance as a function of a fatigue index. The stronger the demanded fatigue, the higher the allowance (see [Figure 9](#)).

— Step 3

New line balancing (see [Figure 10](#)) and calculating the ergonomic factor using the EWA model (see [Figure 11](#)).

In the new line balancing configuration, task distribution among workstations was driven by the quantity of standard work (basic time) and the level of fatigue (allowance) generated by the same tasks assigned to each workstation. The key indicator to get a well-balanced assembly line is the standard time (basic time + allowance), which in [Figure 10](#) is represented by the height of the bars, limited by the total net available minutes per shift (450 min in this case). This procedure leads industrial engineers to level not just the basic time, but also to avoid peaks of fatigue on one workstation and no physical stress on another.



Key

- E ergo points
- T min./shift
- to be reviewed
- ▲ good
- can be improved
- allowance
- basic time

1 work redesign and balancing of work content and workload
 2 max 450 min

Trim line project – workstations – horizontal axis.

Figure 10 — Mirafiori project, step 3

The fatigue index considers the various sources of physical stress and condensates the evaluations in a unique index.

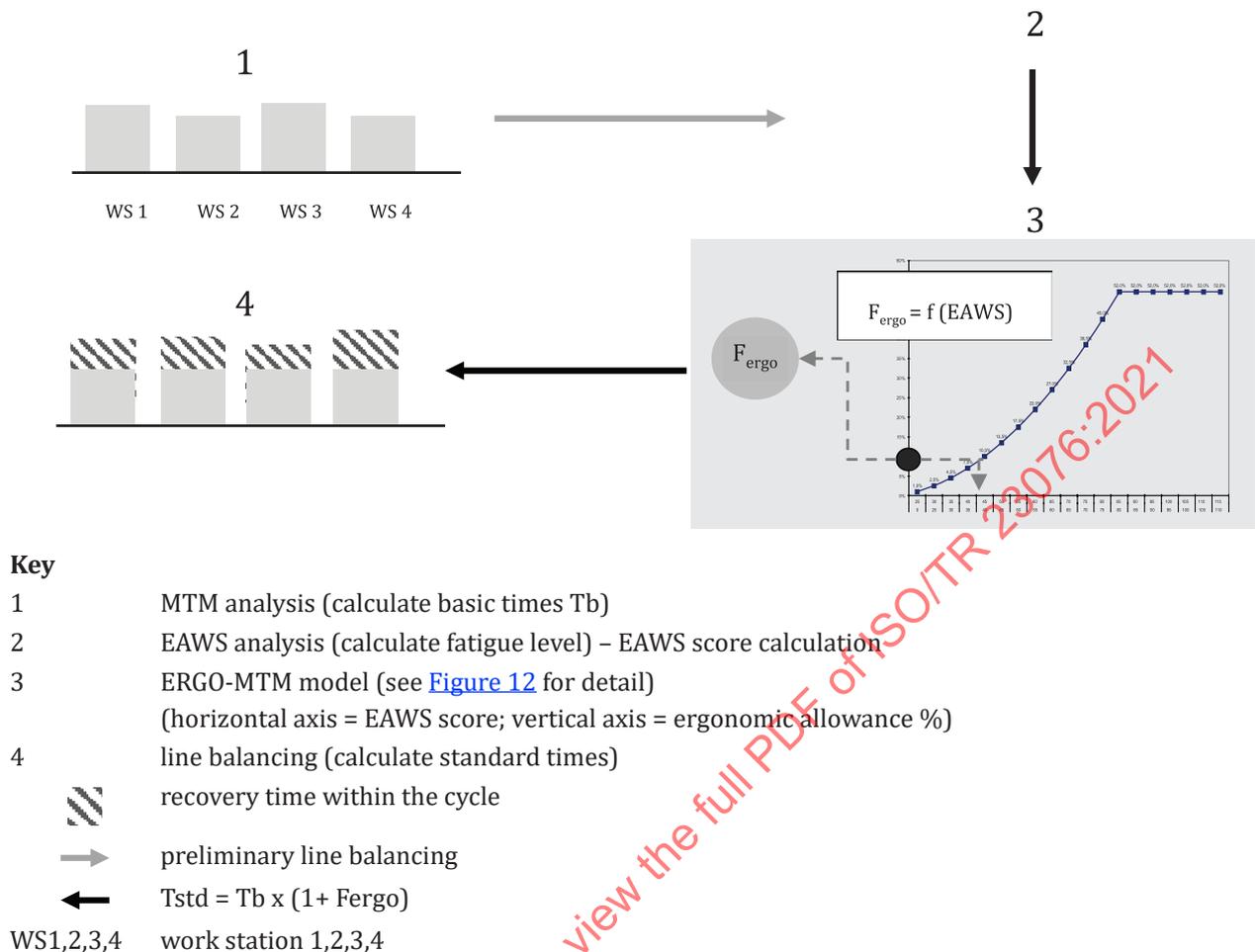


Figure 11 — Ergonomic work allowance model

The main innovation, with respect to other existing allowance systems, is the introduction of the concept of duration. Indeed, traditional methods base the determination of the allowance as a function of the main body posture and the force/load level (intensity), regardless of the duration or the frequency of the motions. The allowance is then applied on each single motion, and, for this reason, the model is called “single-motion allowance”. For example, to lift a load of 18 kg the ILO recommended allowance gives a value of 9% [14], regardless of the number of repetitions of the action during the shift.

The proposed EWA model proposes an ergonomic allowance (fatigue allowance) as a function of the overall load index, which is an index tightly linked to the concept of physical workload. In the EWA model, the physical workload is calculated as follows:

$$\text{Workload} = \text{Intensity} \times \text{Duration}$$

- Intensity is proportional to the degree of awkwardness of the postures, the force intensity or the load weight.
- Duration depends on the duration of static actions and the frequency of dynamic actions.

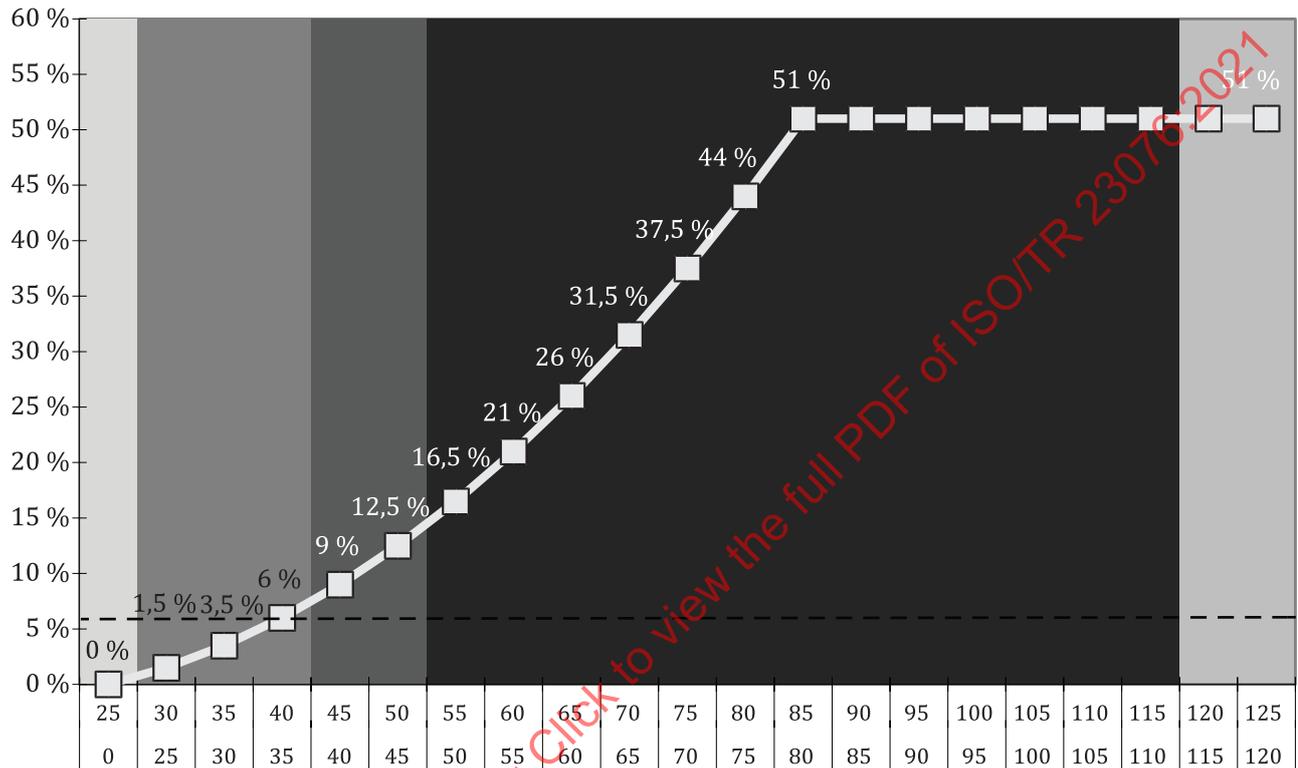
To reach a significant level of workload, it is necessary to have at least a medium intensity with a medium duration. If either one of the two factors is negligible, the resulting workload will be low, even if the other factor is high (in such cases there would be a risk of injury arising from a single identifiable event, which can be lowered through a better method design).

The ergonomic allowance is necessary to dilute standard times and recover from physiological strain (maximum worker’s saturation level is limited or extra breaks are allowed). The nature of physiological

strain depends on the type of muscular contraction involved. There are two types of muscular contractions:

- Dynamic, involving rhythmical contractions of large muscle groups where the length of the muscles is changing (isotonic).
- Static, involving prolonged contraction without a change in the length of the muscles (isometric).

The core of the EWA model is built upon the fundamental principle of allowing a sufficient recovery time to keep the physical load within controlled limits (see [Figure 12](#)).



Key
 EWA ergonomic work allowance (vertical axis)
 OLI overall load index (horizontal axis)
 0 < OLI ≤ 25 low physical stress
 25 < OLI ≤ 40 medium low physical stress
 40 < OLI ≤ 50 medium high physical stress
 OLI > 50 high physical stress

Figure 12 — Ergonomic recovery model

4.6.4 Design criteria

The EWA model was determined setting a curve that starts from 0 % and increases exponentially up to 51 %, trying to match the plotted values and generating a set of points very sensitive to load variations, particularly within the medium risk zone (25 < overall load score < 50), which represents the most common case in the manufacturing industry. To identify the best-fitting EWA curve, numerous calculations were run during a research project, which took place at the FCA Mirafiori automotive plant on the Musa-Ideal final assembly line from 2005 to 2006. In that study, the EAWS system was adopted

by Fiat as the comprehensive ergonomic tool to calculate the overall load index. The drivers in the identification of the function were the following:

- Start from 0 %, since, if there is no significant load, the standard work performance sets the basic times on a level corresponding to the no-stress area (see definition of standard work performance).
- In the middle of the medium load level (medium stress zone in [Figure 12](#)), corresponding to a overall load index of 37,5, set the EWA at 6 %.
- Define the “speed” of the function (first derivative) in order to reduce the workload enough to exit from the red area. An exponential model was selected, since linear models failed.

[Figure 12](#) shows the proposed model, where the traffic light colours indicate three load levels corresponding to three risk zones: low risk (green), medium risk (yellow) and high risk (red).

Since 2006, hundreds of real field applications of the EWA curve have proved its validity, pushing users to continuous improvements on the ergonomic conditions to increase productivity and reduce labour costs.

In Clause 6 a summary of the study about the definition of the EWA function is reported.

4.7 Organizational solutions

4.7.1 General

The EWA model was designed to support and guide industrial engineers to design efficient and safe working methods and set standard times in order to put the worker in the best conditions to operate productively and safely. The EWA model does not end with the definition of allowance. [Figure 2](#) shows that if the overall load index (output of step 4 – biomechanical load measurement) enters into the high-risk zone (with EAWS this would mean having more than 50 points), the EWA process would require a review of the work system under evaluation. This is a fundamental concept: EWA wants to support the (re)design of a safe work system. It would not even be economic trying to increase the allowance, thus reducing the work pace, until the overall load index decreases under the threshold value. This is the reason why the EWA curve flattens at 51 %. In cases where the overall load index is much over the threshold value, the model would not be used to find the allowance value sufficient to exit the red area, but improving the working method and conditions and run again the load calculation would be recommended until the value drops under the threshold or as close as possible to it (constrained optimization). At that point, the application of the EWA could solve the problem.

4.7.2 Strategies to reduce the overall load index

- a) Redesign of the work method in order to reduce the intensity score, for example by allowing the operator to work with a better body posture or by reducing the amount of force needed to perform a certain task (e.g. using a tool). In most of the cases, provisions are “low cost automation” (LCA) initiatives, i.e. small investments with a short payback period (usually shorter than 1 year). The EWA process helps the identification of the critical steps in the work process and gives precious indications as to where the work method will be improved. Another key benefit of the application of the EWA model is that an ergonomic improvement directly generates a cost reduction (less load would mean less allowance and therefore less cost) that is used to justify a LCA improvement.
- b) If no method improvements are possible or justifiable in the short term, then organizational solutions need to be found which do not eradicate the ergonomic issue but offer a way to manage the situation. The most common organizational options are:
 - Review step 3, i.e. the task assignment (line rebalancing); when doing this, attention has to be concentrated on the operations which cause the highest load values and finding an alternative workstation with enough room to receive the additional load, without generating a new ergonomic issue and with the necessary idle time so that, even with the additional operation, its total standard time would not exceed the cycle time of the line. Of course, also take into

consideration the production sequence when moving an operation to a different workstation. It could be necessary to repeat this procedure in a loop more than once before finding a balanced scenario.

- If task assignment cannot be changed or has no effect and no method redesign is possible, one organizational solution is to plan a job rotation among two or more workstations in order to obtain an acceptable weighted average overall load index for each concerned worker.
- Another option is to review the quantity and distribution of the breaks. This option would have a significant impact where repetitive motions of the upper limbs represent the most critical ergonomic area.

The best strategy to consider to reduce risk:

- The economic impact of the identified solution: in general, the addition of a recovery time could increase the production cost, but the implementation is longer. On the contrary, the redesign of the workstation means maintaining a constant (or even increasing) production output, probably involving significant investments. Ideal solutions usually lie in between these two options: low cost automation helps to remove critical loads (focused improvements) and the rest is done through organizational solutions (line rebalancing is the most common).
- The effect of the actions on the intensity/duration score, considering that the intensity and duration score curves have different behaviours in the different sections (body postures, force exertion, handling of loads and repetitive motions of the upper limbs).

5 Ergonomic assessment worksheet (EAWS)

5.1 System overview

EAWS is a risk assessment method for biomechanical load of the whole body and upper limbs used mainly in manufacturing industries as a process design tool for preventive ergonomics and adopted in the production department to map biomechanical stress (630,000 workers estimated to be mapped with EAWS worldwide).

EAWS is an open system, freely available, part of the International MTM Technical Platform, managed by the Fondazione Ergo (www.fondazioneergo.it), a non-profit organization dedicated to the development of the body of knowledge regarding the scientific management of work (all official systems in the international MTM technical platform are available in the main languages, including Chinese).

EAWS offers compliance with the relevant CEN or ISO documents and it is structured in four sections, each one covering a specific risk area: body postures, action forces, manual materials handling and upper limbs in repetitive tasks.

The EAWS scoring procedure is presented in detail in [Annex A](#) and the EAWS manual is available in the main languages.

The EAWS form is freely downloadable in 10 languages from: <https://www.eaws.it/>

5.2 EAWS basic structure

5.2.1 General

EAWS is an ergonomic tool for a detailed biomechanical overload risk assessment, developed to provide an overall risk evaluation that includes every biomechanical risk to which an operator may be exposed during a working task.

In order to effectively address ergonomic issues in the workplace, develop an appreciation for the trade-offs associated with ergonomics. When one considers biomechanical rationale, one finds that it is very difficult to accommodate all parts of the body in an ideal biomechanical environment. It is often the

case that, in attempting to accommodate one portion of the body, the biomechanical situation at another body site is compromised. Therefore, the key to the proper employment of occupational biomechanical principles is to be able to consider the appropriate biomechanical trade-offs with various parts of the body associated with different workplace design options.

The above brief introduction to biomechanics is reported just to give the idea of the level of complexity there is when aiming to measure a biomechanical load index. For this reason, in the field of occupational biomechanics, researchers adopt models which do not have the same level of accuracy as other scientific measuring systems (e.g. methods-time measurement to measure the human work). It is known that all existing systems are an attempt to model the effects of forces and motions on the muscular-skeletal system and none of them currently reflects the actual situation. Proper use of these models and methods involves recognizing the limitations and assumptions of each technique so that they are not applied inappropriately. When properly used, these assessments help assess the risk of work-related injury and illness.

Nonetheless, EAWS design was done based on existing and available research with the aim of finding the most appropriate and reasonable correlation against the CEN and ISO documents dealing with biomechanical load.

The EAWS structure is as follows (see [Figure 13](#)):

a) Macro-Section “Whole body”.

Section 0: Extra points.

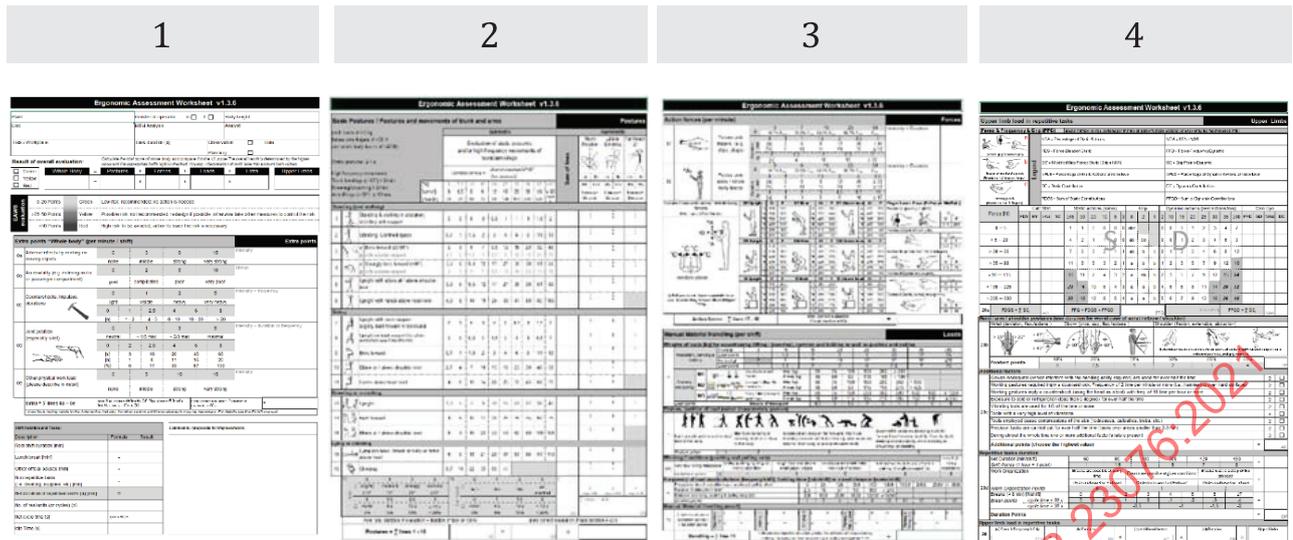
Section 1: Postures (ISO 11226 and EN 1005-4).

Section 2: Action forces (ISO 11228-2 and EN 1005-3).

Section 3: Manual material handling (see ISO 11228-1, ISO 11228-2 and EN 1005-2).

b) Macro-Section “Upper limbs”.

Section 4: Upper limb load in repetitive tasks (see ISO 11228-3 and EN 1005-5).



Key

- 1 page 1 - overall index and extra points
- 2 page 2 - body postures
- 3 page 3 - action forces and MMH
- 4 page 4 - upper limbs repetitive movements

NOTE See [Figure A.60](#), [Figure A.61](#), [Figure A.62](#) and [Figure A.63](#) for detail.

Figure 13 — EAWS form overview

The EAWS system calculates a load index (R), given by the product of the intensity (I) by the duration (D):

$$R = I \times D$$

where:

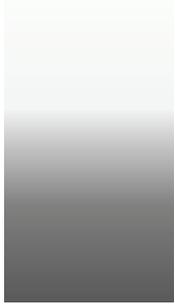
- R is the risk;
- I is the intensity;
- D is the duration.

In Section 1, the user selects the relevant posture in the proper row (intensity) and measures the duration (column). Intersecting the column of duration with the row of intensity, the user easily finds the score.

In Sections 2, 3 and 4, the user calculates the intensity and the duration scores of the concerned task, following specific rules, and eventually multiplies the intensity score by the duration score to find the load index.

The EAWS sheet provides one score for each macro-section. The overall load index of each macro-section is then connected to a traffic light scheme (green, yellow, red) according to the Machinery Directive 2006/42/EC (EN 614) as in [Table 3](#):

Table 3 — EAWS traffic light output

0–25 points	Green		Low risk	Recommended; no action is needed
> 25–50 points	Yellow		Possible risk	Not recommended; redesign if possible, otherwise take other measures to control the risk
> 50 points	Red		High risk	To be avoided; action to lower the risk is necessary

Whole body and upper limbs scores are evaluated on the same scale. It is therefore important to understand which is the most critical macro-section.

5.2.2 Section 0: extra points

Extra points are related to additional extraordinary loads and not considered in the other total body sections. They are therefore covered in this subclause. The standard influencing factors in Section 0 (see [Table 4](#) and [Figure A.60](#)) are:

- working on moving objects;
- difficult accessibility to the working area;
- counter shocks, impulses, vibrations;
- joint position (especially wrist and neck);
- other “special” situations, like above head control work, including looking upward (neck load).

Table 4 — Extra points whole body

Extra points “Whole body” (per minute / shift)							
0a	Adverse effects by working on moving objects	0	3	8	15		
		none	middle	strong	very strong		
0b	Accessibility (e.g. entering motor or passenger compartment)	0	2	5	10		
		good	complicated	poor	very poor		
0c	Countershocks, impulses, vibrations	0	1	2	5		
		light	visible	heavy	very heavy		
		0	1	2,5	4	6	8
		[n]	1 - 2	4 - 5	8 - 10	18 - 20	> 20
0d	Joint position (especially wrist)	0	1	3	5		
		neutral	~ 1/3 max	~ 2/3 max	maximal		
		0	2	2,5	4	6	8
		[s]	3	10	20	40	60
		[n]	1	8	11	16	20
[%]	5	17	33	67	100		
0e	Other physical work load (please describe in detail)	0	5	10	15		
		none	middle	strong	very strong		

5.2.3 Section 1: body postures

On the left side of the page (Figure A.61), load points for symmetric body postures (Figure 14) are be assigned. If there are any asymmetric static posture (Figure 15) due to trunk rotation, lateral trunk bending or arm extension (far reach), use the right side of the page.

Standing (and walking)															
1	1		Standing & walking in alteration, standing with support	0	0	0	0	0,5	1	1	1	1,5	2		
	2		Standing, no body support (for other restrictions see Extra Points)	0,7	1	1,5	2	3	4	6	8	11	13		
	3	a	Bent forward (20-60°)	2	3	5	7	9,5	12	18	23	32	40		
		b	with suitable support	1,3	2	3,5	5	6,5	8	12	15	20	25		
	4	a	Strongly bent forward (>60°)	3,3	5	8,5	12	17	21	30	38	51	63		
		b	with suitable support	2	3	5	7	9,5	12	18	23	31	38		
5		Upright with elbow at / above shoulder level	3,3	5	8,5	12	17	21	30	38	51	63			
6		Upright with hands above head level	5,3	8	14	19	26	33	47	60	80	100			
2	Sitting														
	7		Upright with back support slightly bent forward or backward	0	0	0	0	0	0,5	1	1,5	2			
	8		Upright no back support (for other restriction see Extra Points)	0	0	0,5	1	1,5	2	3	4	5,5	7		
	9		Bent forward	0,7	1	1,5	2	3	4	6	8	11	13		
	10		Elbow at / above shoulder level	2,7	4	7	10	13	16	23	30	40	50		
3	11		Hands above head level	4	6	10	14	20	25	35	45	60	75		
	Kneeling or crouching														
	12		Upright	3,3	5	7	9	12	15	21	27	36	45		
	13		Bent forward	4	6	10	14	20	25	35	45	60	75		
4	14		Elbow at / above shoulder level	6	9	16	23	33	43	62	80	108	135		
	Lying or climbing														
	15		(Lying on back, breast or side) arms above head	6	9	15	21	29	37	53	68	91	113		
	16		Climbing	6,7	10	22	33	50	66						

- Key**
 basic positions:
 1 standing
 2 sitting
 3 kneeling or crouching
 4 lying or climbing

Figure 14 — EAWS symmetric body postures

On this page, static postures (which are defined in EAWS as postures maintained for at least four consecutive seconds) and high-frequency movements are evaluated, including loads weighing less than 3 kg, action forces onto fingers less than 30 N, and whole-body forces less than 40 N.

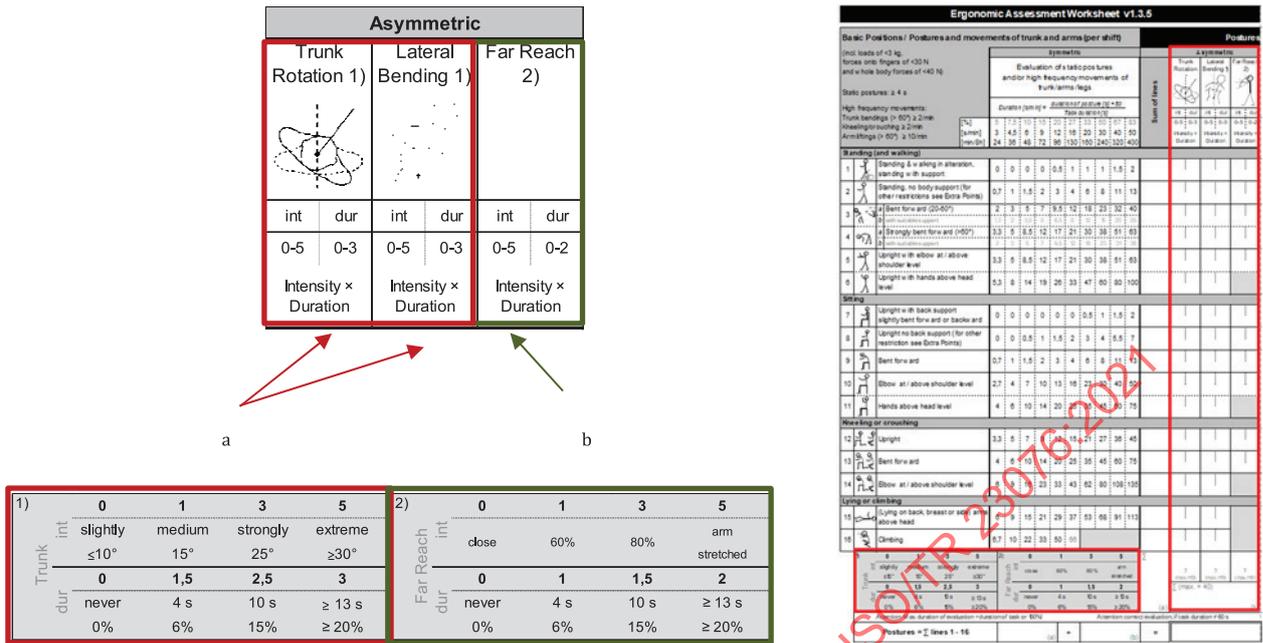
In the EAWS form, Section 2, the columns indicate the duration (in % of the cycle, s/min or % of shift) of a specific posture. The rows show a graphic visualization of different posture types (intensity).

The asymmetric body postures:

- trunk rotation (use duration table a);
- lateral trunk bending (use duration table a);
- arm extension (far reach) (use duration table b);

are evaluated on the right side of the page. At the bottom of the left side (see Figure 15) of the page, there is a table to assign the “intensity” and the “duration” points:

- trunk rotation and lateral bending table (use duration table a);
- far reach table (use duration table b).



Key

- a Trunk - duration table.
- b Far reach - duration table.

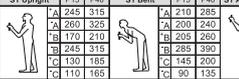
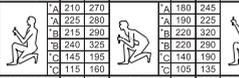
Figure 15 — EAWS asymmetric body postures

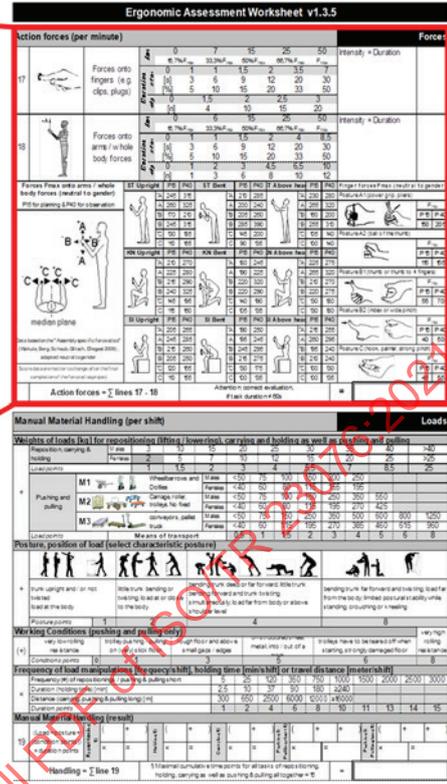
5.2.4 Section 2: action forces

In Section 2, action forces are evaluated:

- Row 17: Forces onto/with fingers if greater than or equal to 30 N;
- Row 18: Action forces onto arms and whole-body forces if greater than or equal to 40 N (excluding manual material handling evaluated in Section 3).

In the lower part of this section (see [Figure 16](#)) data are abstracted from the “Force Atlas”^[27] and represented in figures and values. These values are the result of detailed German academic research about force limits at different anthropometric percentiles for each body and hand postures. In the Force Atlas, the statistical distribution of the maximum forces, depending on the postures of hand, arms and body, is established for significant percentiles. The force values assigned in section 2 of EAWS are the ones for the 15th and 40th percentile neutral gender (in the standard EAWS form neutral gender is set equal to feminine gender). 15th percentile data are used for planning, 40th percentile data for direct observational analyses.

Action forces (per minute)		Forces	
17	 Forces onto fingers (e.g. clips, plugs)	Intensity × Duration 0 7 15 25 50 16.7% F _{max} 33.3% F _{max} 50.0% F _{max} 66.7% F _{max} F _{max}	Intensity × Duration
		Duration start [s] 0 1 1.5 2 3.5 7 [%] 3 6 10 15 20 33 50 stop [s] 0 1.5 2 2.5 3 [%] 4 10 15 20 33 50	
18	 Forces onto arms / whole body forces	Intensity × Duration 0 1 1.5 2 4 8.5 16.7% F _{max} 33.3% F _{max} 50.0% F _{max} 66.7% F _{max} F _{max}	Intensity × Duration
		Duration start [s] 0 1 1.5 2 4 8.5 [%] 3 6 10 15 20 33 50 stop [s] 0 1 2 3 4.5 6.5 10 12 [%] 1 3 6 8 10 12	
Forces F _{max} onto arms / whole body forces (neutral to gender) P15 for planning & P40 for observation		ST Upright P15 P40 ST Bent P15 P40 ST Above head P15 P40 	Finger forces F _{max} (neutral to gender) Posture A1 (power grip, flex) F _{max} P15 P40 Posture A2 (ball of the thumb) F _{max} P15 P40
median plane Data based on the "Assembly specific force atlas" (Wanda, Berg, Schwaiblmair, Griesch, Eberhart 2009), adapted neutral to gender.		KN Upright P15 P40 KN Bent P15 P40 KN Above head P15 P40 	Posture B1 (thumb or thumb to 4 fingers) F _{max} P15 P40 Posture B2 (index or wide pinch) F _{max} P15 P40
Scores (dots are matter to change after the final completion of the force atlas project)		SI Upright P15 P40 SI Bent P15 P40 SI Above head P15 P40 	Posture C (hook, palm, strong pinch) F _{max} P15 P40 Posture C (hook, palm, strong pinch) F _{max} P15 P40
Action forces = ∑ lines 17 - 18		Attention: correct evaluation, if task duration ≠ 60s	



The worksheet includes sections for 'Action forces (per minute)', 'Manual Material Handling (per shift)', and 'Weights of loads (kg) for repositioning, lifting, lowering, carrying and holding as well as pushing and pulling'. It features various diagrams of postures and tasks, with numerical values for force intensity and duration, and a final calculation for 'Handling'.

NOTE See Figure A.62 for details

Figure 16 — EAWS Section 2, body forces

5.2.5 Section 3: manual material handling of loads

In section 3 (see Figure 17), efforts due to manual material handling (greater than or equal to 3 kg) are evaluated subdivided into repositioning, holding, carrying, pushing and pulling (short and long).

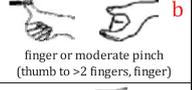
In the case of automotive assembly, enlarge these limits to 20 m or 15 s for easier application. This leads to:

- Repositioning (R): get and place a load within the workplace (approximately equivalent to a maximum displacement of 20 m);
 - Holding (H): hold a load longer than 15 s, no carrying;
 - Carrying (C): get, carry and place for a distance longer than 20 m;
 - Pushing and pulling (P&P): transporting a load with a means of transport;
- Short, if distance ≤ 20 m.
 Long, if distance > 20 m.

Influencing factors:

- weights of loads;
- posture;
- working conditions;
- frequency/duration/distance per shift.

Table 5 — EAWS Section 4: force-frequency-grip score

Force & Frequency & Grip (FFG)		Basis: number of real actions per minute or percent static actions (analyze only the most loaded limb)																												
 <p>a power grip/contact grip</p>  <p>b finger or moderate pinch (thumb to >2 fingers, finger)</p>  <p>c strong pinch (thumb to 1 or 2 fingers)</p>	Legend	%SA = Percentage of Static Actions										%DA = 100% · %SA																		
		FDS = Force-Duration Static										FFD = Force-Frequency Dynamic																		
		GS' = Modified Grip Points Static (Grip x %SA)										GD = Grip Points Dynamic																		
		%FLS = Percentage of Static Actions at force level										%FLD = Percentage of Dynamic Actions at force level																		
		SC = Static Contribution										DC = Dynamic Contribution																		
		FDGS = Sum of Static Contributions										FFGD = Sum of Dynamic Contributions																		
Force [N]	Calc Stat				Static actions (s/min)						Grip				Dynamic actions (real actions/min)								Calc Dyn							
	FDS	GS'	% FLS	SC	≥45	30	20	10	5	3	0	2	4	2-5	10	15	20	25	30	35	≥40	FFD	GD	%FLD	DC					
0 – 5					1	1	0	0	0	0	abc				0	0	0	1	2	3	4	7								
> 5 – 20					4	2	1	1	0	0	ab	bc			0	0	1	2	3	4	6	9								
> 20 – 35					7	5	3	2	1	1	ab	b	c		0	1	2	3	4	6	8	12								
> 35 – 90					11	8	5	3	2	1	a	b	b		1	2	3	5	7	9	12	18								
> 90 – 135					16	11	7	4	3	2	a	ab	b		2	3	5	7	9	12	15	24								
> 135 – 225					21	14	10	6	4	3	a	a	b		4	5	6	8	11	14	20	32								
> 225 – 300					28	18	12	8	5	4	a	a	b		8	6	7	9	12	16	26	40								
20a	FDGS = ∑ SC _i				FFG = FDGS + FFGD						FFG				%DA = ∑ FLD _j								FFGD = ∑ DC _j				%DA			

The following items are evaluated in the lower part of the page (see Table 6):

- posture of hands, arms and shoulders;
- special points;
- duration of repetitive tasks;
 - work organization;
 - number of breaks;
 - shift duration

Table 6 — EAWS Section 4: postures, additional factors and work organization

Hand / arm / shoulder postures (use duration for worst case of		wrist / elbow / shoulder)																	
20b	Wrist (deviaton, flex./extens.)	Elbow (pron, sup, flex./extens.)		Shoulder (flexion, extension, abduction)															
				If shoulders are involved close to or above shoulder height without support or in awkward postures, multiply score x3															
	Posture points	10 % 0	25 % 0,5	33 % 1	50 % 2	65 % 3	85 % 4	PP											
Additional factors																			
20c	Gloves inadequate (which interfere with the handling ability required) are used for over half the time						2												
	Working gestures required imply a countershock. Frequency of 2 time per minute or more (i.e.: hammering over hard surface)						2												
	Working gestures imply a countershock (using the hand as a tool) with freq. of 10 time per hour or more						2												
	Exposure to cold or refrigeration (less than 0 degree) for over half the time						2												
	Vibrating tools are used for 1/3 of the time or more						2												
	Tools with a very high level of vibrations						4												
	Tools employed cause compressions of the skin (rednesses, callosities, blebs, etc.)						2												
	Precision tasks are carried out for over half the time (tasks over areas smaller than 2-3 mm)						2												
	More than one additional factor is present at the same time and overall occupy the whole of the time						3												
	Additional points (choose the highest value)						=		AF										
Repetitive tasks duration																			
20d	Net Duration [min/shift]		< 60		90		180		300		420		≥ 480		+				
	Duration Points		1		1,5		3		5		7		10						
	Work Organization		Breaks are possible at every time		Breaks are possible at given conditions		Breaks lead to a stop of the process								+				
	Work Organization Points		0		1		2												
	Breaks (≥8 min) (#/shift)		0		1		2		3		4		5		6		≥7		
	Break points		cycle time ≤30 s		3		2		1		0		-1		-2		-3		-4
		cycle time >30 s		0		-0,5		-1		-		1,5		-2					
Duration Points																=		DP	

6 EWA effect on EAWS score

6.1 General

An EAWS index higher than 50 points indicates that the workstation generates an excessive demand of load and take immediate actions to reduce the risk. These actions could involve:

- The increase of the standard time per unit, by adding a recovery time to the basic time. This has the effect of reducing the number of repetitions per cycle/shift, thus decreasing the duration score (load = intensity × duration).

- The redesign of the workstation in order to reduce the Intensity score, e.g. by allowing the operator to work with a better body posture or by reducing the amount of force needed to perform a certain task (e.g. using a tool).

When choosing the best strategy to reduce the risk take into account:

- The economic impact of the identified solution: in general, the addition of a recovery time could increase the product cost, but the implementation it is longer. On the contrary, the redesign of the workstation could allow to maintain constant (or even increase) the production output and involve significant investments. Ideal solutions usually lay in between these two options: “low cost automation” help to remove critical loads (focused improvements) and the rest is done through organizational solutions (line rebalancing is the most common).
- The effect of the actions on the intensity/duration score, considering that the Intensity and Duration score curves have different behaviours in the different sections (Body Postures, Force exertion, handling of loads and repetitive motions of the upper limbs).

The effect of the redesign of a workstation on the intensity score is not an easy topic, since it heavily depends on the specific case (there is no standard solution). On the other side, general principles can be found regarding the effect of the addition of recovery time in the different EAWS sections. This strategy, as said before, has the effect of reducing the duration score.

Figure 18 shows the recovery allowance (as a percentage of the basic time) added to a certain operation to reduce the risk score of each section from a red (>50 points) to a yellow (between 25 and 50 points) level.

EXAMPLE 1

The score of section 3 (manual material handling, blue line) of a working station is 60 points. The cycle time of the station is 100 seconds. If the only action taken to reduce the EAWS score to a yellow level is the addition of recovery time, this recovery time will be at least 60 % of the basic time. The standard time of the station would therefore become 100 seconds + 60 % = 160 seconds

EXAMPLE 2

The score of section 4 (repetitive motions of the upper limb, cyan line) of a working station is 60 points. The cycle time of the station is 100 seconds. If the only action taken to reduce the EAWS score to a yellow level is the addition of recovery time, this recovery time will be at least 11 % of the basic time. The standard time of the station would therefore become 100 seconds + 11 % = 111 seconds

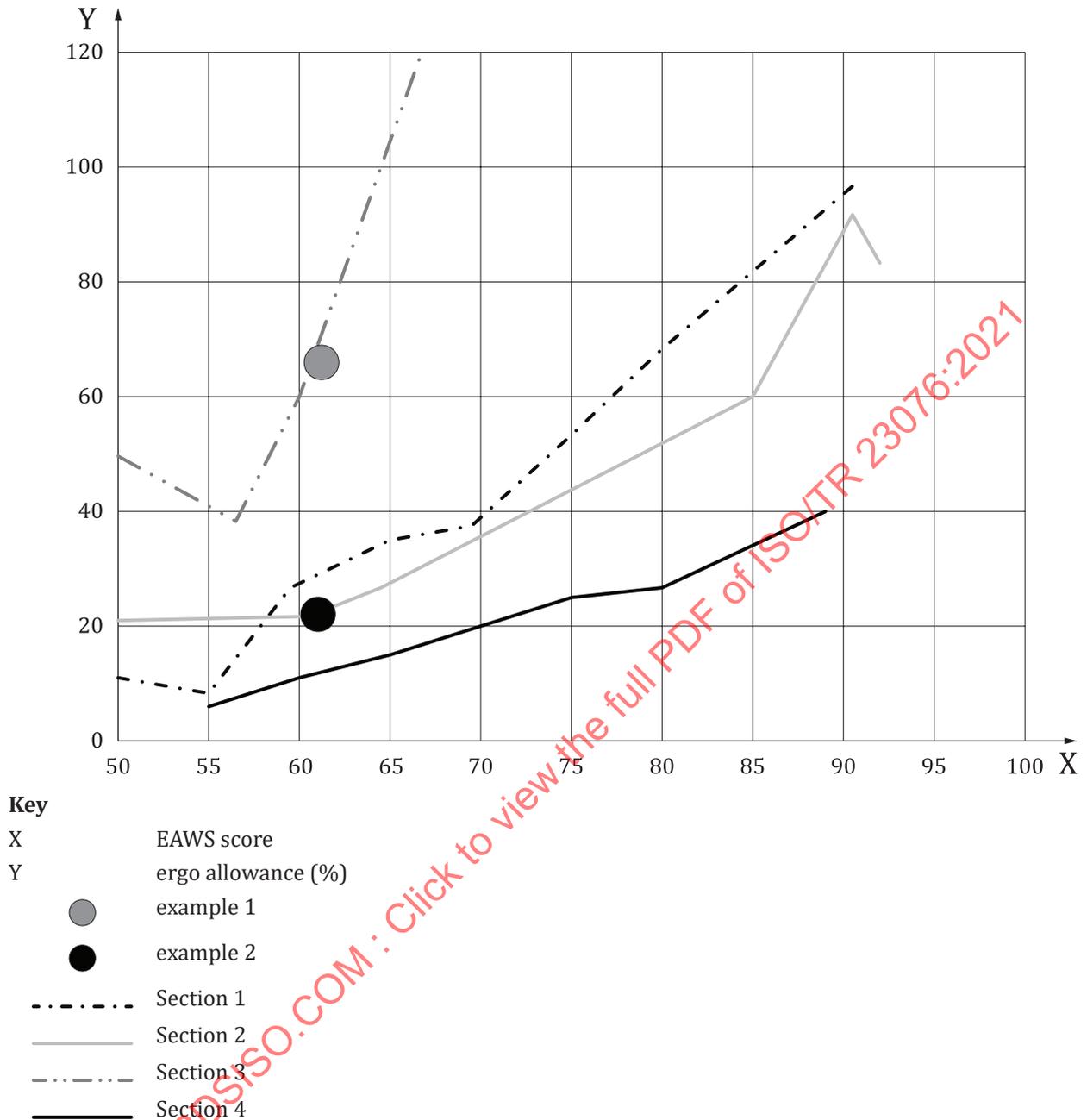


Figure 18 — Minimum allowance needed to decrease risk score to “yellow” level - single sections analysis

Figure 18 clearly shows that the effect of the recovery time (generated by the EWA) in reducing the risk score below the threshold value is very different for the different sections. In particular, there is a significant reduction of the risk score for section 1, 2 and 4, while the effect on section 3 is almost negligible - a very high recovery time is generally added to the station, in order to reduce the risk to an acceptable (yellow) level.

Based on this analysis, the following approach is suggested to reduce the load in each section:

- Section 1 and 2: the simple addition of recovery time is a solution.
- Section 3: it is better to focus on the intensity score rather than on the duration, which means to focus on method redesign or line rebalancing.

- Section 4: the intensity score (driven by force, frequency, grip and postures) strongly depends on the action frequencies. Therefore, the addition of a recovery time has a strong effect of the final score. However, a similar effect is achieved also by working on the work organization and breaks distribution, thus decreasing the duration points. Please refer to the EAWS manual for more details on the score calculation.

No general recommendations are provided for Section 0, since it deals with special working conditions, which are generally analysed case by case.

6.2 Effect of recovery time on typical workstations

The previous paragraph described the effect of the EWA on the score of each EAWS section. However, real workstations usually comprehend a set of activities that involve multiple sections. For this reason, in order to define a general rule to calculate the appropriate recovery time in real workstations, a “blended” recovery allowance curve has been developed, as shown in [Figure 19](#).

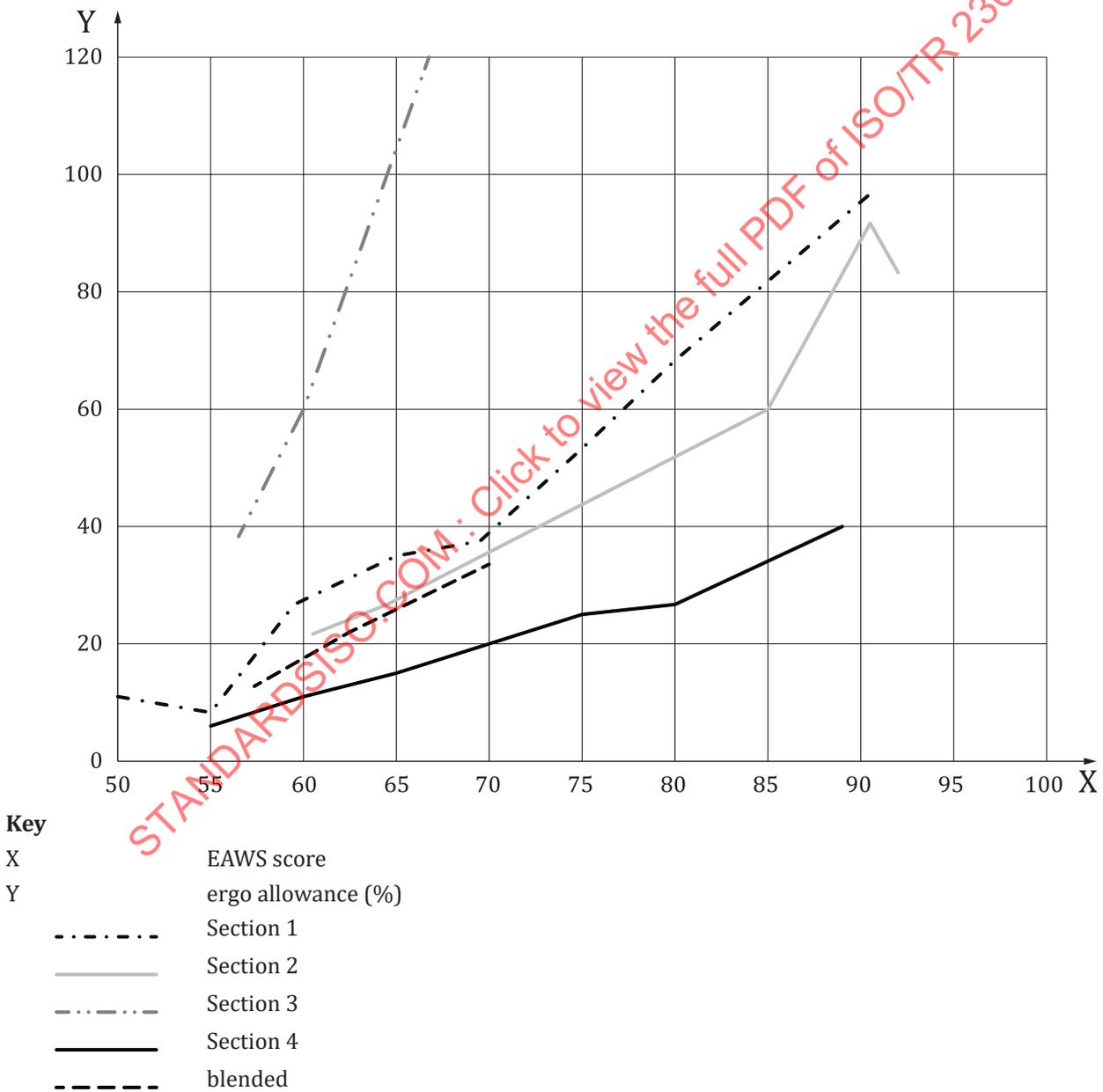


Figure 19 — Minimum allowance needed to decrease risk score to “yellow” level - single sections analysis and blended curve

The blended curve was built on a weighted average of the recovery allowance curve of each single section. Based on an application experience of 10 years of projects in the major industrial groups and the previous considerations, the following weights were used:

- 25 % for Section 1
- 30 % for Section 2
- 5 % for Section 3
- 40 % for Section 4

NOTE In cases where the total score of a workstation depends totally or mostly on the score of a single section (e.g. a logistic workstation, whose score will mostly come from [Section 3](#) only), the recovery time calculated with the blended curve could be insufficient to reduce the risk score under the threshold value.

6.3 EAWS based EWA model

The results of the analysis on the behaviour of the scores in the single sections and on numerous real typical workstations have been exploited to define the EWA model curve defined in [Figure 20](#).

Annex A (informative)

EAWS scoring procedure

A.1 Introduction to the EAWS scoring system

Biomechanics, a complex field, is the application of mechanical principles to living organisms. This includes research and analysis of the mechanics of living organisms and the application of engineering principles to and from biological systems. This research and analysis can be carried forth on multiple levels, from the molecular, wherein biomaterials such as collagen and elastin are considered, all the way up to the tissue and organ level. Some simple applications of Newtonian mechanics can supply correct approximations on each level, but precise details demand the use of continuum mechanics.

Applied mechanics, most notably thermodynamics and continuum mechanics, and mechanical engineering disciplines such as fluid mechanics and solid mechanics, play prominent roles in the study of biomechanics. By applying the laws and concepts of physics, biomechanical mechanisms and structures can be simulated and studied.

It has been shown that applied loads and deformations can affect the properties of living tissue. There is much research in the field of growth and remodelling as a response to applied loads. For example, the effects of elevated blood pressure on the mechanics of the arterial wall, the behaviour of cardio myocytes within a heart with a cardiac infarction, and bone growth in response to exercise, and the acclimatized growth, of plants in response to wind movement, have been widely regarded as instances in which living tissue is remodelled as a direct consequence of applied loads.

Relevant mathematical tools include linear algebra, differential equations, vector and tensor calculus, numeric and computational techniques such as the finite element method.

The study of biomaterials is of crucial importance to biomechanics. For example, the various tissues within the body, such as skin, bone, and arteries each possess unique material properties. The passive mechanical response of a particular tissue can be attributed to characteristics of the various proteins, such as elastin and collagen, living cells, ground substances such as proteoglycans, and the orientations of fibres within the tissue. For example, if human skin were largely composed of a protein other than collagen, many of its mechanical properties, such as its elasticity, would be different.

The study of biomechanics ranges from the inner workings of a cell to the movement and development of limbs, to the mechanical properties of soft tissue, and bones. As we develop a greater understanding of the physiological behaviour of living tissues, researchers are able to advance the field of tissue engineering, as well as, develop improved treatments for a wide array of pathologies.

Biomechanics as a sports science, kinesiology, applies the laws of mechanics and physics to human performance in order to gain a greater understanding of performance in athletic events through modelling, simulation, and measurement. In order to effectively address ergonomic issues in the workplace, develop an appreciation for the trade-offs associated with ergonomics. When one considers biomechanical rationale, one finds that it is very difficult to accommodate all parts of the body in an ideal biomechanical environment. It is often the case, that in attempting to accommodate one portion of the body, the biomechanical situation at another body site is compromised. Therefore, the key to the proper employment of occupational biomechanical principles is to be able to consider the appropriate biomechanical trade-offs with various parts of the body associated with different workplace design options.

This brief introduction to biomechanics is reported in this annex just to give the idea of the level of complexity we have when we aim at measuring a biomechanical load index. For this reason, in the field of occupational biomechanics, models are adopted which do not have the same level of accuracy as

other scientific measuring systems. All existing systems are an attempt to model the effects of forces and motions on our muscular-skeletal system and none of them currently reflect the actual situation.

Proper use of these models and methods involves recognizing the limitations and assumptions of each technique so that they are not applied inappropriately. When properly used, these assessments help identify the risk of work-related injury and illness.

Nonetheless, EAWS design was done based on existing and available research with the aim of finding the most appropriate and reasonable correlation against the CEN and ISO documents dealing with biomechanical load.

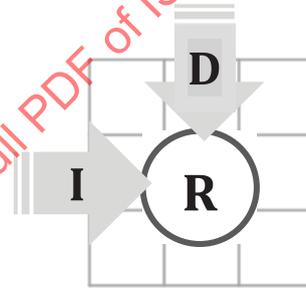
The objective of the EAWS manual is to minimize the applicator deviation when using the EAWS model to assess the biomechanical load.

A.2 Biomechanical Load EAWS Index

A.2.1 General

The EAWS system is based on a load index (R), given by the product of Intensity (I) and Duration (D):

$$R = I \times D$$



Key

- D duration
- I intensity

Figure A.1 — Evaluation of R (load index)

In Section 1, the user selects the relevant posture in the proper row (intensity) and measure the duration (column). Intersecting the column of duration with the row of intensity, the user easily finds the calculated score (see [Figure A.1](#)).

In Sections 2, 3 and 4, the user calculates the intensity and the duration scores of the concerned task, following specific rules, and eventually multiplies the intensity score by the duration score to find the load index.

In the following units, the generation of the EAWS score will be explained/described section by section.

A.2.2 General Rules

For the purposes of EAWS, the following general principles apply, which are subsequently identified as rules.

- General Rule G1

If the cycle has a duration that differs from 60 s, it is necessary to prorate all measured times to a 60 s cycle, in order to calculate the EAWS scores. To do so, this formula is used:

$$T_{60} = (D [s] \times 60 [s]) / (T_C [s]) \quad n_{60} = (n \times 60 [s]) / (T_C [s])$$

where:

T_{60} is the time prorated to a 60 s cycle

n_{60} is the frequency prorated to a 60 s cycle

D is the measured duration [s]

n is the measured frequency

T_C is the total Cycle Time

Prorate values to minutes in every Section, except in Section 3.

EXAMPLE 1

The cycle time is 120 s and the duration of one special Posture is 20 s.

$$\begin{aligned} \text{Conversion: } T_{60} &= (D \times 60) / T_C \\ &= (20 \text{ s} \times 60 \text{ s}) / 120 \text{ s} \\ &= 10 \text{ s} \end{aligned}$$

The result indicates that the employee, based on 60 s, is in this position for 10 s.

EXAMPLE 2

The cycle time is 30 s. During this time, a force is applied 2 times.

$$\begin{aligned} \text{Conversion: } n_{60} &= (n \times 60 \text{ s}) / T_C \\ n_{60} &= (2 \times 60 \text{ s}) / 30 \text{ s} \\ n_{60} &= 4 \end{aligned}$$

Based on a cycle time of 60 s, the force is applied 4 times.

— General Rule G2

As general principle, if there are several load situations in the same cycle (e.g. multiples dynamic action-forces)

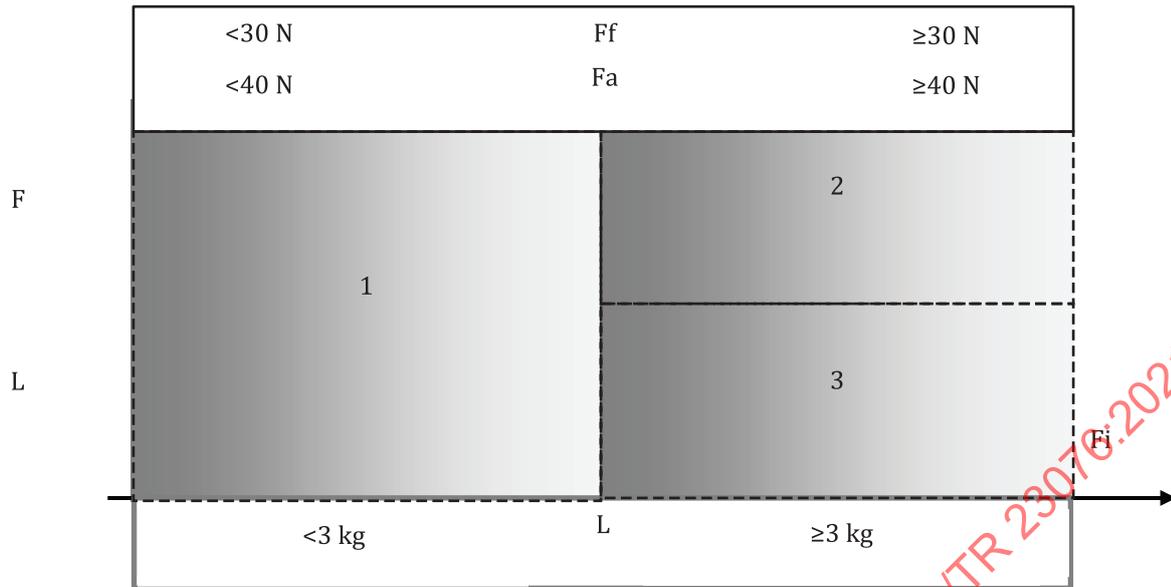
- the duration/frequency is the sum of the individual durations/frequencies,
- the intensities are the weighted average of the individual intensities, where the weights are the respective duration/frequency.

NOTE This general rule will be utilized with examples in the individual sections.

— General Rule G3

The section 1, 2 and 3 are mutually exclusive (one effort to be considered only in one of the 3 Sections of Whole Body). See [Figure A.2](#)

Do not consider awkward postures combined with manual material handling or action forces in Section 1, but just in Section 2 or 3. Force applications are considered in section 2 and handling of loads in Section 3.



- Key**
- Ff forces onto fingers
 - Fa forces onto arms/body
 - L loads
 - F forces
 - Fi force intensity
 - 1,2,3 Section 1, Section 2, Section 3

Figure A.2 — Fields of application sections 1,2 and 3

There are two exceptions to this Rule:

- Line 17 of Section 2 (finger forces): if the finger load is exerted in combination with a static body posture (symmetric or asymmetric), then section 1 is to be analysed additionally. See Rule 2.10 for more details.
- Dynamic actions have to be analysed in Section 2 or 3, but their amount of time is to be also taken into account in Section 1. See Rule 1.6 for more details.
- General Rule G4

A load is considered as static when its actual duration is 4 s or longer.

- General Rule G5

When lines are dashed, linear interpolation is useful.

In Section 1 – Standing (and walking) (see [Table A.1](#)) interpolation of the duration (horizontally) is the operation to do, while interpolation between postures (vertically) is used between lines 3 and 4 and between lines 5 and 6.

Table A.1 — First section extract

Standing (and walking)													
1		Standing and walking in alteration, standing with support	0	0	0	0	0,5	1	1	1	1,5	2	
2		Standing, no body support (for other restrictions see Extra Points)	0,7	1	1,5	2	3	4	6	8	11	13	
3		a	Bent forward (20-60°)	2	3	5	7	9,5	12	18	23	32	40
		b	with suitable support	1,3	2	3,5	5	6,5	8	12	15	20	25
4		a	Strongly bent forward (>60°)	3,3	5	8,5	12	17	21	30	38	51	63
		b	with suitable support	2	3	5	7	9,5	12	18	23	31	38
5		Upright with elbow at / above shoulder level	3,3	5	8,5	12	17	21	30	38	51	63	
6		Upright with hands above head level	5,3	8	14	19	26	33	47	60	80	100	

Interpolation formulas (see [Figure A.3](#)) identify which score x corresponds to the value Tx:



$$x = a + (Tx - Ta) \times \left(\frac{b - a}{Tb - Ta} \right)$$

Key

- Ta and Tb are the marginal values of the interval that contain the value Tx
- Tx represents a duration, a frequency or any other variable to which EAWS assigns a score on a scale (% , s/min , % Fmax...)
- The score “a” corresponds to the value Ta
- The score “b” corresponds to the value Tb
- S score

Figure A.3 — Interpolation Formula

— General Rule G6

Rounding: Intermediate scores are rounded to 1 decimal figure (e.g.: 12,233 41 - > 12,2)

The final score of each section is rounded up to the next 1/2 point. (e.g.: 12,2 - > 12,5)

— General Rule G7

Section 4 is designed to work with repetitive motions of the upper limbs at high frequencies and are to be evaluated separately from all other Sections.

— General Rule G8

EAWS calculates risk score at workstation level. In case of Job Rotation, the risk score for each worker is calculated as the weighted average of each workstation score using hours as weights.

— General Rule G9

Risk calculation for shift durations significantly different from 7 to 8 hours:

— Shift duration < 7 hours: Modified Total Body Risk Score = Weighted average of risk score and “2 points basic posture score” using the respective duration (hours) as weights o Shift duration

$$R_{tb}' = R_{tb} \times \text{Shift duration}/8 + 2 \times (8 - \text{Shift duration})/8$$

— Shift duration > 8 hours: Modified Total Body Risk Score = Linear extrapolation of risk

EXAMPLE 3

Shift duration = 6 hours

Total Body EAWS score = 38 points

Modified Total Body Score = $38 \times 6/8 + 2 \times 2/8 = 27,5$ points

EXAMPLE 4

Shift duration = 9 hours

Total Body EAWS score = 38 points

Modified Total Body Score = $38 \times 9/8 = 43$ points

NOTE See Section 3 rules for additional instructions.

A.2.3 Scoring section 0: Extra Points – Special Load Situations

Extra Points related to special loads not considered in the other sections are assigned in this special section. These loads include:

- Working on moving objects;
- Accessibility to the working area;
- Counter shocks, impulses, vibrations;
- Joint position (especially wrist);
- Other “special” situations, like overhead control work, including looking upward (neck load).

Table A.2 — Extra points Section 0

Extra points “Whole body” (per minute / shift)							
0a	Adverse effects by working on moving objects	0	3	8	15		
		none	middle	strong	very strong		
0b	Accessibility (e.g. entering motor or passenger compartment)	0	2	5	10		
		good	complicated	poor	very poor		
0c	Countershocks, impulses, vibrations 	0	1	2	5		
		light	visible	heavy	very heavy		
		0	1	2,5	4	6	8
		[n]	1 - 2	4 - 5	8 - 10	18 - 20	> 20
0d	Joint position (especially wrist) 	0	1	3	5		
		neutral	~ 1/3 max	~ 2/3 max	maximal		
		0	2	2,5	4	6	8
		[s]	3	10	20	40	60
		[n]	1	8	11	16	20
		[%]	5	17	33	67	100
0e	Other physical work load (please describe in detail)	0	5	10	15		
		none	middle	strong	very strong		

Extra points (see [Table A.2](#)) concern “non-standard” situations, it is very difficult to foresee any possible scenario in a standard manual. Therefore, during the application of the system in a certain company, if necessary build analytical scales of intensity, in which the different levels are characterized by typical and easily recognizable load situations; or to add new elements to the extra point table. The definition of the points and their approval is reserved to the EAWS Technical Board of the EAWS Platform.

— Line 0a: Working on moving objects

This item apply to working on moving objects that generates additional load. The effect is higher if awkward postures are involved (e.g. working on moving object while crouching).

Following extra points (see [Table A.3](#)) are applicable, unless specifically indicated otherwise, for a period equal to 100 % of the cycle time. For different durations it is necessary to linearly re-proportion the scores.

Table A.3 — Extra load points

Points	Extra Load Description
0	Standing upright or walking forward during the work task (low precision)
1	Walking backward / sideways during the work task (low precision)
2	Walking forward during the work task (precision)
3	Walking backward / sideways during the work task (precision)
0	Walking speed V is ≤ 1 Km/H
+3	Walking speed is 1 Km/H 1 < V ≤ 2 Km/H
+5	Walking speed is V > 2 Km / H
15	Walking while laterally bending / crouching during whole task time

— Line 0b: Accessibility

If frequent or unfavourable access to small or uncomfortable working area/objects is needed, extra point can be included.

Accessibility has to be considered as an extra load element only if the work task includes high muscular efforts (e.g. abdominal compartment) or significant strains (e.g. on the hands used as support or on the buttocks used as pivoting or support point).

— Line 0c: Counter Shocks

This item considers the situation where counter shock, impulses or vibrations occur.

Examples hammer blows, beating, hand blows, counter shocks with screwdrivers without clutch, vibration strokes with hands, counter shocks, vibrations.

EXAMPLE 1

Short and rapid strokes (mallet run < 20 cm) with rubber mallet on soft surface



EXAMPLE 2

Short and rapid strokes (mallet run < 20 cm.) with rubber mallet on hard metallic surface



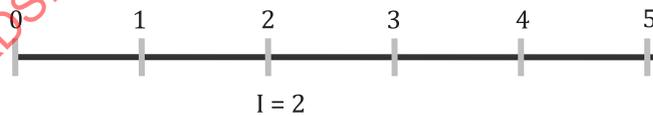
EXAMPLE 3

Strokes with rubber mallet (mallet run > 20 cm.) on soft surface



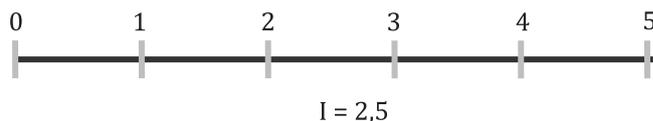
EXAMPLE 4

Strokes with rubber mallet (mallet run > 20 cm.) or with hammer (run ≤ 20 cm.) on hard metallic surface



EXAMPLE 5

Strokes with hammer, 20 cm. < run ≤ 50 cm.



EXAMPLE 6

Strokes with sledge-hammer, run > 50 cm.



— Line 0d: Joint position (especially wrist)

Used if special wrist positions occur at significant force levels. Always consider these positions in Section 4, as well. Section 4 has been specifically developed for analysing upper limb motions at high frequencies.

In critical joint positions, this item is an addition to the load evaluated in Section 2, where forces applied by hands and arms, the type of grip, the force direction and the body posture are evaluated, but the wrist position is not considered.

EXAMPLE 7

Vigorously pushing using the palm, holding a tray, rotate a valve lever.

— Line 0e: Other physical workload

This item considers situations involving unfavourable physical workloads that are not covered within other sections of the worksheet. (e.g. ascending a stack of pallets, standing on the tiptoes or with bent legs). See [Table A.4](#):

Table A.4 — Max extra points for special workload situations

Max Points	Examples of others physical workload
3	Sitting on irregular or uncomfortable surface (e.g. inside car body without seats) Sitting with buttocks and feet at the same level
5	Walking on uncomfortable metal grids Working with heavy protective clothing and masks Working on tiptoe
8	Working on uncomfortable and slippery metal grids Sitting on sloping and uncomfortable surface inside car body
10	Going up and down from a pallet (if frequency > 5 times per min) Working on hidden parts
15	Working with the head bending upward (load on the neck)

The maximum score for each Line is:

Line 0a = 15 points

Line 0b = 10 points

Line 0c = 40 points

Line 0d = 40 points

Line 0e = 15 points

NOTE The overall score is not to exceed 40 extra points.

A.2.4 Scoring: Section 1 – Postures and movements

While Section 1 primarily deals with static body postures, special rules allow the use of Section 1 with dynamic body postures (see [Figure A.4](#)).

In this section, postures and movements with loads of less than 3 kg., action forces of less than 30 N and whole body forces of less than 40 N are evaluated.

— Body Position

Body Position refers to the main position of the body when performing the work task.

The main body position is expressed as:

- Standing (Lines 1 - 6)
- Sitting (Lines 7 - 11)
- Kneeling or crouching (Lines 12 - 14)
- Lying or climbing (Lines 15 - 16)

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Basic Positions / Postures and movements of trunk and arms (per shift)												Postures																
(incl. loads of <3 kg, forces onto fingers of <30 N and whole body forces of <40 N) Static postures: ≥ 4 s High frequency movements: Trunk bendings (> 60°) ≥ 2/min Kneeling/crouching ≥ 2/min Arm liftings (> 60°) ≥ 10/min												Symmetric										Asymmetric						
												Evaluation of static postures and/or high frequency movements of trunk/arms/legs										Sum of lines	Trunk Rotation 1)		Lateral Bending 1)		Far Reach 2)	
												Duration [s/min] = $\frac{\text{duration of posture [s]} \times 60}{\text{Task duration [s]}}$											int	dur	int	dur	int	dur
												[%]	5	7,5	10	15	20	27	33	50	67		83	0-5	0-3	0-5	0-3	0-5
[s/min]	3	4,5	6	9	12	16	20	30	40	50	Intensity × Duration		Intensity × Duration		Intensity × Duration													
[min/8h]	24	36	48	72	96	130	160	240	320	400																		
Standing (and walking)																												
1		Standing & walking in alteration, standing with support	0	0	0	0	0,5	1	1	1	1,5	2																
2		Standing, no body support (for other restrictions see Extra Points)	0,7	1	1,5	2	3	4	6	8	11	13																
3		a Bent forward (20-60°)	2	3	5	7	9,5	12	18	23	32	40																
		b with suitable support	1,3	2	3,5	5	6,5	8	12	15	20	25																
4		a Strongly bent forward (>60°)	3,3	5	8,5	12	17	21	30	38	51	63																
		b with suitable support	2	3	5	7	9,5	12	18	23	31	38																
5		Upright with elbow at / above shoulder level	3,3	5	8,5	12	17	21	30	38	51	63																
6		Upright with hands above head level	5,3	8	14	19	26	33	47	60	80	100																
Sitting																												
7		Upright with back support slightly bent forward or backward	0	0	0	0	0	0	0,5	1	1,5	2																
8		Upright no back support (for other restriction see Extra Points)	0	0	0,5	1	1,5	2	3	4	5,5	7																
9		Bent forward	0,7	1	1,5	2	3	4	6	8	11	13																
10		Elbow at / above shoulder level	2,7	4	7	10	13	16	23	30	40	50																
11		Hands above head level	4	6	10	14	20	25	35	45	60	75																
Kneeling or crouching																												
12		Upright	3,3	5	7	9	12	15	21	27	36	45																
13		Bent forward	4	6	10	14	20	25	35	45	60	75																
14		Elbow at / above shoulder level	6	9	16	23	33	43	62	80	108	135																
Lying or climbing																												
15		(Lying on back, breast or side) arms above head	6	9	15	21	29	37	53	68	91	113																
16		Climbing	6,7	10	22	33	50	66																				
1) Trunk			0	1	3	5																						
int			slightly ≤10°	medium 15°	strongly 25°	extreme ≥30°																						
dur			never	4 s	10 s	≥ 13 s																						
			0%	6%	15%	≥ 20%																						
2) Far Reach			0	1	3	5																						
int			close	60%	80%	arm stretched																						
dur			never	4 s	10 s	≥ 13 s																						
			0%	6%	15%	≥ 20%											(a)				(b)							
Attention: Max. duration of evaluation = duration of task or 100%!												Attention: correct evaluation, if task duration ≠ 60 s																
Postures = ∑ lines 1 - 16													(a)	+											(b)	=		

Figure A.4 — Body positions

Posture duration is expressed as in Figure A.5.

Ergonomic Assessment Worksheet v1.3.5																			
Basic Positions / Postures and movements of trunk and arms (per shift)										Postures									
(incl. loads of ~3 kg, forces onto fingers of ~30 N and whole body forces of ~40 N) Static postures: = 4 s High frequency movements: Trunk bendings (> 60°) = 2min Kneeling/crouching = 2min Arm lifts (> 60°) = 10min										Symmetric					Asymmetric				
										Evaluation of static postures and/or high frequency movements of trunk/arms/legs					Sum of Arms				
Duration (sum) = duration of posture (s) × 60					Task duration (s)					Trunk Rotation (1)		Lateral Bending (1)		Far Reach (2)					
[N]	5	7.5	10	15	20	27	33	50	67	83	rot	lat	rot	lat	rot				
[min]	3	4.5	6	9	12	16	20	30	40	50	rot	lat	rot	lat	rot				
[min]	24	36	48	72	96	130	160	240	320	400	Intensity + Duration								
Standing (and walking)																			
1	Standing & walking in alternation, standing with support	0	0	0	0	0.5	1	1	1.5	2									
2	Standing, no body support (for other restrictions see Extra Points)	0.7	1	1.5	2	3	4	6	8	11									
3	a Bent forward (20-60°) b with suitable support	2	3	5	7	9.5	12	18	23	32									
4	a Strongly bent forward (>60°) b with suitable support	3.3	5	8.5	12	17	21	30	38	51									
5	Upright with elbow at / above shoulder level	3.3	5	8.5	12	17	21	30	38	51									
6	Upright with hands above head level	5.3	8	14	19	26	33	47	60	80									
Sitting																			
7	Upright with back support slightly bent forward or backward	0	0	0	0	0.5	1	1.5	2										
8	Upright no back support (for other restriction see Extra Points)	0	0	0.5	1	1.5	2	3	4	5.5									
9	Bent forward	0.7	1	1.5	2	3	4	6	8	11									
10	Elbow at / above shoulder level	2.7	4	7	10	13	16	23	30	40									
11	Hands above head level	4	6	10	14	20	25	35	45	60									
Kneeling or crouching																			
12	Upright	3.3	5	7	9	12	15	21	27	36									
13	Bent forward	4	6	10	14	20	25	35	45	60									
14	Elbow at / above shoulder level	6	9	16	23	33	43	62	80	108									
Lying or climbing																			
15	Lying on back, breast or side; arms above head	6	9	15	21	29	37	53	68	91									
16	Climbing	6.7	10	22	33	50	66												

3		a	Bent forward (20-60°)
		b	with suitable support
4		a	Strongly bent forward (>60°)
		b	with suitable support

9		Bent forward
---	--	--------------

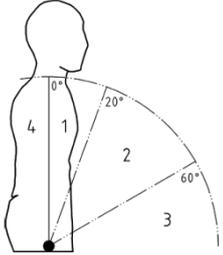
13		Bent forward
----	--	--------------

NOTE See [Figure A.61](#) for detail

Figure A.7 — Symmetric trunk bending, forward or backward

Body inclination is evaluated when bending forward or backward and is assigned to an appropriate zone (see [Table A.5](#)).

Table A.5 — Zones of trunk movement; bending, forward or backward (symmetric postures)

Zone 1 to 4 according to EN 1005-4:	Zone	static posture	movement	
			low frequency (<2 per min)	high frequency (≥2 per min)
	1	green	green	green
	2	yellow	green	red
	3	red	yellow	red
	4	yellow	yellow	red

Key

Green acceptable

Yellow partly acceptable

Red not acceptable

Yellow considered acceptable: when the entire body is supported.

Condition: the health risk for, nearly, all healthy adults, in view of the possible useful life of the machine, is low and can be proven negligible.

NOTE EN 1005-4 is a standard applied to the design phase, where the constraints are more demanding.

When “not acceptable”, points are assigned, considering the transition times into and out of these postures as part of the static posture.

Acceptable according to EN 1005-4: working positions with a straight body posture are preferred, in particular, if the machine is used for a long time by one person and a static position is necessary, without sufficient recovery time, body support or high frequency movements.

Additional posture points are considered when the postures involve trunk rotations and lateral trunk bending (asymmetrical body postures).

— Scoring of asymmetric postures

Asymmetrical postures (see [Figure A.8](#)) occur in conjunction with:

- Standing, trunk rotation (Lines 1 to 6)
- Standing, lateral trunk bending (Lines 1 to 6)
- Sitting, trunk rotation (Lines 7 to 11)
- Sitting, lateral trunk bending (Lines 7 to 11)
- Kneeling or crouching, trunk rotation (Lines 12 to 14)
- Lying and climbing, trunk rotation (Lines 15 and 16)
- Lying and climbing, lateral trunk bending (Lines 15 and 16)

Trunk Rotation 1)		Lateral Bending 1)	
int	dur	int	dur
0-5	0-3	0-5	0-3
Intensity × Duration		Intensity × Duration	

1)	Trunk	int	0	1	3	5
			slightly	medium	strongly	extreme
			≤10°	15°	25°	≥30°
dur		0	1,5	2,5	3	
		never	4 s	10 s	≥13 s	
		0%	6%	15%	≥20%	

NOTE See Figure A.61 for detail

Figure A.8 — Asymmetric trunk postures

The Table A.6 categorizes the lateral trunk bending (to the left or to the right) and the trunk rotation (to the left or to the right) and assigns to each case, one of the zones.

Table A.6 — Zones of trunk rotation and lateral trunk bending

according to EN 1005-4:	Zone	Static Posture	movement	
			low frequency (<2 per min)	high frequency (≥2 per min)
	1	green	green	green
	2	red	yellow	red

Key:

- Zone 1 is not clearly recognizable (10° or less)
- Zone 2 is clearly recognizable (about 10° or more)
- Green is acceptable
- Yellow is partly acceptable
- Red is not acceptable

Specific feature for yellow: Yellow is considered not acceptable, if the machine is used by the same person for a long period of time.

When “not acceptable”, points are assigned considering these postures as static postures, including the transition times.

— Far reach

Far reach involves postures where the upper arms are within an angle of 30° below and 60° above shoulder height.

Asymmetric Postures (arm extension) occur in conjunction with:

- Standing (Lines 1 to 5)
- Sitting (Lines 7 to 10)
- Kneeling (Lines 12 and 13)

For the grey fields (Lines 6, 11, 14, 15 and 16), the asymmetric point reviews of far reach are included in the symmetrical evaluation.

Ergonomic Assessment Worksheet v1.3.5

Basic Positions / Postures and movements of trunk and arms (per shift)
 (incl. loads of <3 kg, forces onto fingers of <30 N and whole body forces of <40 N)
 Static postures: ≥ 4 s
 High frequency movements:
 Trunk bendings (> 60°) ≥ 2min
 Kneeling/crouching ≥ 2min
 Arm liftings (> 50°) ≥ 10min

Postures	Symmetric		Asymmetric	
	0	1	0	1
1 Standing & walking in alternation, standing with support	0	0	0	0
2 Standing, no body support (for other restrictions see Extra Points)	0.7	1	1.5	2
3 Bent forward < 20°	2	3	4	5
4 Elbow at / above shoulder level	3.5	5	8.5	12
5 Upright w/ th elbow at / above shoulder level	3.5	5	8.5	12
6 Upright w/ th hands above head level	5.5	8	14	19
7 Upright w/ th back support slightly bent forward or backward	0	0	0	0
8 Upright no back support (for other restriction see Extra Points)	0	0	0.5	1
9 Bent forward	0.7	1	1.5	2
10 Elbow at / above shoulder level	2.7	4	7	10
11 Hands above head level	4	6	10	14
12 Upright	3.5	5	7	9
13 Bent forward	4	6	10	14
14 Elbow at / above shoulder level	6	9	10	13
15 (Lying on back, breast or side) arms above head	6	9	10	13
16 Climbing	6.7	10	14	19

Postures = Σ lines × 100
 (a) = (b) × 100

Far Reach	int	0	1	3	5
		close	60%	80%	arm stretched
dur		0	1	1,5	2
		never	4 s	10 s	≥ 13 s
		0%	6%	15%	≥ 20%

NOTE See Figure A.61 for detail

Figure A.9 — Asymmetric postures (Far Reach)

Far reach (see Figure A.9) occurs while working outside of the normal working area. The elbow moves further away from the body and the shoulder is more involved. Far Reach is expressed in a range from -30° to +60° with respect to the horizontal line at the shoulder point.

Table A.7 determines how the reach of the arm is to be classified and shows the zones based on shoulder movements (abduction and flexion).

Table A.7 — Zones of upper arm posture (asymmetric posture)

Zones 1 to 4 according to EN 1005-4:	Zone	Static posture	movement	
			low frequency (<2 per min)	high frequency (≥2 per min)
	1	green	green	green
	2	(A) yellow	green	(C) yellow
	3	red	(B) yellow	red
	4	red	(B) yellow	red
<p>Key:</p> <p>Green is acceptable</p> <p>Yellow is partly acceptable</p> <p>Red is not acceptable</p> <p>A - Acceptable if entire arm support is given; if entire arm support is not given, the acceptability depends on the duration of the posture and the recovery time.</p> <p>B - Not acceptable if the machine is used by the same person for a long time period.</p> <p>C - Not acceptable with a frequency ≥ 10 per minute and/or if the machine is used by the same person for a long time period.</p> <p>NOTE When “not acceptable”, points are assigned considering these postures as static postures, including the transition times.</p>				

Acceptable according to EN 1005-4: working positions with hanging upper arms are the most practical, in particular, if the machine is used by the same person for a long time period and a static position without sufficient recovery time or body support, or a static position involving high frequency (>10) extreme movements.

- Rules for scoring in Section 1
 - Rule 1.1

If the same static posture occurs more than once (minimum of 4 s. each), the total duration is the sum of the individual durations.

EXAMPLE 2

Two non-consecutive postures involving “standing with hands above head” of 5 s. each, generates a total duration of 5 + 5 = 10 s.

- Rule 1.2

If two or more consecutive postures with, at least, one duration < 4 s., but total duration ≥ 4 s. occur and if these postures are separated on the EAWS form by a dashed line (e.g. lines 3 and 4), then they are assigned one score calculated as a weighted average. The procedure is as follows:

- Add the durations
- Calculate the respective scores based on the total duration

Calculate the weighted average, using as weights the respective durations

EXAMPLE 3

See [Figure A.10](#)

Cycle time 60 s.

Standing; 3 s. bent forward (line 3a) + 3 s. strongly bent forward (line 4a)

-> Total duration = 6 s.

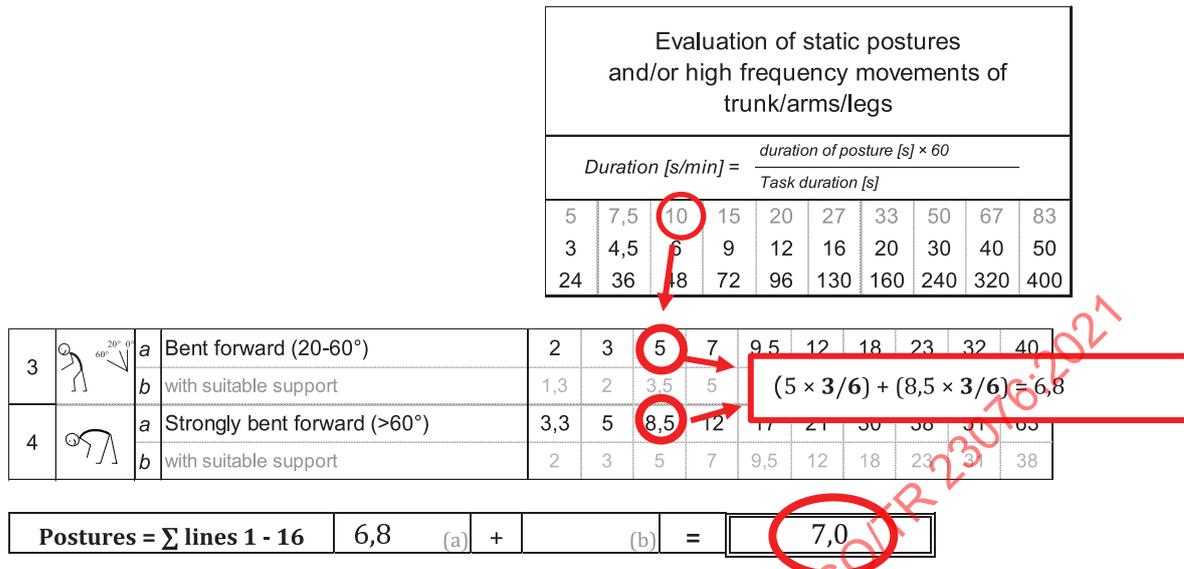


Figure A.10 — Example for rule 1.2

— Rule 1.3

For postures where the elbows are at shoulder level, above shoulder level or above head level, we don't distinguish between left and right arm when measuring the durations, but differentiate according to the following pattern:

- Simultaneous postures: utilize the time of the posture which takes the longest
- Overlapping postures: utilize the total time
- Consecutive or independent postures: utilize by adding the two durations

EXAMPLE 4

While a worker is holding a component part for 6 s. with the left arm (elbow at shoulder level), he secures the part with the right arm during 4 s. at the same level.

-> 6 s in line 5

EXAMPLE 5

A worker attaches a component part during 4 s. with the left arm (elbow at shoulder level). Ten s. later he attaches another component part during 4 s. with the right arm (elbow at shoulder level).

-> 8 s. in line 5.

— Rule 1.4

If there are consecutive “kneeling/crouching” postures (lines 12/13/14) with individual durations of < 4 s., but a total duration of ≥ 4 s., these postures have to be classified in line 12 with a total duration equal to the sum of their individual durations.

EXAMPLE 6

3 s. crouching upright, then 3 s. crouching bent forward

-> 6 s. in line 12

EXAMPLE 7

2 s. crouching bent forward, then 3 s. crouching, elbow at shoulder level

- > 5 s. in line 12

EXAMPLE 8

5 s. crouching upright, 4 s. crouching bent forward

- > 5 s. in line 12 and 4 s. in line 13

— Rule 1.5

Posture line 2 is only considered if the operator is working permanently in a workplace where horizontal movements are limited (i.e. maximum workplace dimensions < 1,5 m², including the distance to the material racks). See [Figure A.11](#) dashed area < 1,5 m².

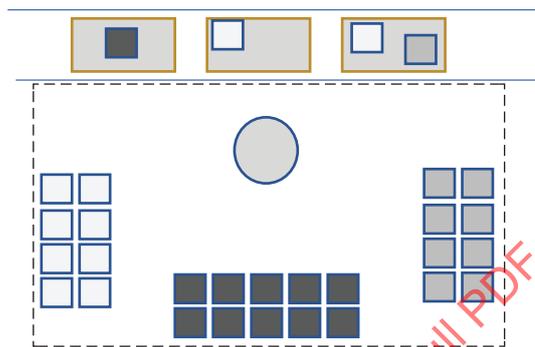


Figure A.11 — Example of Rule 1.5

— Rule 1.6a

The idle time in a cycle (non-utilized or waiting time) is classified in line 1, if body position is standing, or line 7, if sitting.

— Rule 1.6b

All the time intervals not classified as static postures (dynamic motions), have to be considered in posture 1 or 2, if standing, or in posture 7 or 8, if sitting. That posture is named as “basic posture”.

In case of a workplace with simultaneous presence of postures 1 / 2 and 7 / 8, select the basic posture as the one with the longest duration.

EXAMPLE 9

Total cycle time = 60 s

Idle time: 5 s (Line 1 - Rule 1.6a)

Static postures: 30 s (Various Lines)

Standing postures not classified as static: 25 s (Line 1 - Rule 1.6b)

Sum: 60 s and 100 % of cycle time

— Rule 1.7

Section 1 is also applied to dynamic postures in cases of high frequency movements. If there is:

— Trunk bending (>60°), ≥ 2 / min (lines 4a and 4b)

— Movements involving kneeling or crouching, frequency ≥ 2 / min (lines 12 and 13)

- Arm lifts $\geq 10/\text{min}$ (lines 5 and 6; 10 and 11; 14 and 15)

include *transition time* to determine posture duration.

High-frequency body movements are to be classified on the corresponding lines as static postures. For this purpose, calculate the duration of the dynamic motions as the sum of the *transition time* and *dwell time*.

NOTE Rule 1.7 follows the recommendations included in ISO 11226 and EN 1005-4 has a slightly different approach: High frequency body motions (bending, kneeling or arms lifting) leads to an automatic “high risk” evaluation.

EXAMPLE 10

In a cycle time of 90 s., the worker has to strongly bend forward 3 times.

Normalized to a cycle time of 60 s., it results in a frequency of 2 times per minute. Since the frequency is ≥ 2 , the total time would include the bending, dwell and arise from bending.

EXAMPLE 11

In a cycle time of 40 s., the worker has to move into kneeling and arise from kneeling one time.

Normalized to a cycle time of 60 s., it yields a frequency of 1,5 which is < 2 . According to rule 1.7, the action would not be analysed as high frequency movement.

- Rule 1.8

If conditions of postures 4 (strongly bent) and 6 (hands above head level) occur simultaneously, the posture is assigned to posture 4 along with an additional far reach asymmetric posture.

- Rule 1.9

Asymmetric posture scores are reported on the same line as the corresponding symmetric posture.

EXAMPLE 12

If a task demands a static trunk rotation while sitting upright, this asymmetric posture is assessed in line 7 or 8 (sitting with/without back support)

- Rule 1.10

Each asymmetric posture score is given by the product of duration and intensity.

If it is necessary to consider an asymmetric posture more than once in the same line, the duration is given by the sum of each duration and the intensity is given by the weighted average of all intensities using as weights their respective durations.

EXAMPLE 13

Within a task of 60 s., standing upright (without support), a trunk rotation of 25° to the left side (4 s.) and a trunk rotation of 15° to the right side (6 s.) is necessary (See [Figure A.12](#)).

- Symmetric posture is analysed as 60 s in line 2
- Asymmetric posture is analysed as follows:
 - Duration: 4 s. + 6 s. = 10 s. - \rightarrow 2,5 duration points
 - Intensity: $(25^\circ \times 4 + 15^\circ \times 6) / 10 = 19^\circ$ - \rightarrow 1,8 intensity points

Standing (and walking)																	
1		Standing & walking in alteration, standing with support	0	0	0	0	0,5	1	1	1	1,5	2					
2		Standing, no body support (for other restrictions see Extra Points)	0,7	1	1,5	2	3	4	6	8	11	13		1,8	2,5		
3		a Bent forward (20-60°)	2	3	5	7	9,5	12	18	23	32	40					
		b with suitable support	1,3	2	3,5	5	6,5	8	12	15	20	25					
4		a Strongly bent forward (>60°)	3,3	5	8,5	12	17	21	30	38	51	63					
		b with suitable support	2	3	5	7	9,5	12	18	23	31	38					
5		Upright with elbow at / above shoulder level	3,3	5	8,5	12	17	21	30	38	51	63					
6		Upright with hands above head level	5,3	8	14	19	26	33	47	60	80	100					
1)			0	1	3	5	2)			0	1	3	5	Σ			
Trunk	int	slightly ≤10°	medium 15°	strongly 25°	extreme ≥30°	Far Reach			int	close	60%	80%	arm stretched		Σ (max.=15)	Σ (max.=15)	Σ (max.=10)
	dur	0	1,5	2,5	3	dur			never	4 s	10 s	≥ 13 s		Σ (max. = 40)			
			0%	6%	15%	≥ 20%				0%	6%	15%	≥ 20%	(a)	4,5 (b)		
Attention: Max. duration of evaluation = duration of task or 100%!													Attention: correct evaluation, if task duration ≠ 60 s				
Postures = Σ lines 1 - 16						(a)	+	4,5			(b)	=					

Figure A.12 — Calculation example of asymmetric body postures total score of asymmetric postures

The total score of asymmetric postures is the sum of the scores assigned to the 3 columns, as illustrated in [Figure A.13](#):

Σ	1	2	3	
	Σ (max. = 15)	Σ (max. = 15)	Σ (max. = 10)	
(a)	Σ (max. = 40)			(b)

Key

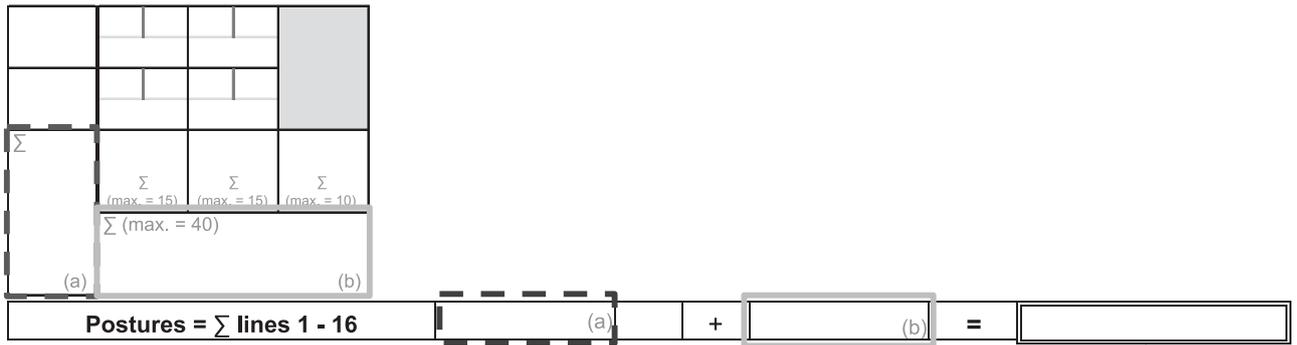
- a Sum of scores of symmetric postures.
- b Sum of score of asymmetric postures.

NOTE Maximum score of asymmetric postures (b): 15 (1 = trunk rotation) + 15 (2 = lateral bending) +10 (3 = far reach) = 40.

Figure A.13 — Sum of asymmetric postures scores

— Scoring of Section 1

The total score of section 1 is the sum of the scores assigned to symmetric postures and the score assign to asymmetric postures (see [Figure A.14](#)):



Key

- a Sum of scores of symmetric postures.
- b Sum of score of asymmetric postures.

NOTE See [Figure A.61](#) for detail

Figure A.14 — Sum of scores for Section 1

— Examples – Section 1

EXAMPLE 14

Calculate the EAWS score of section 1 during the following working task:

- Cycle time: 180 s.;
- Walking to the following car carrying a toolbox (weight 2,5 kg.). Duration: 10 s.;
- Fix cables bent forward at a level of approximately 90° for 90 s.;

During this operation:

the trunk is rotated 25° for 30 s.;

the arm is extended completely for 30 s. to reach the zone of the hand break;

- While in an upright position, with elbow at the shoulder level, fix cables in the hatchback. Duration: 60 s.

Solution (see [Table A.8](#) - [Table A.9](#) - [Table A.10](#) - [Figure A.15](#) - [Figure A.16](#) - [Figure A.17](#))

Cycle time ≠ 60 s, therefore prorate:

Table A.8 — Information list from task

No.	Description	Section 1 [line]	Cycle time [180 s]	prorate [T ₆₀]
1	Walking to the car	Line 1	10 s.	$\frac{10 \times 60}{180} = 3,3 \text{ s.}$
^a Rule 1.6a – consider in line 1				

Table A.8 (continued)

No.	Description	Section 1 [line]	Cycle time [180 s]	prorate [T ₆₀]
2	Fix cables	Line 4	90 s.	$\frac{90 \times 60}{180} = 30 \text{ s.}$
	— Trunk rotation 25°	Line 4 asymmetric posture	30 s.	$\frac{30 \times 60}{180} = 10 \text{ s.}$
	— arm completely extended	Line 4 asymmetric posture	30 s.	$\frac{30 \times 60}{180} = 10 \text{ s.}$
3	Standing, arms at the shoulder level, fix cables	Line 5	60 s.	$\frac{60 \times 60}{180} = 20 \text{ s.}$
4	Calculation: Idle time + Time left (not evaluated)	Line 1	20 s.	$60 - (3,3 + 30 + 20) = 6,7 \text{ s}^a$

^a Rule 1.6a – consider in line 1

Symmetric postures

Table A.9 — Defining symmetric posture points

Line	Duration [s]		Calculate or read points	
Line 1	3,3 s. + 6,7 s.	10 s.	$0 + \frac{(0,5-0)}{(12-9)} \times (10-9) = 0,2 \text{ Points}$	0,2 Points
Line 4		30 s.	read directly	38,0 Points
Line 5		20 s.	read directly	30,0 Points
Σ symmetric postures = 0,2 + 38 + 30 = 68,2 Points				68,2 Points

(incl. loads of <3 kg, forces onto fingers of <30 N and whole body forces of <40 N) Static postures: ≥ 4 s High frequency movements: Trunk bendings (> 60°) ≥ 2/min Kneeling/crouching ≥ 2/min Arm liftings (> 60°) ≥ 10/min		Symmetric										
		Evaluation of static postures and/or high frequency movements of trunk/arms/legs										
		$Duration [s/min] = \frac{duration\ of\ posture [s] \times 60}{Task\ duration [s]}$										
		[%]	5	7,5	10	15	20	27	33	50	67	83
		[s/min]	3	4,5	6	10	16	20	20	30	40	50
		[min/8h]	24	36	48	72	96	130	160	240	320	400
Standing (and walking)												
1		Standing & walking in alteration, standing with support	0	0	0	0,2	0,5	1	1	1	1,5	2
2		Standing, no body support (for other restrictions see Extra Points)	0,7	1	1,5	2	3	4	6	8	11	13
3		a Bent forward (20-60°)	2	3	5	7	9,5	12	18	23	32	40
		b with suitable support	1,3	2	3,5	5	6,5	8	12	15	20	25
4		a Strongly bent forward (>60°)	3,3	5	8,5	12	17	21	30	38	51	63
		b with suitable support	2	3	5	7	9,5	12	18	23	31	38
5		Upright with elbow at / above shoulder level	3,3	5	8,5	12	17	21	30	38	51	63
6		Upright with hands above head level	5,3	8	14	19	26	33	47	60	80	100

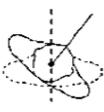
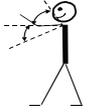
Figure A.15 — Classification of symmetrical postures

Asymmetric postures

In line 4; see also Rule 1.9

Table A.10 — Defining asymmetrical posture points

Sum	Load		Calculate or read points	
Trunk Rotation	Duration	10 s.	read directly	2,5 Points
	Level of Intensity	25°	read directly	3,0 Points
result	Intensity points × Duration points = 3,0 × 2,5			7,5 Points
Far Reach	Duration	10 s.	read directly	1,5 Points
	Level of Intensity	arm completely extended	read directly	5,0 Points
result	Intensity points × Duration points = 5,0 × 1,5			7,5 Points
Σ asymmetric postures=7,5 + 7,5=15 Points				15,0 Points

Asymmetric									
Trunk Rotation 1)			Lateral Bending 1)			Far Reach 2)			
									
int	dur		int	dur		int	dur		
0-5	0-3		0-5	0-3		0-5	0-2		
Intensity × Duration			Intensity × Duration			Intensity × Duration			
3			2,5			5			1,5

1)					2)					
Trunk	int				dur	Far Reach	int			
	slightly	medium	strongly	extreme			close	60%	80%	arm stretched
≤10°	15°	25°	≥30°	never	4 s	10 s	≥ 13 s			
0	1,5	2,5	3	0	1	1,5	2			
never	4 s	10 s	≥ 13 s	never	4 s	10 s	≥ 13 s			
0%	6%	15%	≥ 20%	0%	6%	15%	≥ 20%			

Figure A.16 — Classification of asymmetric postures

Total score – Section 1:

Σ Section 1 = Σ symmetric posture + Σ asymmetric posture

Σ Section 1 = 68,2 + 15 = 83,2 - > 83,5 Points

Score of Section 1:

Basic Positions / Postures and movements of trunk and arms (per shift)											Postures																																																																																														
(incl. loads of <3 kg, forces onto fingers of <30 N and whole body forces of <40 N) Static postures: ≥ 4 s High frequency movements: Trunk bendings (> 60°) ≥ 2/min Kneeling/crouching ≥ 2/min Arm liftings (> 60°) ≥ 10/min											Symmetric										Asymmetric																																																																																				
											Evaluation of static postures and/or high frequency movements of trunk/arms/legs										Trunk Rotation 1)		Lateral Bending 1)		Far Reach 2)																																																																																
											$Duration [s/min] = \frac{duration\ of\ posture [s] \times 60}{Task\ duration [s]}$																																																																																														
	[%]	5	7,5	10	15	20	27	33	50	67	83	int		int		int																																																																																									
	[s/min]	3	4,5	6	9	12	16	20	30	40	50	dur		dur		dur																																																																																									
	[min/8h]	24	36	48	72	96	130	160	240	320	400	0-5		0-5		0-5																																																																																									
												Intensity × Duration		Intensity × Duration		Intensity × Duration																																																																																									
Standing (and walking)																																																																																																									
1		Standing & walking in alteration, standing with support	0	0	0	0	0,5	1	1	1	1,5	2	0,2																																																																																												
2		Standing, no body support (for other restrictions see Extra Points)	0,7	1	1,5	2	3	4	6	8	11	13																																																																																													
3		a) Bent forward (20-60°)	2	3	5	7	9,5	12	18	23	32	40																																																																																													
		b) with suitable support	1,3	2	3,5	5	6,5	8	12	15	20	25																																																																																													
4		a) Strongly bent forward (>60°)	3,3	5	8,5	12	17	21	30	38	51	63	38	3	2,5		5	1,5																																																																																							
		b) with suitable support	2	3	5	7	9,5	12	18	23	31	38																																																																																													
5		Upright with elbow at / above shoulder level	3,3	5	8,5	12	17	21	30	38	51	63	30																																																																																												
6		Upright with hands above head level	5,3	8	14	19	26	33	47	60	80	100																																																																																													
<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td colspan="3">1)</td> <td colspan="3">2)</td> <td colspan="2">Σ</td> <td colspan="2"></td> <td colspan="2"></td> <td colspan="2"></td> </tr> <tr> <td rowspan="2">Trunk</td> <td>int</td> <td>0</td><td>1</td><td>3</td><td>5</td> <td rowspan="2">Far Reach</td> <td>int</td> <td>0</td><td>1</td><td>3</td><td>5</td> <td rowspan="2">Σ</td> <td>7,5</td> <td></td> <td>7,5</td> </tr> <tr> <td></td> <td>slightly</td><td>medium</td><td>strongly</td><td>extreme</td> <td></td> <td>close</td><td>60%</td><td>80%</td><td>arm stretched</td> <td></td> <td>(max.=15)</td> <td>(max.=15)</td> <td>(max.=10)</td> </tr> <tr> <td></td> <td>dur</td> <td>0</td><td>1,5</td><td>2,5</td><td>3</td> <td></td> <td>dur</td> <td>0</td><td>1</td><td>1,5</td><td>2</td> <td colspan="3">Σ (max. = 40)</td> </tr> <tr> <td></td> <td></td> <td>never</td><td>4 s</td><td>10 s</td><td>≥ 13 s</td> <td></td> <td></td> <td>never</td><td>4 s</td><td>10 s</td><td>≥ 13 s</td> <td colspan="3">15</td> </tr> <tr> <td></td> <td></td> <td>0%</td><td>6%</td><td>15%</td><td>≥ 20%</td> <td></td> <td></td> <td>0%</td><td>6%</td><td>15%</td><td>≥ 20%</td> <td colspan="3">(a) (b)</td> </tr> </table>																	1)			2)			Σ								Trunk	int	0	1	3	5	Far Reach	int	0	1	3	5	Σ	7,5		7,5		slightly	medium	strongly	extreme		close	60%	80%	arm stretched		(max.=15)	(max.=15)	(max.=10)		dur	0	1,5	2,5	3		dur	0	1	1,5	2	Σ (max. = 40)					never	4 s	10 s	≥ 13 s			never	4 s	10 s	≥ 13 s	15					0%	6%	15%	≥ 20%			0%	6%	15%	≥ 20%	(a) (b)		
1)			2)			Σ																																																																																																			
Trunk	int	0	1	3	5	Far Reach	int	0	1	3	5	Σ	7,5		7,5																																																																																										
		slightly	medium	strongly	extreme			close	60%	80%	arm stretched			(max.=15)	(max.=15)	(max.=10)																																																																																									
	dur	0	1,5	2,5	3		dur	0	1	1,5	2	Σ (max. = 40)																																																																																													
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		0%	6%	15%	≥ 20%			0%	6%	15%	≥ 20%	(a) (b)																																																																																													
Attention: Max. duration of evaluation = duration of task or 100%																																																																																																									
Attention: correct evaluation, if task duration ≠ 60 s																																																																																																									
Postures = Σ lines 1 - 16			68,2 (a)			+		15 (b)			=		83,5																																																																																												

Figure A.17 — Results of Example section 1

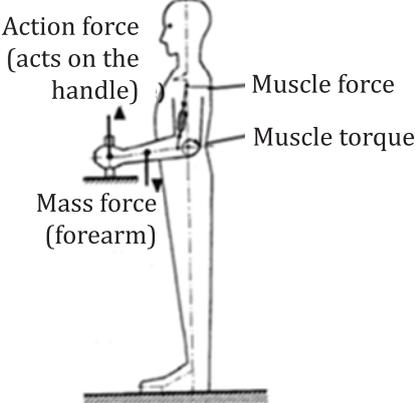
A.2.5 Scoring: Section 2 – Action Forces

— Action forces

An action force is a force exerted by the hand-finger system and/or by the body-arm system. A force is be static or dynamic. The hand/finger forces are analysed in Line 17. The arm and whole body forces in Line 18 (see Table A.11). See Figure A.62

Influencing Factors

Table A.11 — Content and parameters for the action forces



Action forces		Force exertion		Scoring R = D × I	
Forces onto fingers	Forces onto arms / whole body forces				
		static	≥ 4 seconds	D	Duration per minute
Line 17:	Line 18:	dynamic	< 4 seconds	I	Force level
— Type of grip	— Postures			D	Frequency of action forces per minute
— Force percentile	— one hand			I	Force level
— Force level	— both hands				
— Duration / min	— Force direction				
— Frequency / min	— Force percentile				
	— Force level [N]				
	— Duration / min				
	— Frequency / min				

NOTE An action is static when it lasts at least 4 seconds. The duration is determined evaluation the seconds per minute of force exertion. An action is dynamic when it lasts less than 4 seconds. The duration is determined as number of actions per minute (frequency n).

The load is calculated in the following way:

- Load index (R) = Duration (D) × Intensity (I);
- Duration of static applications: s/min; % of cycle → duration score;
- Duration of dynamic applications: frequency of actions/min → duration score.

Minimum threshold values are:

- 30 N for line 17 (hands-fingers), one handed;
- 40 N for line 18 (arms), two handed.

For forces below these thresholds, no load points are assigned in Section 2, since the biomechanical load, due to action forces below these thresholds, is already included in the scores of Section 1 (postures).

The maximum force depends on the force percentile.

— Percentile

Percentile is a value on a scale of 100 that indicates the percent of a distribution that is equal to or below.

EXAMPLE 1

If we consider the 15th percentile, the sustainable force will be achievable by 85 % of the reference population.

EAWS uses two percentiles:

- 15th percentile for planning/designing workplaces/machines (Planning analysis)
- 40th percentile for observational analysis (Production analysis)

Calculation of the score

— Intensity score

The intensity score has a scale that ranges from 0 to 50 points. Select its value depending on the percentage of the measured Force F over F_{max} . See [Figure A.18](#).

17		Forces onto fingers (e.g. clips, plugs)	Int	0	7	15	25	50		
				16,7 % F_{max}	33,3 % F_{max}	50,0 % F_{max}	66,7 % F_{max}	F_{max}		
			Duration stat	0	1	1	1,5	2	3,5	7
			[s]	3	6	9	12	20	30	
			[%]	5	10	15	20	33	50	
Duration dyn	0	1,5	2	2,5	3					
[n]	4	10	15	20						
18		Forces onto arms / whole body forces	Int	0	6	15	25	50		
				16,7 % F_{max}	33,3 % F_{max}	50,0 % F_{max}	66,7 % F_{max}	F_{max}		
			Duration stat	0	1	1	1,5	2	4	6,5
			[s]	3	6	9	12	20	30	
			[%]	5	10	15	20	33	50	
Duration dyn	0	1	2	3	4,5	6,5	10			
[n]	1	3	6	8	10	12				

Figure A.18 — Action Forces scales

Line 17 (Force onto fingers):

F_{max} is the maximum force that can be exerted for a given percentile, with a given type of grip. The F_{max} values are based on the results of the project “Assembly specific force Atlas” (Wakula et al., 2009) and are shown on the worksheet in the form of the table below. They represent conservative values and are neutral to gender.

To use the correct F_{max} value (see [Figure A.19](#)), it is necessary to identify the *type of grip* and to select the *appropriate percentile*. There are two percentiles on the table:

- P15: 15th percentile for the design mode
- P40: 40th percentile for the observational mode

The P15 values are more conservative.

Finger forces F_{max} (neutral to gender)		
Posture A1 (power grip, pliers)		
	F_{max}	
	P15	P40
	150	205
Posture A2 (ball of the thumb)		
	F_{max}	
	P15	P40
	115	155
Posture B1 (thumb or thumb to 4 fingers)		
	P15	P40
	55	70
	Posture B2 (index or wide pinch)	
	F_{max}	
	P15	P40
	40	50
Posture C (hook, palmar, strong pinch)		
	F_{max}	
	P15	P40
	45	55

Key

Type of grip of force application

A1 power grip (e.g. pliers)

A2 ball of the thumb

B1 thumb or thumb to 4 fingers

B2 index or wide pinch grip

C hook, palmar, strong pinch grip

Force percentile

P15 for planning analysis

P40 for production analysis

Figure A.19 — Force atlas (maximum forces) line 17 finger forces

Line 18 (Body Forces onto arms):

For line 18, the following force Atlas for the two-handed version is used (See Rule 2.10).

Maximum force values refer to feminine gender. Values for masculine gender are also available in the force Atlas and in EAWS electronic forms.

17		Forces onto fingers (e.g. clips, plugs)	Int	0	7	15	25	50		
				16,7 % F _{max}	33,3 % F _{max}	50,0 % F _{max}	66,7 % F _{max}	F _{max}		
			Duration stat	0	1	1	1,5	2	3,5	7
				[s]	3	6	9	12	20	30
			[%]	5	10	15	20	33	50	
			Duration dyn	0	1,5	2	2,5	3		
				[n]	4	10	15	20		
18		Forces onto arms / whole body forces	Int	0	6	15	25	50		
				16,7 % F _{max}	33,3 % F _{max}	50,0 % F _{max}	66,7 % F _{max}	F _{max}		
			Duration stat	0	1	1	1,5	2	4	8,5
				[s]	3	6	9	12	20	30
			[%]	5	10	15	20	33	50	
			Duration dyn	0	1	2	3	4,5	6,5	10
				[n]	1	3	6	8	10	12

Figure A.21 — Static duration points of finger forces and arm/body forces

EXAMPLE 3

Apply force for 9 seconds with the right thumb (cycle time 60 s.)

-> Line 17, duration points = 1,5 Points

EXAMPLE 4

Pull a rope downward with 2 hands for 20 % of the cycle time (60 s.)

-> Line 18, duration points = 2,0 Points

Dynamic action forces (duration < 4 s.): frequency of applications/minute (n). See [Figure A.22](#).

17		Forces onto fingers (e.g. clips, plugs)	Int	0	7	15	25	50		
				16,7 % F _{max}	33,3 % F _{max}	50,0 % F _{max}	66,7 % F _{max}	F _{max}		
			Duration stat	0	1	1	1,5	2	3,5	7
				[s]	3	6	9	12	20	30
			[%]	5	10	15	20	33	50	
			Duration dyn	0	1,5	2	2,5	3		
				[n]	4	10	15	20		
18		Forces onto arms / whole body forces	Int	0	6	15	25	50		
				16,7 % F _{max}	33,3 % F _{max}	50,0 % F _{max}	66,7 % F _{max}	F _{max}		
			Duration stat	0	1	1	1,5	2	4	8,5
				[s]	3	6	9	12	20	30
			[%]	5	10	15	20	33	50	
			Duration dyn	0	1	2	3	4,5	6,5	10
				[n]	1	3	6	8	10	12

Figure A.22 — Dynamic duration points of finger forces and arm/body forces

EXAMPLE 5

4 × apply force > 30 N with the left index finger (Cycle time 60 s.)

-> Line 17, duration points = 1,5 Points

EXAMPLE 6

8 × pull a rope downward with 2 hands (force > 40 N, cycle time 60 s.),

-> Line 18, duration points = 4,5 Points

— Rules for scoring of Section 2

— Rule 2.1

To use Section 2 (Action Forces) consider a minimum threshold of force intensity:

- 30 N relative to line 17 (hand-finger) (Warning: the posture is still to be evaluated in Section 1)
- 40 N relative to line 18 (arm-shoulder)

Below those limits of force intensity, Section 2 is not applied (do not calculate/evaluate load points).

The biomechanical load exerted by action forces below these limits is evaluated in Section 1 (postures).

EXAMPLE 6

- Pull a rope downward with 2 hands, intensity 50 N.
 - Line 18, intensity = 50 N.
- Pull a rope downward with 1 hand, intensity 35 N.
 - included in Section 1
- Insert a pin with fingers, intensity 35 N.
 - Line 17, intensity = 35 N.
- Insert a cover with fingers using 2 hands, total resistance force = 40 N.
 - included in Section 1 (as 20 N per hand is below the threshold limit of line 17)
- Hold a button with the thumb, intensity 20 N.:
 - $F < 30 \text{ N}$, no rating in line 17
- Pulling a lever forward in standing position, intensity 50 N. with both hands:
 - rating in line 18 because $F \geq 40 \text{ N}$.
 - Rule 2.2

The intensity points are calculated by interpolation between the limiting values of the considered intervals.

- 16,7 % - 33,3 % F_{\max}
- 33,3 % - 50,0 % F_{\max}
- 50,0 % - 66,7 % F_{\max}
- 66,7 % - 100,0 % F_{\max}
- Rule 2.3

If there are both static and dynamic actions, the scores will be calculated separately and the total score of Lines 17 or 18 will be calculated using:

- as duration points, the sum of the duration points both static and dynamic, and as intensity points, the weighted average of the intensity points (for dynamic and static forces), using the respective (static and dynamic) duration points as weights.
- Rule 2.4

To calculate the total scores of groups of dynamic or static actions (1...i), it is necessary to calculate the Intensity score (I_{s_i}), the Duration Score (D_{s_i}) and the Risk score $Rs_i = I_{s_i} \times D_{s_i}$ of each action (static and dynamic).

Then, both groups of dynamic and static actions are ranked according to their risk score (R_{s_i}), from the highest one to the lowest one. In case, two actions have the same Risk score, the action with higher intensity score I_{s_i} prevails. At this point, it is necessary to calculate the overall duration score, PDS or PDD, respectively for the static or dynamic actions, which is the sum of the duration (in seconds or quantity) of all the actions.

The duration points (D^*s) for each activity are corrected, according to those actions with highest risk score, as follow:

1. Starting from the action with the highest ranking, the corrected duration score D^*s_i of each static or dynamic action is obtained with the following formula: $D^*s_i = PDS$ (or PDD) - $\sum_{j=1}^{i-1} Ds_j$
 All D^*s_i whose value is lower than 0 are set to 0. For the action with the highest ranking ($i=1$), it is obviously $D^*s_i = Ds_i$
2. For each static or dynamic action "i", calculate the corrected risk score $R^*s_i = I_{s_i} \times D^*s_i$

The overall risk score, for each action either static or dynamic, it is calculated with the following formula:

$$R_{dyn} \text{ (Total score dynamic actions)} = \sum R^*s_i = (I_{dyn_1} \times D^*s_{1+..+} + I_{dyn_i} \times D^*s_{ij})$$

$$R_{stat} \text{ (Total score static actions)} = \sum R^*s_i = \sum (I_{stat_1} \times D^*s_{1+..+} + I_{stat_i} \times D^*s_{ij})$$

Calculation Steps of rule 2.4 (valid for static or dynamic actions, see Rule 2.3 for combined static and dynamic actions calculation):

a) Score Calculation of Action 1 (A1)

1.1 Calculation of Intensity Points, by interpolation if necessary (I_{s_1})

1.2 Calculation of Duration Points, by interpolation if necessary (Ds_1)

1.3 Calculation of Score A1 ($Rs_1 = I_{s_1} \times DPs_1$)

b) Score Calculation of Action 2 (A2)

2.1 Calculation of Intensity Points, by interpolation if necessary (I_{s_2})

2.2 Calculation of Duration Points, by interpolation if necessary (Ds_2)

2.3 Calculation of Score A2 ($Rs_2 = I_{s_2} \times Ds_2$)

c) Score Calculation of Action 'n' (An)

2.1 Calculation of Intensity Points, by interpolation if necessary (I_i)

2.2 Calculation of Duration Points, by interpolation if necessary (D_i)

2.3 Calculation of Score An ($Rs_n = I_{s_i} \times Ds_i$)

d) Calculation of the corrected risk duration points

3.1 Rank all actions according to their risk score R_{s_i} , from the highest one to the lowest one. In case two actions have the same Risk score, the action with higher Intensity score I_{s_i} prevails.

3.2 Sum the duration (in seconds or quantity) respectively of all static or dynamic actions and calculate the overall duration score PDS or PDD.

3.3 Starting from the first action in the rank, calculate the corrected duration score D^*s_i of each action with the following formula: $D^*s_i = PDS$ - $\sum_{j=1}^{i-1} Ds_j$

— All D^*s_i whose value is lower than 0 are set to 0.

- For the action with the highest ranking ($i = 1$), it is obviously $D^*s_i = D_{s_i}$.
- e) Calculate for each action the corrected risk score as $\rightarrow R^*s_i = I_{s_i} \times D^*s_i$
- f) The overall risk score is $\rightarrow R = \sum R^*s_i$
 R_{s_i} = Score of the single action

Calculation Procedure for the overall risk score (Static + Dynamic) is in [Figure A.23](#):

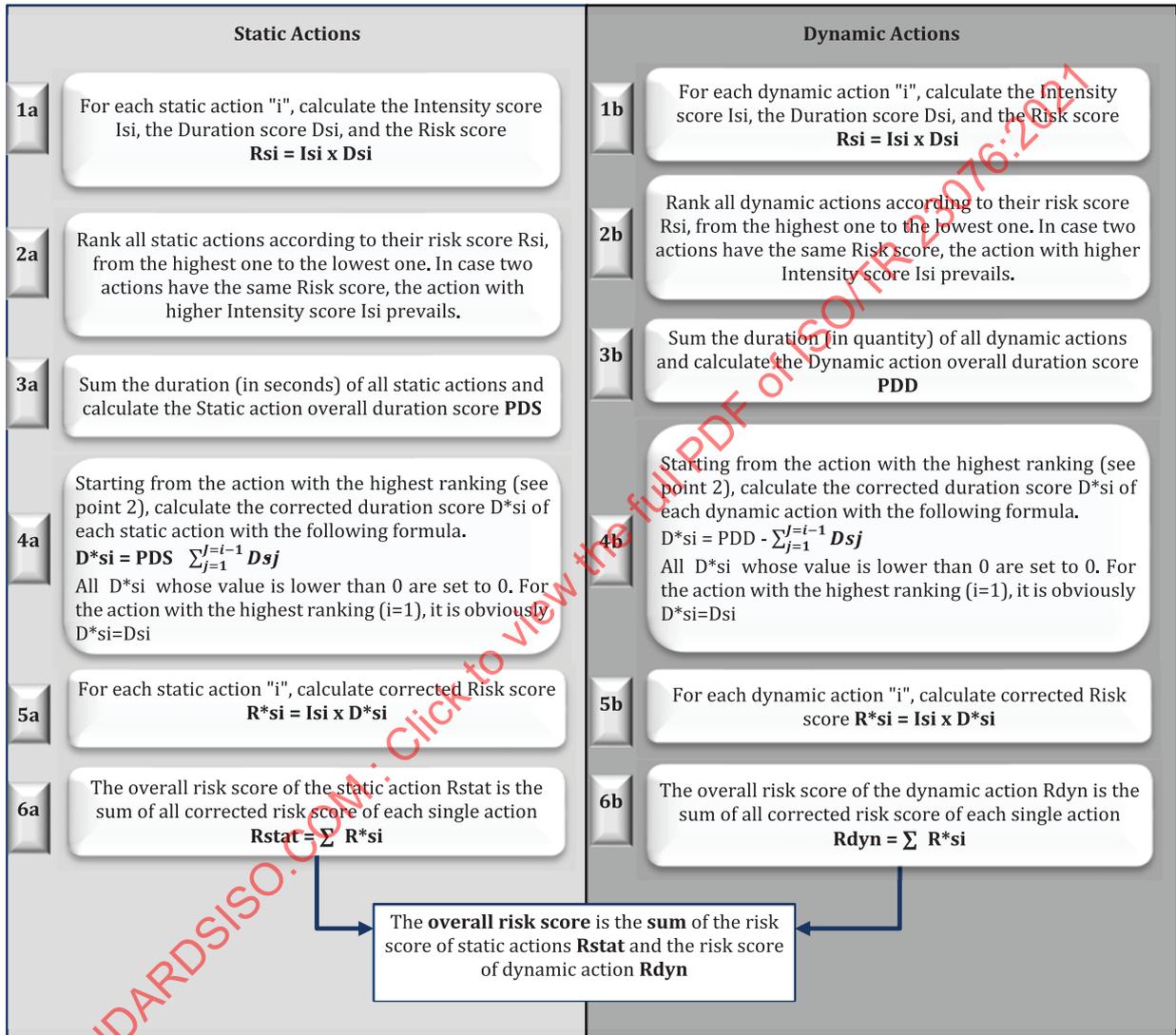


Figure A.23 — Calculation procedure of Section 2 (Action Forces)

EXAMPLE 7

- Action A_1 : Dynamic, 50 % F_{max} , 4 times/cycle
- Action A_2 : Dynamic, 33,3 % F_{max} , 10 times/cycle

Solution:

- A_1 Score
- I_1 : 50 % $F_{max} = 15$ Points
- D_1 : 4 times/cycle = 1,5 Points

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- $A_1 = I_1 \times D_1 = 15 \times 1,5 = 22,5$ Points - > Worst Case
- A_2 Score
- $I_2: 33,3 \% F_{\max} = 7$ Points
- $D_2: 10$ times/cycle = 2 Points
- $A_2 = I_2 \times D_2 = 7 \times 2 = 14$ Points

Risk Score Calculation (R)

Rank the intensity score of each activity and calculate the corrected duration point, then obtain the Total risk score:

Total Duration points: 2,4 pt (interpolation)

Ranking 1:

- Intensity (15 pt.)
- $D^* = D_{s1} = 1,5$
- Risk Score = $15 \times 1,5 = 22,5$

Ranking 2:

- Intensity (7 pt.)
- $D^*s_2 = PDD - D_{s1} = 2,4 - 1,5 = 0,9$
- Risk Score = $7 \times 0,9 = 6,3$

Risk Score = 28,8 points

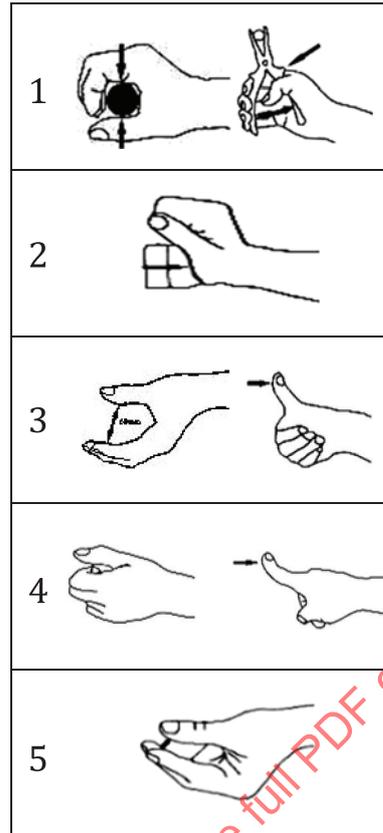
- Rule 2.5

If line 18 is used (forces onto arms/whole body greater than or equal to 40 N), the biomechanical load onto the fingers is already included in the score. It is not necessary to also use line 17, unless rule 2.6 is applicable.

- Rule 2.6

If line 18 is used (forces onto arms/whole body greater than or equal to 40 N) and the grip is not a contact or power grip (e.g. high pressure onto fingers), line 17 has to be used in addition to line 18. See [Figure A.24](#).

NOTE In the development of the model, different grip types were put together, for the sake of simplicity.

**Key**

- 1 Posture A1 (power grip, pliers) - Line 18
- 2 Posture A2 (ball of the thumb) - Line 18
- 3 Posture B1 (thumb or thumb to 4 fingers) - Line 17 and Line 18
- 4 Posture B2 (index or wide pinch) - Line 17 and Line 18
- 5 Posture C (hook, palmar, strong pinch) - Line 17 and Line 18

Figure A.24 — Use of lines according to Rule 2.6

— Rule 2.7

To calculate the frequencies and/or the durations, we do not distinguish between right and left arm for hand/finger forces and arm/whole body forces. The total frequency is the sum of the frequencies of both arms.

EXAMPLE 8

Forces onto fingers with the left hand exerted 4 times within the cycle time and additional forces onto finger with the right hand 6 times.

Solution:

The duration is $4 + 6 = 10$ times

Intensity points of the two finger forces are evaluated in line 17 (see rule 2.4) with a total frequency of 10 times.

— Rule 2.8

In line 17, force intensities are considered to be applied by one arm. In case a given pressure is applied by two hands, force is equally distributed between the 2 hands.

EXAMPLE 9

Exert a force with both thumbs, $F = 70 \text{ N}$.

Solution:

Analysed in line 17, $F = 35 \text{ N}$. with a frequency of $n = 2$

— Rule 2.9

In line 18, force intensities are considered to be applied by 2 arms symmetrically. When forces are applied by one arm, it is necessary to consider the F_{max} value multiplied by 60 % (i.e. equivalent to multiplying the intensity of the exerted force by about 1,7), see also the application note below.

In line 18, when forces are applied by one arm, consider, depending on the type of posture, a value for F_{max} which ranges from 40 % to 80 % of the values reported on the EAWS form (atlas force). To simplify the calculation procedure, use an average value of 60 %.

EXAMPLE 10

Exert a pulling force (+B) with one hand standing upright.

Solution:

For the posture and the force direction, it is determined a maximum force of 210 N for P40. Since the force application is done with only one hand, only 60 % of the maximum force is used as the basis for further calculation.

$$60 \% \times 210 \text{ N} = 126 \text{ N}$$

— Rule 2.10

Line 18 is mutually exclusive with respect to Section 1 and Section 3, whereas Line 17 needs Section 1.

The measure of the load onto fingers is independent from the body posture (e.g. it might happen when pressing a button with 30 N located above the operator's head).

EXAMPLE 11

An operator performs an action of force $> 40\text{N}$. while kneeling.

Solution:

The posture "kneeling" is one of the factors considered in the selection of the F_{max} value and therefore falls within the risk score calculated on line 18. In Section 1, this period will be classified as idle time, according to rule 1.6b (it would be considered 100 % of the cycle time in section 1).

EXAMPLE 12

An employee has to apply a dynamic force, $F > 30 \text{ N}$., with the index finger, while kneeling upright for 6 s.

Solution:

The force application will be analysed in line 17 with the maximum force for the index finger. The kneeling will be evaluated in section 1 in line 12 (duration 6 s.)

— Total score of section 2

The points for lines 17 and 18, in each case, result from the product of the assessed intensity and duration points.

The score of section 2 (see [Figure A.25](#)) is the sum of line 17 (action forces onto fingers) and line 18 (action forces with arms/whole body):

Action forces (per minute)										Forces						
17		Forces onto fingers (e.g. clips, plugs)	Intensity × Duration													
			Int	0	7	15	25	50								
				16,7% F _{max}	33,3% F _{max}	50,0% F _{max}	66,7% F _{max}	F _{max}								
			Duration	0	1	1	1,5	2	3,5			7				
18		Forces onto arms / whole body forces	Intensity × Duration													
			Int	0	6	15	25	50								
				16,7% F _{max}	33,3% F _{max}	50,0% F _{max}	66,7% F _{max}	F _{max}								
			Duration	0	1	1	1,5	2	4			8,5				
			stat	[s]	3	6	9	12	20	30						
			dyn	[n]	5	10	15	20	33	50						
			stat	[s]	3	6	9	12	20	30						
			dyn	[n]	1	3	6	8	10	12						
Forces F _{max} onto arms / whole body forces (neutral to gender) P15 for planning & P40 for observation			ST Upright	P15	P40	ST Bent	P15	P40	ST Above head	P15	P40	Finger forces F _{max} (neutral to gender)				
				*A	245	315		*A	210	285		*A	230	280	Posture A1 (power grip, pliers)	F _{max}
				*A	260	325		*A	200	240		*A	265	320		P15
				*B	170	210		*B	205	260		*B	160	200	Posture A2 (ball of the thumb)	F _{max}
				*B	245	315		*B	285	390		*B	255	310		P15
				*C	130	185		*C	145	200		*C	105	140	Posture B1 (thumb or thumb to 4 fingers)	F _{max}
				*C	110	165		*C	90	135		*C	100	140		P15
				*A	210	270		*A	180	245		*A	225	275	Posture B2 (index or wide pinch)	F _{max}
				*A	225	280		*A	190	225		*A	265	320		P15
				*B	215	290		*B	220	320		*B	210	270	Posture C (hook, palmar, strong pinch)	F _{max}
				*B	240	325		*B	220	290		*B	220	275		P15
				*C	145	195		*C	140	190		*C	130	180	Posture C (hook, palmar, strong pinch)	F _{max}
				*C	115	160		*C	105	135		*C	130	180		P15
				*A	205	265		*A	190	250		*A	215	255	Posture C (hook, palmar, strong pinch)	F _{max}
				*A	245	285		*A	195	245		*A	260	295		P15
				*B	215	260		*B	245	295		*B	195	240	Posture C (hook, palmar, strong pinch)	F _{max}
				*B	205	250		*B	215	275		*B	210	240		P15
				*C	120	165		*C	130	175		*C	100	130	Posture C (hook, palmar, strong pinch)	F _{max}
				*C	110	155		*C	100	135		*C	100	135		P15
Action forces = ∑ lines 17 - 18			Attention: correct evaluation, if task duration ≠ 60s							=						

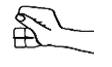
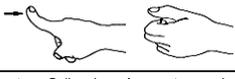
Figure A.25 — Total score of Section 2

EXAMPLE 13

Line 17 (static and dynamic forces)

- Observing a task
- In a cycle of 60 s, using the index finger:
- Push button P1 4 times with F = 35 N. → dynamic
- Hold button P2 pushed for 12 s with F = 50 N. → static

Solution:

Finger forces F _{max} (neutral to gender)		
Posture A1 (power grip, pliers)		
	F _{max}	
	P15	P40
	150	205
Posture A2 (ball of the thumb)		
	F _{max}	
	P15	P40
	115	155
Posture B1 (thumb or thumb to 4 fingers)		
	F _{max}	
	P15	P40
	55	70
Posture B2 (index or wide pinch)		
	F _{max}	
	P15	P40
	40	50
Posture C (hook, palmar, strong pinch)		
	F _{max}	
	P15	P40
	45	55

F _{max} = 50 N

Figure A.26 — Finger forces - F_{max}

Duration

P1: 4 times per minute → PDD = 1,5 Points

— P2: 12 s per minute → PDS = 2 Points

— D = PDS + PDD

Intensity (See [Figure A.26](#)):

P40: F_{max} = 50 N.

%FD_{P1} = 35 N / 50 N. × 100 % = 70 % F_{max}

Intensity points (ID): Interpolation

$$25 + \frac{(50-25)}{(100\%-66,7\%)} \times (70\%-66,7\%) = 27,5 \text{ Points}$$

$$R_{dyn} = ID \times PDD = 41,3$$

$$\%FSP2 = 50 \text{ N.} / 50 \text{ N.} \times 100 \% = 100 \%$$

Intensity points (IS): 50 Points

$$R_{stat} = 50 \times 2 = 100$$

Overall risk score ([Figure A.27](#))

$$R_{dyn} + R_{stat} = 41,3 + 100 = 141,3 - > 141,5$$

17		Forces onto fingers (e.g. clips, plugs)	Intensity × Duration						141,3	
			Int	0	7	15	25	50		27,5 x 1,5 = 41,3 50 x 2 = 100
				16,7% F _{max}	33,3% F _{max}	50,0% F _{max}	66,7% F _{max}	F _{max}		
			Duration stat	0	1	1,5	2	3,5		7
	[s]	3	6	9	12	20	30			
	[%]	5	10	15	20	33	50			
	dyn	0	1,5	2	2,5	3				
	[n]	4	10	15	15	20				

Action forces = ∑ lines 17 - 18	Attention: correct evaluation, if task duration ≠ 60s	=	141,5
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Figure A.27 — Scoring of example 3

EXAMPLE 14

Line 18 (different dynamic forces)

Observing a task:

- Posture: sitting upright;
- Close 2 latches pulling (direction +B) using right hand, F = 52 N;
- Tighten 6 screws with power screwdriver pushing (direction -B) with F = 75 N;
- Cycle time: 60 s., 8 actions.

Solution:

When forces are applied by one arm, it is necessary to consider the F_{max} value multiplied by 60 % (see Rule 2.9)

F1 Score:

- Intensity Points: 52 N. / 156 N. × 100 % = 33,3 % = 6 Points
- Duration Points: 2 times/cycle = 1,5 Points
- F1 = I1 x D1 = 6 x 1,5 = 9 Points

F2 Score:

- Intensity Points: 75 N / 150 N × 100 % = 50 % = 15 Points
- Duration Points: 6 times/cycle = 3 Points
- F2 = I2 x D2 = 15 x 3 = 45 Points - > Worst Case

Risk Score Calculation (R)

Rank the intensity score of each activity and calculate the corrected duration point, then obtain the Total risk score as follow in Table A.12:

Table A.12 — Calculation of risk score of Line 18

Ranking	Intensity Value	Total Duration points	Corrected duration point	Total Risk Score
1	15pt.	4,5 # of actions = 8	D* s ₁ = Ds ₁ = 3	15*3 = 45pt
2	6pt.		D*s ₂ = PDD - Ds ₁ = 4,5-3 = 1,5	6*1,5 = 9pt
Total				54 points

A.2.6 Scoring: Section 3 – Manual Material Handling

Manual material handling operations are carried out in most industrial plants. Each handling task poses unique demands on the worker. However, the design of the workplace can help workers to perform these tasks safely and easily by implementing and adhering to proper policies and procedures.

— Manual – Material Handling

Manual Material Handling considers the activities of Repositioning, Carrying, Holding and Pushing and Pulling one or more loads.

NOTE 1 A load is an object that can fall on your feet.

To assess the physical stress due to manual material handling, the following factors will be evaluated:

- The handled load
- The structure of the activities
- The environment in which the activities are performed
- The way by which the user performs the assigned operations

When these factors interact with each other, they can create hazards that result in injuries.

A load is hazardous because of:

- Weight;
- Size;
- Shape (making it awkward to handle);
- Coupling (type of grip on the load);
- Slippery or damaged surfaces;
- Absent or inappropriate handles;
- Imbalance (i.e. changing centre of gravity).

The task or method of handling is hazardous when it involves:

- Lifting or lowering
 - repetitively
 - quickly
 - for extended periods of time
 - while seated or kneeling
 - immediately after prolonged flexion
 - shortly after a period of rest
- An inability to get close to the load
- Moving the load over large distances
- Accuracy and precision are useful because of
 - fragile loads, or

- specific unloading locations
- Materials positioned too low or too high
- Hazardous movements or postures (e.g. twisting, extended bending and reaching)
- Multiple handling requirements (e.g. lifting, carrying, unloading)

Environmental factors include:

- Temperature (beyond a 19–26 °C range)
- Relative humidity (beyond a 35–50 % range)
- Lighting
- Noise
- Time constraints (e.g. machine-paced work or deadline pressures)
- Physical conditions, such as
 - obstacles
 - floor surfaces (e.g. slippery, uneven or damaged)

Environmental factors, except for the physical conditions, and partially, for the time constraints, are not considered in EAWS, because they do not directly influence the biomechanical load.

- Influencing factors

The influencing factors in Section 3 are the following:

- Handled load (expressed in kg.)
- Gender of operator (male/female)
- Handling method
 - Repositioning (R), holding (H) and short distance pushing and pulling (P&P) are related to handlings within the work area.
 - Carrying (C) and long distance pushing and pulling are related to handling outside of the work area.
- Means of transport (if any)
- Posture
- Working conditions (only for P&P)
- Frequency per shift expressed in:
 - Frequency/shift (R and P&P short)
 - Distance covered per shift (C and P&P long)
 - Minutes per shift (H)
- Calculation of the score of Section 3 ([Figure A.28](#)):

Weights of loads [kg] for repositioning (lifting / lowering), carrying and holding as well as pushing and pulling															
Reposition, carrying & holding		Males	3	10	15	20	25	30	35	40	>40				
		Females	2	5	7	10	12	15	20	25	>25				
Load points			1	1,5	2	3	4	5,5	7	8,5	25				
1 →	+	Pushing and pulling	M1	Wheelbarrows and Dollies		Males	<50	75	100	150	200	250			
				Females	<40	60	80	115	155	195					
			M2	Carts, roller trolleys, No fixed rollers		Males	<50	75	100	150	250	350	550		
				Females	<40	60	80	115	195	270	425				
			M3	Carts, roller conveyors, pallet truck		Males	<50	75	150	250	350	500	600	800	
				Females	<40	60	115	195	270	385	460	615	960		
Load points			0,5	1	1,5	2	3	4	5	6	8				
Posture, position of load (select characteristic posture)															
2 →		+		trunk upright and / or not twisted load at the body		little trunk bending or twisting; load at or close to the body	bending trunk deep or far forward; little trunk bending forward and trunk twisting simultaneously; load far from body or above shoulder level	bending trunk far forward and twisting; load far from the body; limited postural stability while standing; crouching or kneeling							
3 →		+		Posture points		1	2	4							
Working Conditions (pushing and pulling only)															
4 →		+		very low rolling resistance		trolley pushing / pulling on (very) slick floor	rough floor and above small gaps / edges	on structured sheet metal, into / out of a track	trolleys have to be teared off when starting, strongly damaged floor	very high rolling resistance					
5 →		+		Conditions points		0	1	3	5	6	8				
Frequency of load manipulations (frequency/shift, holding time [min/shift] or travel distance [meter/shift])															
x		+		Frequency (#) of repositionings / pushing & pulling short		5	25	120	350	750	1000	1500	2000	2500	3000
		+		Duration (holding time) [min]		2,5	10	37	90	180	≥240				
		+		Distance (carrying, pushing & pulling long) [m]		300	650	2500	6000	12000	≥16000				
		+		Duration points		1	2	4	6	8	10	11	13	14	15
Manual Material Handling (result)															
19		+		(Load + posture + (condition points)) × duration points		((((((((((
		+		Repositioning (R)		x	x	x	x	x	x	x	x	x	x
		+		Holding (H)		=	=	=	=	=	=	=	=	=	=
		+		Carrying (C)		=	=	=	=	=	=	=	=	=	=
		+		Pushing & Pulling short (P&P short)		=	=	=	=	=	=	=	=	=	=
		+		Pushing & Pulling long (P&P long)		=	=	=	=	=	=	=	=	=	=
		+		Handling = ∑ line 19		=	=	=	=	=	=	=	=	=	=
		+		1) Maximal cumulative duration points for all tasks of repositioning, holding, carrying as well as pushing & pulling all together = 15		=	=	=	=	=	=	=	=	=	=

Key

- 1 handled according to gender (male/female, min. 3 kg). for planning use female. values are expressed in kg and refer to an handling using both arms
- 2 means of transport
- 3 posture
- 4 floor conditions (only if means of transport are used)
- 5 frequency/distance covered/Minutes per shift

Figure A.28 — Layout of Section 3

These steps are followed to determine the score in Section 3:

- Step 0 – Select the handling method
 - Repositioning (R): get and place a load within the workplace (<5 m or < 20 m for automotive industry)
 - Holding (H): hold a load within the work area, no carrying (≥5 s or ≥ 15 s for automotive industry)
 - Carrying (C): get, carry and place outside the work area (≥20 m)
 - Pushing and Pulling (P&P): transporting a load with a means of transport
 - Short, if within the work area (<20 m)
 - Long, if outside the work area (≥20 m)

NOTE 2 Practical experience, particularly in the automotive industry, has shown that borders of 20 m or 15 s deliver a more realistic load assessment.

- STEP 1: Determine the correct load points (see Table A.13)
 - For Repositioning, Holding and Carrying:

Determine the intensity points depending on the weight of the load and the gender of the operator, if the load is moved systematically using only one hand, multiply its weight by 1,7, (see Rule 3.1).

EXAMPLE 1

A load of 10 kg generates 1,5 load points for a male and 3 points for a female.

Table A.13 — Load points for Reposition, Holding and Carrying

Reposition, carrying and holding	Males	3	10	15	20	25	30	35	40	> 40
	Females	2	5	7	10	12	15	20	25	> 25

To determine intensity and frequency, any load greater than or equal to 3 kg. generates one independent manual handling, frequency 1 (Repositioning, Carrying, Holding).

- For loads handled with one hand, see rule 3.1 (multiply weight by 1,7), on condition that the weight is at least 3 kg.
- When two loads are handled, one in each hand, and the sum is greater than or equal to 4 kg, and each load weighs less than 3 kg., than use Section 3 with an effective net load equal to the sum of the loads considering as just one handling.
- When just one load is greater than or equal to 3 kg., only one handling is to be considered with an effective net load equal to the sum of the weights multiplied by 1,7.

In [Table A.14](#) some examples referring to repositioning are shown:

Table A.14 — Repositioning combinations

left hand	right hand	2 hands	Number of repositions	effective net load	Explanation
2 kg.			0	Include in section 1	< 3 Kg.
1 kg.	1 kg.		0	Include in section 1	< 2 Kg. for each hand
1,9 kg.	1,9 kg.		0	Include in section 1	< 2 Kg. for each hand
		4 kg.	1	4	1 reposition with 4 Kg.
2 kg.	2 kg.		1	4	1 reposition with 4 Kg. (loads > 2kg. but less than 3 kg.)
3 kg.	3 kg.		2	3 × 1,7 3 × 1,7	2 reposition with 5,1 Kg. (rule 3.1)
3 kg.	2 kg.		1	5 × 1,7	1 reposition with 8,5Kg. (loads > 2kg. for each hand but one load is bigger than 3 Kg. In this case consider only one handling with an effective net load equal to the sum of the weights multiplied by 1,7 .)
4 kg.			1	4 × 1,7	1 reposition with 6,8 Kg. (rule 3.1)
4 kg.	2 kg.		1	6 × 1,7	1 reposition with 10,2 Kg. (loads > 2kg. for each hand but one load is bigger than 3 Kg. In this case consider only one handling with an effective net load equal to the sum of the weights multiplied by 1,7 .)
6 kg.			1	6 × 1,7	1 reposition with 10,2 Kg. (rule 3.1)
		6 kg.	1	6	1 reposition with 6 Kg.
4 kg.	4 kg.		2	4 × 1,7 4 × 1,7	2 reposition with 6,8 Kg. (rule 3.1)
		8 kg.	1	8	1 reposition with 8 Kg.

- For Pushing and Pulling

Evaluate (see [Table A.15](#)):

- a) Weight of the transported load summed with the weight of the means of transport (e.g. dolly = 50 kg, load = 200 kg → total load of 250 kg)

- b) Gender of the operator
- c) Type of means of transport:

M1: Wheelbarrows and Dollies

M2: Carriage, roller, trolleys. No fixed rollers

M3: Carts, roller conveyors, pallet truck.

Table A.15 — Load points of Pushing and Pulling

Pushing and pulling	M1	Wheelbarrows and Dollies	Males	< 50	75	100	150	200	250			
			Females	< 40	60	80	115	155	195			
	M2	Carriage, roller, trolleys. No fixed rollers	Males	< 50	75	100	150	250	350	550		
			Females	< 40	60	80	115	195	270	425		
	M3	Carts, roller conveyors, pallet truck	Males	< 50	75	150	250	350	500	600	800	1 250
			Females	< 40	60	115	195	270	385	460	615	960
Load points		Means of transport		0,5	1	1,5	2	3	4	5	6	8

— STEP 2: Assess posture points

Calculate points due to posture and load position (see [Table A.16](#)).

Table A.16 — Posture points

Posture, position of load (select characteristic posture)													
+	<table border="1" style="width: 100%;"> <tr> <td>trunk upright and / or not twisted load at the body</td> <td>little trunk bending or twisting; load at or close to the body</td> <td>bending trunk deep or far forward; little trunk bending forward and trunk twisting simultaneously; load far from body or above shoulder level</td> <td>bending trunk far forward and twisting; load far from the body; limited postural stability while standing; crouching or kneeling</td> </tr> <tr> <td>Posture points</td> <td>1</td> <td>2</td> <td>4</td> </tr> <tr> <td></td> <td></td> <td></td> <td>8</td> </tr> </table>	trunk upright and / or not twisted load at the body	little trunk bending or twisting; load at or close to the body	bending trunk deep or far forward; little trunk bending forward and trunk twisting simultaneously; load far from body or above shoulder level	bending trunk far forward and twisting; load far from the body; limited postural stability while standing; crouching or kneeling	Posture points	1	2	4				8
trunk upright and / or not twisted load at the body	little trunk bending or twisting; load at or close to the body	bending trunk deep or far forward; little trunk bending forward and trunk twisting simultaneously; load far from body or above shoulder level	bending trunk far forward and twisting; load far from the body; limited postural stability while standing; crouching or kneeling										
Posture points	1	2	4										
			8										

— For Repositioning

Using the pictures above, assess the posture score to get the load under control and the score to place the load at its final position. Then, calculate the average score.

— For Holding and Carrying

Using the pictures above, assess the posture to hold or carry (main posture) and determine the score. Then, select the individual scores to:

- Get the load under control
- Hold / carry the load and
- Place the load at its final position.

Then, calculate the average score from the get and place of the load and compare with the point values for holding or carrying. Take the highest value between the holding or carrying and the average of the get and place score (see Rules 3.4 and 3.5).

- STEP 3 – Assess working conditions (only for P&P)

Table A.17 — Working conditions P&P

Working Conditions (pushing and pulling only)							
(+)	very low rolling resistance	trolley pushing / pulling on (very) slick floor	rough floor and above small gaps / edges	on structured sheet metal, into / out of a track	trolleys have to be teared off when starting, strongly damaged floor	very high rolling resistance	
	<i>Conditions points</i>	0	1	3	5	6	8

Assessing working conditions (see [Table A.17](#)) was developed for 2 main reasons:

- To consider the floor conditions, which have a strong influence on the necessary force to push and pull the means of transport;
- To tune the intensity score among different means of transport belonging to the same family (M1, M2 or M3). Base the tuning of course on experimentation and measurement of different force levels generated by different means of transport loaded with the same load.

Determining the points related to the floor conditions:

- 0 points very low rolling resistance, means of transport in perfect condition;
- 1 point regular and (very) slick floor;
- 3 points rough floor and small gaps/edges;
- 5 points on structured sheet metal, into/out of a truck;
- 6 points trolleys have to be teared off when starting, strongly damaged floor;
- 8 points very high rolling resistance.

In normal conditions (means of transport and floor in good conditions) 0-1 points are assigned in this sector.

- STEP 4 – Calculate the frequency, duration or distance points

Table A.18 — Frequency / Duration / Distance points

Frequency of load manipulations [frequency/shift], holding time [min/shift] or travel distance [meter/shift]											
x	Frequency (#) of repositionings / pushing and pulling short	5	25	120	350	750	1 000	1 500	2 000	2 500	≥ 3 000
	Duration (holding time) [min]	2,5	10	37	90	180	≥ 240				
	Distance (carrying, pushing and pulling long) [m]	300	650	2 500	6 000	12 000	≥ 16 000				
	<i>Duration points</i>	1	2	4	6	8	10	11	13	14	15

As opposed to the other sections, the calculation refers to duration per shift and not to the cycle time. It is not necessary to do a conversion according to Rule G.1.

To accomplish this, determine the following per shift (see [Table A.18](#)):

- For Repositioning and Pushing and Pulling short: the frequency of the handling (frequency of Repositioning / P&P per shift);

- For Carrying and Pushing and Pulling long: travel distance in meters per shift;
- For Holding: total Holding time in minutes per shift (Holding time during each cycle multiplied by the quantity of cycles in a shift).
- STEP 5 – Calculate the total score of Section 3

For each handling method, sum the load points, posture points and working condition points (only for Pushing and Pulling) according to Rule 3.7 and multiply by the duration, frequency or distance points according to Rule 3.6.

The total score of Section 3 is the sum of the scores of “Repositioning”, “Holding”, “Carrying” and “Pushing & Pulling” (short and long). See [Table A.19](#).

Table A.19 — Total score of section 3

19	(Load + posture + (condition points)) × duration points	Repositioning () +) × = a	Holding () +) × = b	Carrying () +) × = c	Pushing & Pulling short () +) × = d	Pushing & Pulling long () +) × = e
----	---	-----------------------------	-----------------------	------------------------	---------------------------------------	--------------------------------------

Handling = Σ line 19	1) Maximal cumulative duration points for all tasks of repositioning, holding, carrying as well as pushing and pulling all together = 15	=	Line 19 = a+b+c+d+e
Key Line 19 = a+b+c+d+e = Repositioning + Holding + Carrying + Pushing and Pulling (short and long)			

- Rules for scoring of Section 3
 - Rule 3.1

Manual material handling is usually considered as being performed by two hands. If the load is moved systematically using only one hand, its weight has to be multiplied by 1,7 (EN 1005-2). As a general rule, the minimum weight defined to use this section is 3 kg (for women the interpolation limit is 2 kg).

EXAMPLE 2

A screwdriver with a weight of 2 kg is handled with one hand:

- > No evaluation in section 3

EXAMPLE 3

A work piece with 3 kg one handed moves:

- > Evaluation in section 3, Load 3 kg. × 1,7 = 5,1 kg.

- Rule 3.2

The aggregate duration score referred to time and/or distance of handling is not to exceed the limit of 15 points. If this occur, apply the following procedure:

- Step 1: Assign the points of the most severe method¹⁾ (t1) if t1 ≤ 15; otherwise assign 15 duration points and the procedure is over
- Step 2: Next, consider the most second severe method and assign its points (t2) if total duration points (t1 + t2) ≤ 15. Otherwise, assign only the value (15 - t1) and the procedure is over

1) Selection of the most severe method is based on Intensity points (Load + Posture) for each Manual Material Handling method.

— Step 3: Repeat Step 2 until the total duration points achieve the maximum value of 15

EXAMPLE 4 (see [Table A.20](#) - [Table A.21](#) - [Table A.22](#)):

Table A.20 — Example 1 of MMH index calculation

19	(Load + posture + (condition points)) × duration points	Repositioning (I)	(4 + 4)	= 48	Holding (I)	(2 + 4)	= 30	Carrying (I)	(2 + 2)	= 32	Pushing & Pulling (short I)	(+ +)	=	Pushing & Pulling (long I)	(1,5 + 1 + 1)	= 7
			× 6			× 5			× 8			× 2				

Table A.21 — Calculation of duration points with multiple handling methods

Check the sum of	R	H	C	P&P	Sum
Frequency, duration, distance points	6	5	8	2	21 > 15 Rule 3.2
Determine the order of the Intensity points					
Intensity points	4 + 4 = 8	2 + 4 = 6	2 + 2 = 4	1,5 + 1 + 1 = 3,5	
Order	1	2	3	4	
Correction begins at the highest Intensity Points					
	<i>Repositioning</i>			15 - 6 = 9	
Additional correction	<i>Holding</i>			9 - 5 = 4	
Additional correction	<i>Carrying</i>			4 - 8 = -4	
For further calculation, the following frequency, duration and distance points are used:					
Duration points	6	5	4	0	15

Table A.22 — Example 2 of MMH index calculation

19	(Load + posture + (condition points)) × duration points	Repositioning (I)	(4 + 4)	= 48	Holding (I)	(2 + 4)	= 30	Carrying (I)	(2 + 2)	= 16	Pushing & Pulling (short I)	(+ +)	=	Pushing & Pulling (long I)	(1,5 + 1 + 1)	= 0
			× 6			× 5			× 4			× 0				

— Rule 3.3

In Pushing and Pulling, the gross weight to consider (weight of means of transport + weight of load)

EXAMPLE 5

The worker transports 4 wheels (30 kg. each) located on a wooden pallet (25 kg.) with a pallet truck (80 kg.) - > gross weight: 225 kg.

— Rule 3.4

In the assessment of Carrying and Holding is already included the biomechanical load generated by the action of Get and Place the load (for restrictions see Rule 3.5). The posture points to be considered are the worst between Get and Place and Carrying/Holding.

EXAMPLE 6

Handling Method: Carrying

Posture points:

get: 1 Point

carrying 3 Points

place 3 Points

Calculation:

Average get and place = $(1 + 3) / 2 = 2$ Points

Worst situation between get and place and carrying:

Carrying with 3 posture Points. Posture points have to be assigned to this handling.

— Rule 3.5

If for Carrying or Holding, the posture conditions of Get and Place are extremely uncomfortable (weighted posture points ≥ 4), assess and add an additional Repositioning. In this case, the posture of the Carrying or the Holding is determined exclusively on the carrying or holding phase (excluding the posture points of Get and Place).

EXAMPLE 7

Handling Method: Carrying

Posture points:

get 4 Points

carrying 1 Point

place 8 Points

Calculation: Posture points for Get and Place: $(4 + 8) / 2 = 6$ Points ≥ 4 Points -> Rule 3.5

Evaluation of one handling method "Carrying" with 1 posture point

+

Evaluation of one handling method "Repositioning" with 6 posture points.

EXAMPLE 8

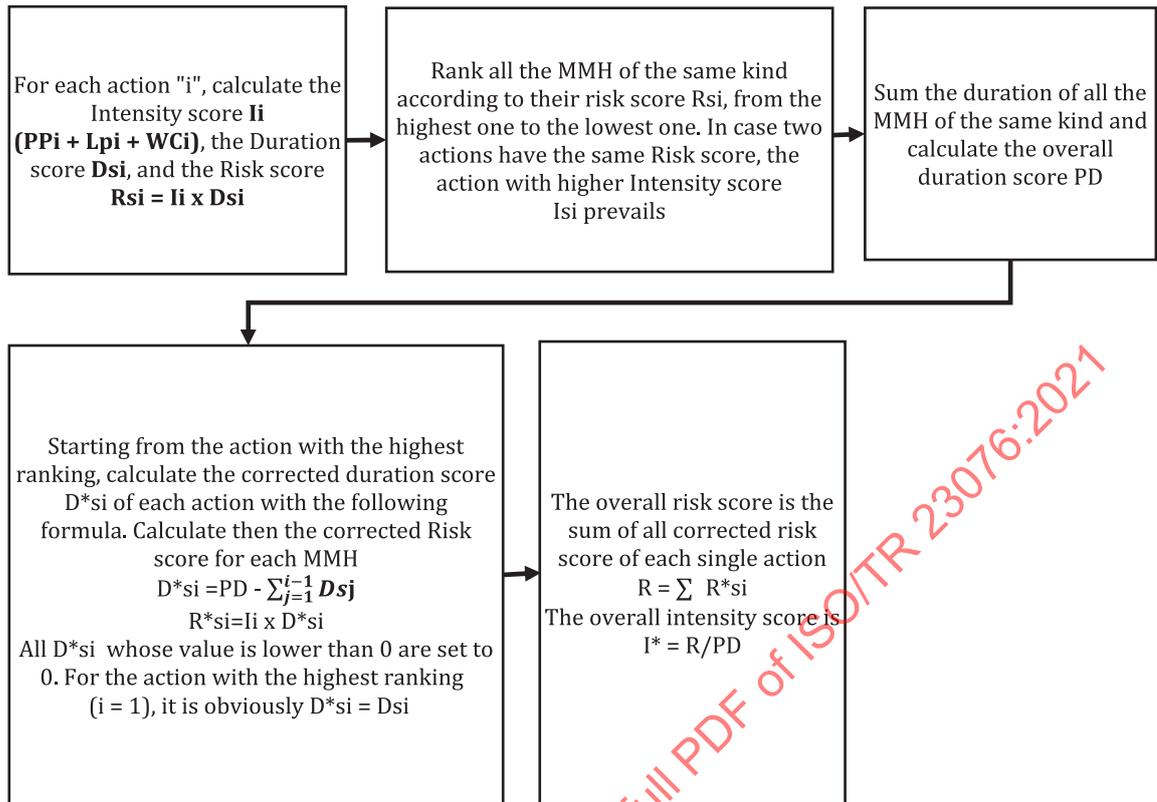
In case of multiple handling methods (e.g. Repositioning), it is necessary to calculate a unique score of each method. Total score of Section 3 is the sum of the scores of each method.

— Rule 3.6

In case of multiple handling methods (e.g. Repositioning and Carrying), it is necessary to calculate a unique score of each method. Total score of Section 3 is the sum of the scores of each method.

— Rule 3.7

In case of different loads handled with the same method (e.g. Repositioning), it is necessary to calculate the score of each load and subsequently to calculate the total score. To define the overall risk score (see [Figure A.29](#)), all the actions will be ranked according to their Risk score, from the highest to the lowest, and the duration points will be corrected starting from those actions with the highest ranking, following the step described below.



Key

- PD duration points
- PP posture points
- LP load points
- D*s corrected duration points
- Ii risk score activity "i"
- Rsi risk score activity "i"

Figure A.29 — Process flow of Rule 3.7

Calculation Steps of rule 3.7:

- 1) Score Calculation of Load 1 (L1)
 - 1.1 Calculation of Posture Points (PP₁)
 - 1.2 Calculation of Load Points (LP₁)
 - 1.3 If Pushing and Pulling, calculation of Working Conditions Points (WC₁)
 - 1.4 Calculation of Intensity Points (I₁ = PP₁ + LP₁ + WC₁)
 - 1.5 Calculation of Duration Points (DP₁)
 - 1.6 Calculation of Score L1 (RS₁ = I₁ x DP₁)
- 2) Score Calculation of Load 2 (L2)
 - 2.1 Calculation of Posture Points (PP₂)
 - 2.2 Calculation of Load Points (LP₂)
 - 2.3 If Pushing and Pulling, calculation of Working Conditions Points (WC₂)

2.4 Calculation of Intensity Points ($I_2 = PP_2 + LP_2 + WC_2$)

2.5 Calculation of Duration Points (DP_2)

2.6 Calculation of Score L2 ($RS_2 = I_2 \times DP_2$)

3) Score Calculation of Load 'n' (Ln)

3.1 Calculation of Posture Points (PP_n)

3.2 Calculation of Load Points (LP_n)

3.3 If Pushing and Pulling, calculation of Working Conditions Points (WC_n)

3.4 Calculation of Intensity Points ($I_n = PP_n + LP_n + WC_n$)

3.5 Calculation of Duration Points (DP_n)

3.6 Calculation of Score Ln ($RS_n = I_n \times DP_n$)

4) Calculation of the corrected scores

4.1 Rank all the MMH activities of the same type, according to their risk score RS_i , from the highest one to the lowest one. In case two actions have the same Risk score, the action with higher Intensity score $I_i = (PP_i + LP_i + WC_i)$ prevails

4.2 Sum the duration of MMH activities of the same type and calculate the overall duration score PD

4.3 Calculate the corrected duration score D^*s_i of each action with the following formula: $D^*s_i = PD - \sum_{j=1}^{i-1} Ds_j$.

All D^*s_i whose value is lower than 0 are set to 0. For the action with the highest ranking ($i = 1$), it is obviously $D^*s_i = Ds_i$.

5) Calculation of the overall risk score

5.1 Calculation of the corrected risk score of each MMH activity $R^*s_i = I_i \times D^*s_i$

5.2 Calculation of the overall risk score as the sum of all corrected risk score of each single action $R = \sum R^*s_i$

5.3 Calculation of the overall intensity score for the specific kind of MMH $I^* = (PP^* + LP^* + WC^*) = R/PD$

Remark: Working conditions points (WC_i) are considered in Pushing&Pulling only.

RS_i = Score of the single tasks.

EXAMPLE 9

Place the part R1 (weight 25 kg) 700 times per shift with 1 posture point. Then, place the part R2 (weight 3 kg) 700 times per shift with 1 posture point. Male worker.

Solution:

- a) R1: Posture Points: 1 point / Load Points: 4 Points;
- b) Intensity Points: $4 + 1 = 5$ Points;
- c) Duration Points: 7,8 Points;
- d) Total score R1: 38,8 Points - > Worst Case (Highest Risk Score);
- e) R2: Posture Points: 1 Point / Load Points: 1 Point;
- f) Intensity Points: $1 + 1 = 2$ Points;

- g) Duration Points: 7,8 Points;
- h) Total score R2: 15,5 Points;
- i) R_{tot} → Rank the intensity score of each activity and calculate the corrected duration point, then obtain the Total risk score.

Total Duration points: 10,8 pt (interpolation)

Ranking 1

- Intensity: 5 pt
- Corrected duration point: $D*s_1 = Ds_1 = 7,8$
- Total Risk Score: $5*7,8 = 38,8$

Ranking 2

- Intensity: 2 pt
- Corrected duration point: $D*s_2 = PDD-Ds_1 = 3$
- Total Risk Score: $2*3 = 6$

Total Risk Score: 44,8 points

Section 3 duration calculation if shift is longer than 8 hours or is less than 7 hours.

If Rule G9 applies, duration calculation can be prorated to 450 minutes. Use of Section 2 to assess push and pulling of transport means:

- a) Line 18 in Section 2 assess Push and Pulling tasks, if applied force levels are known (or models and references are available for calculation) and frequency is considered relevant.
- b) Specific force measurements from the shop floor are needed to properly assess Push and Pulling tasks in Section 2.
- c) In this case, to evaluate a dynamic force to overcome initial inertia and a static force (only if ≥ 4 seconds) during the movement. Actual exerted efforts have to be used to assign force intensity levels.
- d) The use of sub-Section “Push & Pulling” in Section 3 (line 19) is normally used if operative conditions are not known (e.g. in planning phase).
- e) The use of Section 2 for the evaluation of push and pull tasks in manual materials handling is preferred to Section 3, if the requirements are fulfilled. Section 2 offers more realistic results. Section 3 always leads to high scores, as the operative conditions are not known and are estimated very conservatively.
- f) Please ensure that the initial forces (to overcome inertia) do not exceed the corresponding F_{max} values.

EXAMPLE 10

In a work task of 3 minutes (observation):

Push a trolley 9 times for 10 meters. The trolley requires 210 N of force at the beginning of the movement and 79 N of continuous effort are needed to keep the trolley in motion.

Solution:

- One Dynamic action: 210 N, posture type: Standing upright, force direction -B

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- Seconds of Static action: 79 N, Standing upright, -B
- Dynamic
- Intensity score calculation:
- F_{max} (Standing upright; -B) = 315 N \rightarrow $\% F_{max} = 210 \text{ N} / 315 \text{ N} = 66 \% F_{max} \rightarrow$ Intensity points = 25 Points
- Duration score calculation:
- Frequency 3 times/minute \rightarrow Duration points = 2 Points
- Static
- Intensity score calculation:
- F_{max} (STU; -B) = 315 N \rightarrow $\% F_{max} = 79 \text{ N} / 315 \text{ N} = 25 \% F_{max} \rightarrow$ Intensity points = 3 Points
- Duration score calculation:
- 27 s/minute \rightarrow Duration points = 7,2 Points
- P&P Section 2 Score
- $R = I \times D \rightarrow I = (25 \times 2 + 3 \times 7,2) / 9,2 = 7,8 \rightarrow$ Score R = $7,8 \times 9,2 = 71,7$ Points
- Example Section 3

EXAMPLE 11

A load of 10 kg is manipulated by a man, 375 times per shift:

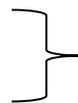
- Operation 1: Repositioning load from storage rack (height 160 cm) to a table (height 90 cm);
- Operation 2: After measuring, reposition load to floor. Due to uncomfortable conditions, it is necessary to bend forward and place the load away from the body with a significant trunk rotation.

Solution (see [Figure A.30](#)):

O₁: Posture Points: 3 Points (4 Points at get; 2 Points at place) / Load Points: 1,5 Points (10 kg, man)

Intensity Points: 3 + 1,5 = 4,5 Points

Duration Points: 375 times/shift = 6,1 Points



Total score **R1: 27,5 Points**

O₂: Posture Points: 5 Points (2 Points at get; 8 Points at place) / Load Points: 1,5 Points (10 kg, man)

Intensity Points: 5 + 1,5 = 6,5 Points

Duration Points: 375 times/shift = 6,1 Points



Total score **R2: 39,7 Points - > Worst Case**

Total Duration points: 8 pt.

Ranking 1

- Intensity: 6,5pt.
- Corrected duration point: $D*s_1 = Ds_1 = 6,1$
- Total Risk Score: $6,5*6,1 = 39,7$

Ranking 2

- Intensity: 4,5 pt.
- Corrected duration point: $D*s_2 = PDD-Ds_1 = 1,9$
- Total risk score: $4,5*1,9 = 8,55$

Total Risk Score: 48,25 points

Weights of loads [kg] for repositioning (lifting / lowering), carrying and holding as well as pushing and pulling															
+	Reposition, carrying & holding		Males	3	10	15	20	25	30	35	40	>40			
			Females	2	5	7	10	12	15	20	25	>25			
	Load points			1	1,5		3	4	5,5	7	8,5	25			
	Pushing and pulling	M1	Wheelbarrows and Dollies		01; 02		<50	75	100	150	200	250			
		M2	Carriage, roller, trolleys. No fixed rollers	Males	<50	75	100	150	250	350	550				
				Females	<40	60	80	115	195	270	425				
	M3	Carts, roller conveyors, pallet truck	Males	<50	75	150	250	350	500	600	800	1250			
			Females	<40	60	115	195	270	385	460	615	960			
	Load points						0,5	1	1,5	2	3	5	6	8	
	Means of transport														
Posture, position of load (select characteristic posture)															
+				little trunk bending or twisting; load at or close to the body				bending trunk deep or far forward; little trunk bending forward and trunk twisting simultaneously; load far from the body; limited postural stability while							
	Posture points			1	2	4	8								
Working Conditions (pushing and pulling only)															
(+)	very low rolling resistance		trolley pushing / pulling on (very) slick floor	rough floor and above small gaps / edges	on structured sheet metal, into / out of a track	trolleys have to be teared off when starting, strongly damaged floor		very high rolling resistance							
	Conditions points		0	1	3	5	6	8							
Frequency of load manipulations [frequency/shift], holding time [min/shift] or travel distance [meter/shift]															
x	Frequency (#) of repositionings / pushing & pulling short				5	25	120	350	700	1000	1500	2000	2500	3000	
	Duration (holding time) [min]				2,5	10	37	90	180	≥240					
	Distance (carrying, pushing & pulling long) [m]				300	650	2500	6000	12000	≥16000					
	Duration points					2	4	6	8	1	11	13	14	15	
Manual Material Handling (result)															
19	(Load + posture + (condition points))		Repositioning (1)	(1,5 + 4,53)	Holding (1)	() + ()	Carrying (1)	() + ()	Pushing & Pulling short (1)	() + ()	Pushing & Pulling long (1)	() + ()	() + ()		
	x duration points		x 8	= 48,3	x	x	=	x	=	x	=	x	=		
Handling = ∑ line 19				1) Maximal cumulative duration points for all tasks of repositioning, holding, carrying as well as pushing & pulling all together = 15				=				48,5			

Key

- 01 operation 1
- 02 operation 2

Figure A.30 — Score, Example 1

A.2.7 Scoring: Section 4 – Upper Limb Load in Repetitive Tasks

Section 4 addresses the effects of repetitive manual activities on the upper limbs, which originate from high frequency manipulation of objects or application of machines and devices.

- Upper Limb

Upper Limb includes the shoulder belt (scapula and collarbone), as well as, the free upper limb – the arm. The arm is made up of the upper arm, the elbow, the forearm and the hand, including wrist, metacarpus and fingers.

- Influencing Factors:

- Action Frequency

- Dynamic actions: frequency (real actions/minute)

- Static actions: duration (seconds/minutes holding a static position)
- Force level
- Type of grip (posture of the fingers)
- Posture of the wrist, elbow and the shoulder
- Additional risk factors
- Duration:
 - Shift duration (net time with repetitive tasks)
 - Number of breaks
 - Work organization (man-machine type of relation)

NOTE 1 Section 4 measures the load generated by repetitive tasks on the upper limbs.

NOTE 2 Section 4 overlaps the previous 3 sections and considers several load factors, which have already been accounted for in Sections 1, 2 and 3.

NOTE 3 Section 4 treats every extremity by itself (left and right). Only the most heavily loaded hand is evaluated.

— The score of Section 4 is calculated as follows:

— LINE 20a

Assess the most critical limb (left or right) considering the frequency of the actions and the force levels (in case of doubts, analyse both arms). Considering the selected arm:

- Identify and count the dynamic actions
- Identify, measure the duration and prorated all static actions to a 60 s. cycle
- Estimate the force level of each action
- Classify the type of grip of each action
- Calculate FFG sub-score (Force-Frequency-Grip) following the process calculation illustrated in [Figure A.34](#)
- LINE 20b
 - Determine awkward postures of wrist, elbow and shoulder in each dynamic and static action
 - Find the posture points for the three components of the upper limbs: wrist, elbow and shoulder = PP
- LINE 20c
 - Determine specific conditions which cause extra load situations
 - Assign the points due to additional factors = AF
- LINE 20d
 - Calculate the net-working time utilized for repetitive work
 - Select the break point scale, based on the cycle time duration (\leq or $>$ 30 s)
 - Determine the break points, based on the total number of breaks

- Determine the work organization points
- Calculate the duration points = DP

Determine the total risk score for the upper limbs in Section 4 (see [Table A.23](#) and [Figure A.31](#)) using the formula (intensity × duration):

$$UL = (FFG + PP + AF) \times DP$$

Table A.23 — Table of Abbreviations, Sec. 4

Abbreviation	Key
FFG	Force-Frequency-Grip
PP	Posture points
AF	Additional factors
DP	Durations points
UL	Upper limbs

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EXAMPLE 1

- Get a jumbled screw from a container and insert it into a threaded hole (MTM-UAS building block: AF.) →1 RA
- Manual fastening (turn-in): (MTM-UAS building block ZA1 or ZB1) →1 RA/screw cycle
- Get a clip and insert it with pressure into a hole (MTM-UAS building block A..) → 1 RA
- Get a screwdriver, place it onto a screw and aside it after fastening cycles (MTM-UAS building block H..) →2 RA (fastening not considered)

a) How to determine the number of Real Actions in a manual working activity

The manual working activity is a cycle where the operations execution time is completely under the operator control, so that it can be analysed with any MTM building block systems.

The determination of the real actions in the planning phase it's important the link with MTM building blocks, while in the production phase both a link with MTM, as well as, the observation of the working process are suitable.

In the design phase – link with MTM:

In the MTM analysis, determine the number of RA using a table describing basic MTM motions and RA. The following MTM-UAS table (see [Table A.24](#)) has been made available by the International MTM Directorate:

Table A.24 — MTM-UAS table linked with real actions

MTM-UAS	Description	RA
A	Get and Place	1
P	Place	1
H	Get, place and aside tool	2
EH	Get and aside tool	1
ZA	One motion	1
ZB	Motion sequences, e.g. a screw cycle	
ZD	Tighten or loosen	
ZC	Reposition a tool + 1 motion	2
B	Operate (lever, buttons ...)	1
K	Body motions	0
VA	Visual control	0

NOTE 1 EH is used when using any standard operation building block.

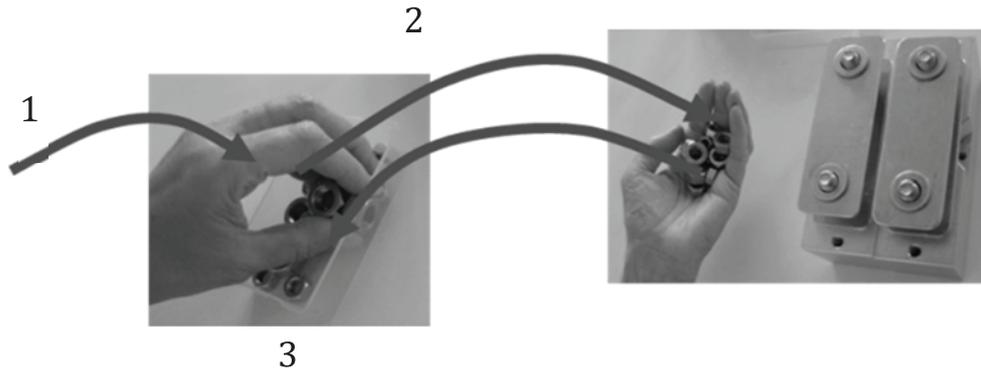
NOTE 2 ZA1, ZB1, BA1 – When the frequency of these motions is > 3 and they are performed consecutively, their MTM-UAS codes are be converted to Real Actions by applying a 0,5 factor to the frequency in excess of the original 3.

EXAMPLE 2 (see [Table A.25](#) and [Figure A.32](#)):

- Turn in a screw with a screwdriver: ZA1, ZB1 × 2 → 3 RA
- Clean the surface of a machine table with cloth: 20 × ZB1 → 3 + $\frac{17}{2}$ = 11,5 RA

EXAMPLE 3

Real Action identification:



- Key**
- 1 nuts
 - 2 within the work area
 - 3 remaining nuts aside

Figure A.32 — Example of Real Action

Table A.25 — Example of counting Real Actions

Description	UAS-Code	TMU	A × H	Real Actions		TMU
				LH	RH	
Nuts in work area	AG2	65	1 × 1	1		65
Place 4 nuts	AF1	40	4 × 1		4	160
Fasten 4 nuts	ZB1	10	4 × 4		14	160
aside nuts	PA2	20	1 × 1	1		20
			Σ	2	18	385

Explaining the determination of the Real Actions:

To understand the counting of the Real Actions in the example, it is useful to look at the sequence of consecutive movements: the MTM-UAS analysis includes 4 ZB1 to screw a nut, corresponding to 3,5 Real Actions. This sequence is then repeated for each nut (4), thus the final number of Real Actions is $3,5 \times 4 = 14$.

NOTE In the direct observation: identify the Real Actions with the help of the definitions (in general every assembled component generates at least one Real Action).

This task is easier if the ergonomic analyst is also a certified MTM analyst.

b) How to determine Real Action quantities in a partially manual working activity

A partially manual work activity is a cycle where the execution time is NOT completely under the operator’s control and therefore, the analysed with MTM systems is not possible (MTM is used only with human work).

A typical example is in painting and sealing processes, where the execution speed is limited by the paint or seal supply process. In this case, it is necessary to identify and count the number of real actions based on direct observation, and to define the standard method to be used during the design phase. This approach is well known by Industrial Engineers, as used in projects to build standard operation blocks.

c) Comparison between OCRA Technical Actions and EAWS Real Actions

Compared to OCRA, which is the main reference for Section 4, the EAWS developers made the choice to define the Real Actions instead of using the OCRA Technical Actions. The reasons for this choice were for the sake of simplicity and the desire to limit applicator deviation.

It is easier to observe complete movements with an average duration of 1,5 seconds than detect micro-movements with duration of some tenths of a second (a "Regrasp" has a value of 0,2 second according to the MTM-1 Data Card).

The scoring system of EAWS Section 4 was established in such a way to insure a strong correlation with the OCRA Index system. Given that the expected ratio between Real Actions and Technical Actions is within the range 1,6-1,8 (if the sample size is sufficiently large and unbiased – see publication at <https://www.fondazionergo.it/upload/press/IL-EAWS4-OCRA-correlation-for-upper-limbs-load-risk-score-evaluation.pdf>), the upper frequency limit of technical actions considered in the OCRA INDEX system (70) can be compared to the maximum value of Real Action frequency used in EAWS (40).

The choice to use Real Actions was also driven by the fact that the typical field of application in which EAWS is applied involves manufacturing industries (e.g. automotive, electro-mechanical, machining, appliances), where the work design is traditionally managed MTM Systems where work content is very close or identical to the RA definition. Other sectors, such as the food and textile industries typically present extremely short and highly repetitive motions, where using RA runs the risk of not being representative. For those who know the MTM systems, MTM-UAS Basic Operations fit with the RA and the MTM-2 Motion Sequences fit with the Technical Actions (TA).

By applying EAWS, the user does not have to be concerned with this design choice, since in Section 4, the calculation algorithms are designed to use as input the number of RA. Therefore, the measurement of the biomechanical load is absolutely comparable with the OCRA INDEX system, which utilizes Technical Actions input into a different set of calculation algorithms (i.e. two cars running, respectively, at a speed of 100 miles/hour and 160 km/hour would cover the same distance in the same time).

— LINE 20a: Calculating FFG (Force, Frequency, Grip)

a) Introduction and base concepts:

The FFG Score (Force-Frequency-Grip) is the core of Section 4 and it is also the most complex part of the calculation procedure, especially when static and dynamic actions with different force levels and different types of grips coexist in the same cycle. Calculate further by the following four steps.

The first step is to select the most loaded upper limb, as the analysis is made for an individual upper limb. If it is difficult to decide which upper limb is the most loaded, count the real actions of both arms. They are normally the determining factor to find the most stressed upper limb. However, also consider forces, postures, grip modes and the other factors. Therefore, analyse both upper limbs, when the number of actions is well distributed between the upper limbs.

When the objective of the analysis is to identify ergonomic issues and redesign the method to minimize such issues, both upper limbs are to be analysed, regardless which is the most loaded. If the objective of the analysis is to determine the ergonomic risk factor (ERGO-MTM system), the score associated with the most loaded limb would be enough.

The second step is to identify and count the Real Actions. This is important to determine the frequency of actions (Real Actions/minute), which is the leading risk factor affecting Section 4.

Static actions are actions lasting longer than 4 seconds. These are not very frequent in highly repetitive tasks. If any static action exists, take this into account together with dynamic actions following the FFG scoring rules.

The third step is to measure or assess the force level implied for each identified RA.

NOTE In the case of material or tool handling, the force applied by each limb is approximately equal to the object or tool weight divided by the number of limbs used to move it (i.e. 2 kg box with 2 hands -> applied force by each limb = 1 kg = 10 N).

Then, for each identified RA, determine the type of grip.

The final step is to calculate the weighted average of the Force-Frequency-Grip points for each force level for both static and dynamic actions and obtain the total FFG score.

b) Grip types and grip points:

Depending on the force level, the grip points assume different values for the same type of grip. The same type of grip, at the same force level, generate a different score depending on the comfort of the grip (e.g. in force level 2, grip b: comfortable = 0 points; not comfortable = 2 points; medium = 1 point), see for example [Figure A.33](#).

Force & Frequency & Grip (FFG)		Basis: number of real actions per minute or percent static actions (analyze only the most loaded limb)																								
	Legend	%SA = Percentage of Static Actions										%DA = 100% - %SA														
		FDS = Force-Duration Static										FFD = Force-Frequency Dynamic														
		GS' = Modified Grip Points Static (Grip x %SA)										GD = Grip Points Dynamic														
		%FLS = Percentage of Static Actions at force level										%FLD = Percentage of Dynamic Actions at force level														
		SC = Static Contribution										DC = Dynamic Contribution														
		FDGS = Sum of Static Contributions										FFGD = Sum of Dynamic Contributions														
Force [N]	Calc Stat				Static actions (s/min)							Grip				Dynamic actions (real actions/min)							Calc Dyn			
	FDS	GS'	%FLS	SC	≥45	30	20	10	5	3	0	2	4	2-5	10	15	20	25	30	35	≥40	FFD	GD	%FLD	DC	
0 – 5					1	1	0	0	0	0	abc			0	0	0	1	2	3	4	7					
> 5 – 20					4	2	1	1	0	0	ab	bc		0	0	1	2	3	4	6	9					
> 20 – 35					7	5	3	2	1	1	ab	b	c	0	1	2	3	4	6	8	12					
> 35 – 90					11	8	5	3	2	1	a	b	b	1	2	3	5	7	9	12	18					
> 90 – 135					16	11	7	4	3	2	a	ab	b	2	3	5	7	9	12	15	24					
> 135 – 225					21	14	10	6	4	3	a	a	b	4	5	6	8	11	14	20	32					
> 225 – 300					28	18	12	8	5	4	a	a	b	5	6	7	9	12	16	26	40					

NOTE 1 In the development of the model, different grip types were put together, for the sake of simplicity. Use the grip type which is closest to reality.

NOTE 2 See [Figure A.63](#) for detail

Figure A.33 — Grip points

The comfort of the grip depends on the dimension of the contact area between the finger/fingers and the object. The larger the dimensions of the contact area the more comfortable is the applied grip (think about the comfort while inserting a thin pin in a narrow hole with one finger; it is much better when the pin has a flat and wide head).

EXAMPLE 4

Plug in connectors - Depending on the size of the plug and the accessibility of the joint, grip conditions may be good, average or poor.

To reduce the application deviation in the choice of grasp ergonomic points, we recommend the use of the [Table A.26](#), where the values are set using an average grasp comfort level:

Table A.26 — Table for grip points

Force level	Recommended grip points (0 - 2 - 4)			Grip		
	a	b	c	0	2	4
1	0	0	0	abc		
2	0	1	2	ab	bc	
3	0	1	4	ab	b	c
4	0	3	-	a	b	b
5	1	3	-	a	ab	b
6	1	4	-	a	a	b
7	1	4	-	a	b	b

Type of grip a – Power grip or contact grip

Type of grip b – Finger press or light pinch:

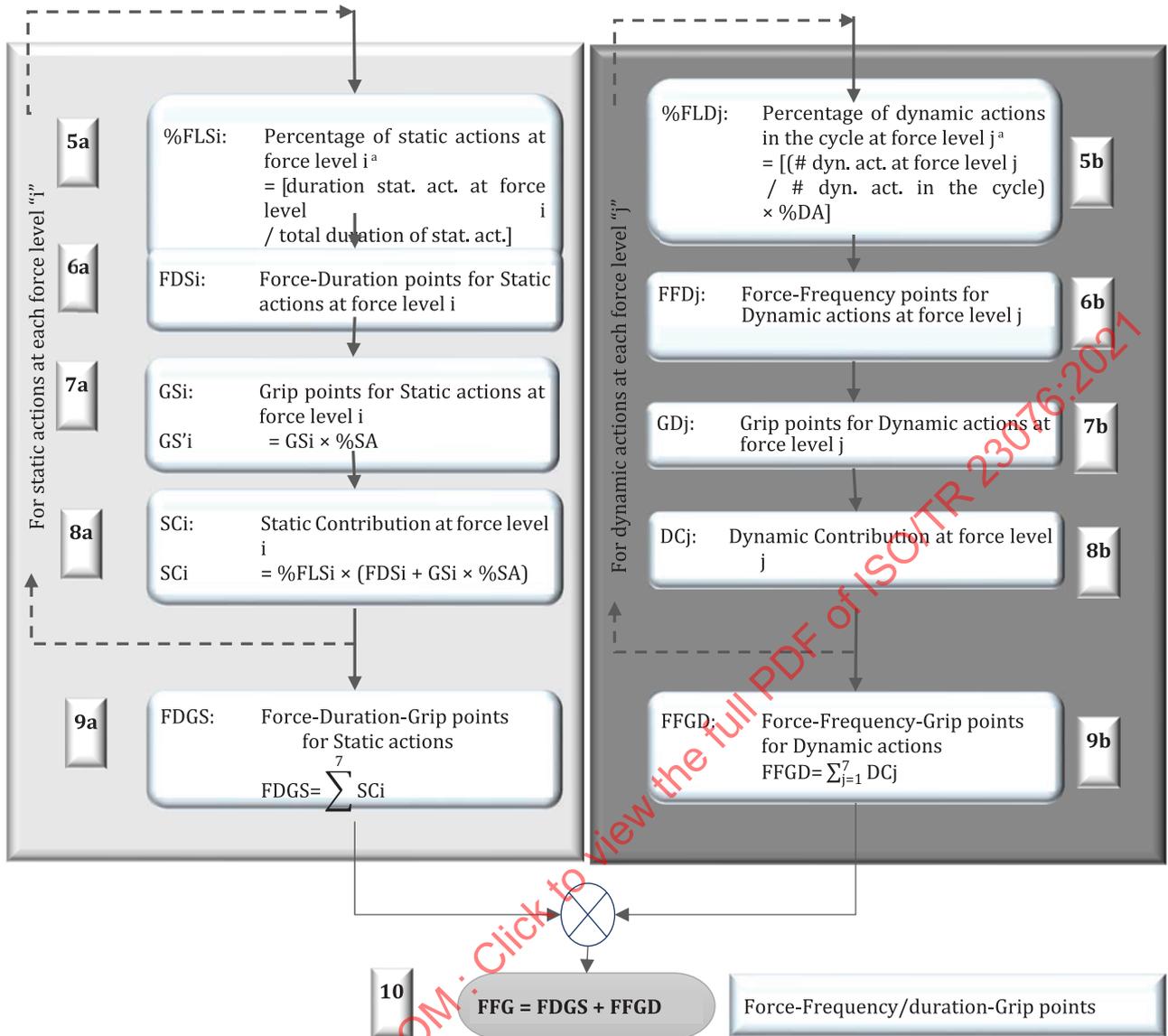
- thumb to > 2 fingers or thumb to 2 fingers with object larger than 3 mm × 3 mm × 3 mm
- pressure executed by finger

Type of grip c – Strong pinch: thumb to 1 finger or thumb to 2 fingers with object smaller than 3 mm × 3 mm × 3 mm; hook or palmar grip. In general, case c covers situations where the grip operation needs the use of the last phalanx.

The standardization of the grip points assigned to each combination of “type of grip-force level” introduces a small system deviation counterbalanced by a reduction of the applicator deviation (i.e. two analysts that use the same system get different results). Applicator deviation is not tolerated by companies and unions because it reduces the credibility of a system. In our long experience in designing MTM systems, we learned to benefit, within reasonable and controlled limits, from a limited applicator deviation at the expense of a larger system deviation.

c) Step by step FFG calculation

The flow chart [Figure A.34](#) shows the step by step the calculation process of the FFG:



NOTE (*) $\sum_{i=1}^7 FLSi = 100\%$ and $\sum_{j=1}^7 FLDj = \% DA$

Figure A.34 — FFG calculation procedure

Elements to calculate the FFG-points (see Table A.27):

Table A.27 — Table of Abbreviations to calculate FFG in Sec. 4

Abbreviation	Key
%SA	% Static Actions
%DA	% Dynamic Actions
DSA	Duration Static Actions
FDA	Frequency Dynamic Actions
%FLSi	% Force Level for Static Actions @ Force Level i
%FLDj	% Force Level for Dynamic Actions @ Force Level j
FDSi	Force-Duration points for Static Actions @ Force Level i

Table A.27 (continued)

Abbreviation	Key
FFDj	Force-Frequency points for D ynamic Actions @ Force Level j
GSi	Grip points for S tatic Actions @ Force Level i
GS'i	Grip points for Static Actions with % Static Actions @ Force Level i
GDj	Grip points for D ynamic Actions @ Force Level j
SCi	Static Contribution @ Force Level i
DCj	D ynamic Contribution @ Force Level j
FDGS	Force- D uration- G rip points for S tatic Actions
FFGD	Force- F requency- G rip points for D ynamic Actions
FFG	Force-Frequency/duration- G rip points
#	Frequency

EXAMPLE 5

In a working cycle using both hands ($T_c = 90$ s):

- a) Take one screw with the right hand and one with the left (both for 2 times);
- b) 3 actions for inserting screws with the right hand and with the left hand (2 times);
- c) Get electric screwdriver (2 Kg), place onto 4 screws and put it back (right hand);
- d) Tighten 4 screws (process time = 5 s each, right hand, force = 30 N);
- e) Get 4 plastic caps and apply them on the screws with pressure (right hand, force = 30 N);
- f) Push button to start the process cycle, hold button for 5 s (right hand, force = 25 N)

1

Force & Frequency & Grip (FFG)		Basis: number of real actions per minute or percent static actions (analyze only the most loaded limb)														
Legend	a	%SA = Percentage of Static Actions							%DA = 100% - %SA							
	b	FDS = Force-Duration Static							FFD = Force-Frequency Dynamic							
	c	GS' = Modified Grip Points Static (Grip x %SA)							GD = Grip Points Dynamic							
	%FLS = Percentage of Static Actions at force level							%FLD = Percentage of Dynamic Actions at force level								
	SC = Static Contribution							DC = Dynamic Contribution								
	FDGS = Sum of Static Contributions							FFGD = Sum of Dynamic Contributions								
		2	3													

Force [N]	Calc Stat				Static actions (s/min)					Grip			Dynamic actions (real actions/min)								Calc Dyn					
	FDS	GS'	%FLS	SC	≥45	30	20	10	5	3	0	2	4	2-5	10	15	20	25	30	35	≥40	FFD	GD	%FLD	DC	
0 – 5					1	1	0	0	0	0	abc			0	0	0	1	2	3	4	7					
> 5 – 20					4	2	1	1	0	0	ab	bc		0	0	1	2	3	4	6	9					
> 20 – 35					7	5	3	2	1	1	ab	b	c	0	1	2	3	4	6	8	12					
> 35 – 90					11	8	5	3	2	1	a	b	b	1	2	3	5	7	9	12	18					
> 90 – 135					16	11	7	4	3	2	a	ab	b	2	3	5	7	9	12	15	24					
> 135 – 225					21	14	10	6	4	3	a	a	b	4	5	6	8	11	14	20	32					
> 225 – 300					28	18	12	8	5	4	a	a	b	5	6	7	9	12	16	26	40					
20a	FDGS = ∑ SC _i				FFG = FDGS + FFGD										%DA = ∑ FLD _j				FFGD = ∑ DC _j				%DA			

- Key**
- 1 duration / frequency
 - 2 force level
 - 3 FDS / FFD – points

Figure A.35 — FFG points

Steps to calculate the score of Section 4 (see [Figure A.35](#) – FFG points):

STEP 1:

Count the number of Real Actions performed by each upper limb. Use this information for a first determination of the most loaded upper limb (see [Table A.28](#) and example [Table A.29](#)):

Table A.28 — MTM-UAS-Analysis to define the most loaded upper limb

Nr.	Description	Code	TMU	Q × F	Real Actions		Sum	
					LH	RH	TMU	s
1	2 bolt to threaded hole	AF2	65	2 × 1	1	1	130	4,7
2	Interaction	AF1	40	2 × 1	1	1	80	2,9
3	Turn in bolt	ZB1	10	2 × 3	6	6	60	2,2
4	Screwdriver to first screw	HC2	70	1 × 1	0	2	70	2,5

Key:

Q × F quantity × frequency

TMU Time Measurement Unit - 1 TMU = 0,036 s

NOTE In our example, the right hand is dominant: 17 dynamic real actions

Table A.28 (continued)

Nr.	Description	Code	TMU	Q × F	Real Actions		Sum	
					LH	RH	TMU	s
5	to 2nd - 4th screw	PC1	30	3 × 1	0	3	90	3,2
6	Screw	PTSEC	28	4 × 5	0	0	560	20,0
7	Place the cap	AF2	65	4 × 1	0	4	260	9,4
8	operate the button	BA1	10	1 × 1	0	0	10	0,4
9	Hold the button	PTSEC	28	1 × 5	0	0	140	4,6
Real Actions					8	17		

Key:

Q × F quantity × frequency

TMU Time Measurement Unit - 1 TMU = 0,036 s

NOTE In our example, the right hand is dominant: 17 dynamic real actions

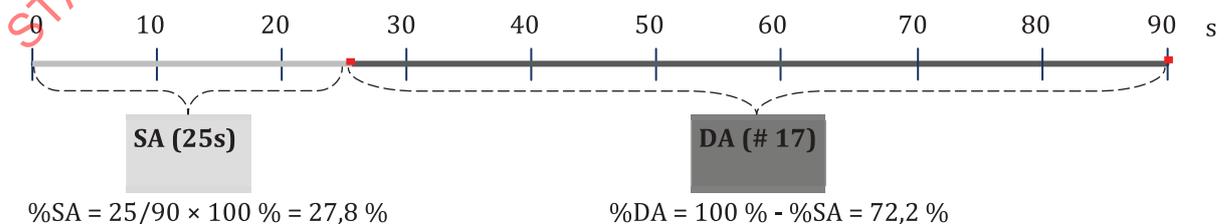
Table A.29 — Dominant upper limb example

Description		Right Hand			
		Duration [s]	Frequency [# RA]	F [N]	Grip
1..2	Bolt to threaded hole		2	3	c
3	Turn in bolt		6	3	c
4..5	Handling screwdriver		5	20	a
6	Fastening	20		30	a
7	Assembly caps		4	30	c
8..9	Push button	5		25	b
Σ#	Frequency of Dynamic Actions		17		
Σ s	Duration of Static Actions	25			

STEP 2:

Calculate the percentage of static actions (%SA) and dynamic actions (%DA) in the cycle according to the following definition and [Figure A.36](#):

- Static action: maintain the same hand/arm posture for at least 4 seconds consecutively
- The static actions percentage (%SA) is the part of the cycle covered by static actions only
- The dynamic actions percentage (%DA) is the part of the cycle not covered by static actions (%DA = 100 % - %SA)



Key

SA static actions

DA dynamic actions

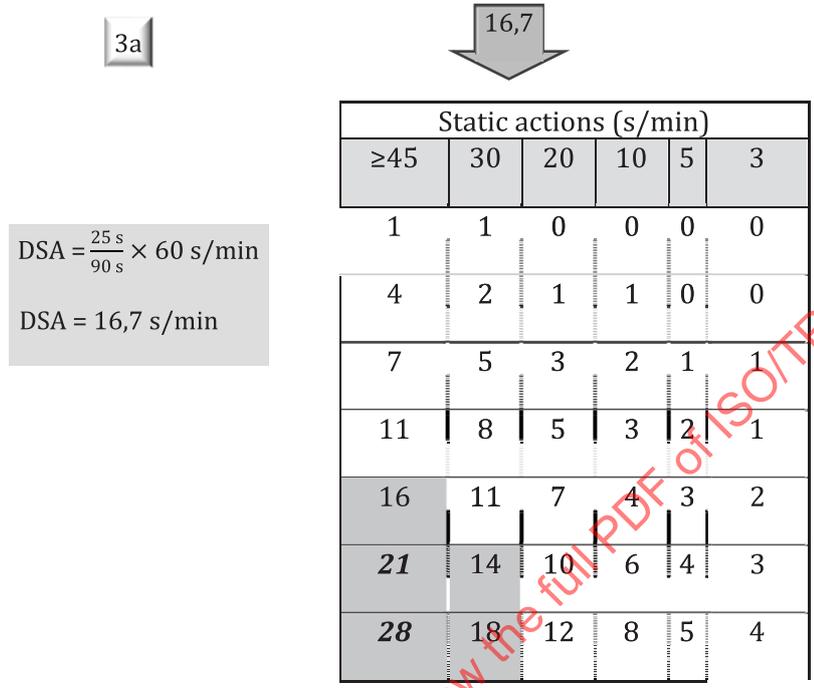
Figure A.36 — Percentage static and dynamic actions

STEP 3:

This step is different for dynamic and static actions.

Static actions:

Determine the duration of the static actions (Figure A.37).



NOTE 1

STEP 3a → DSA: Duration of Static Actions (s/min)

(duration of stat. actions [s.] /cycle time [s.] × 60 [s./min.])

$$DSA = \frac{\text{duration static action [s]}}{\text{cycle time [s]}} \times 60\text{ s./min.}$$

NOTE 2 The DSA-score in the “≥ 45 s duration column” is to be considered as a maximum value.

Figure A.37 — Determination of the duration of static actions

Dynamic actions:

Determine the frequency of the dynamic actions (Real Actions/minute based on the part of the cycle not covered by static actions). See Figure A.38.

3b



$$FDA = \frac{17 \text{ actions}}{(90 \text{ s} - 25 \text{ s})} \times 60 \frac{\text{s.}}{\text{min.}}$$

$$FDA = 15,7 \text{ actions/min}$$

Dynamic actions (real actions/min)							
2-5	10	15	20	25	30	35	≥40
0	0	0	1	2	3	4	7
0	0	1	2	3	4	6	9
0	1	2	3	4	6	8	12
1	2	3	5	7	9	12	18
2	3	5	7	9	12	15	24
4	5	6	8	11	14	20	32
5	6	7	9	12	16	26	40

NOTE 1

STEP 3b → FDA: Frequency of Dynamic Actions (real actions per min (# dyn. act. / (cycle time [s.] - static actions [s.]) × 60 [s./min.]])

$$FDA = \frac{\text{Sum \#actions}}{(\text{Cycle time [s]} - \text{static actions [s]})} \times 60 \text{ s./min.}$$

NOTE 2 FDA score in the “≥ 40 frequency column” is considered as a maximum value.

Figure A.38 — The frequency calculation of the dynamic actions

STEP 4:

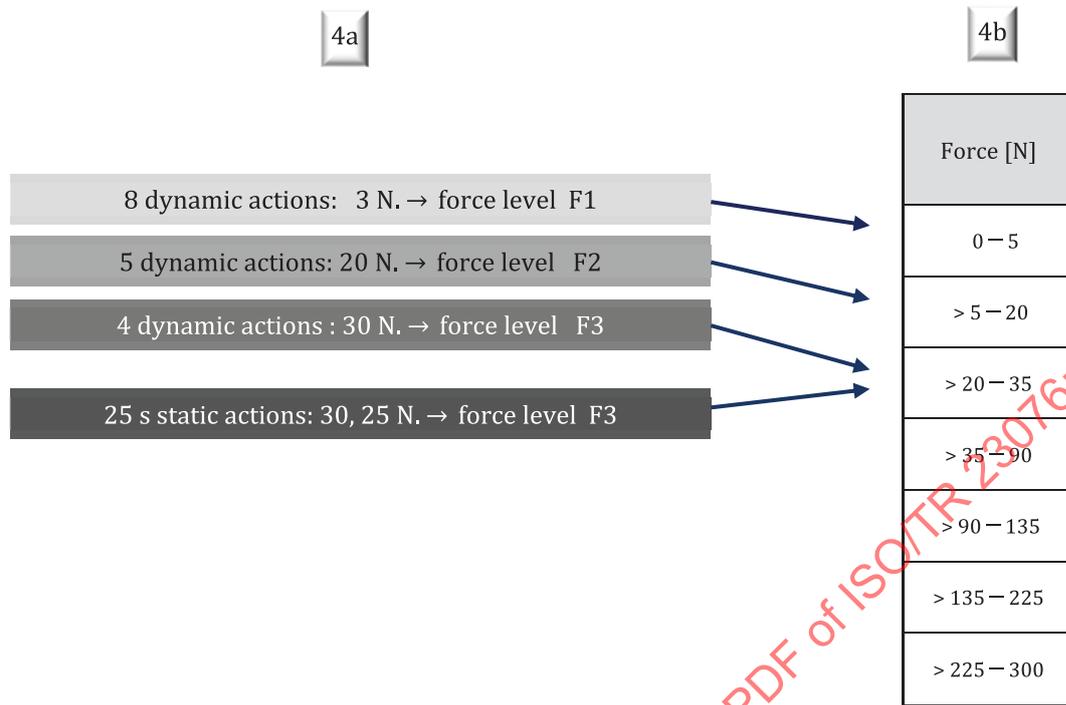
Estimate or measure the forces of each action, then group actions by force level and calculate the % of actions at each force level (total percentage of dynamic actions is exactly equal to the percentage of cycle time without static actions, if any).

Since it is hard to measure exactly the intensity of a force, we recommend working with ranges of intensity. In Section 4, there are seven different levels of intensity:

- Level 1: from 0 to 5 N. (0,0 kg. - 0,5 kg.)
- Level 2: > from 5 to 20 N. (> 0,5 kg. - 2,0 kg.)
- Level 3: > from 20 to 35 N. (> 2,0 kg. - 3,5 kg.)
- Level 4: > from 35 to 90 N. (> 3,5 kg. - 9,0 kg.)
- Level 5: > from 90 to 135 N. (> 9,0 kg. - 13,5 kg.)
- Level 6: > from 135 to 225 N. (> 13,5 kg. - 22,5 kg.)
- Level 7: > from 225 to 225 N. (> 22,5 kg. - 30,0 kg.)

It is possible to vertically interpolate the Force-Frequency score related to the force level pointed out. Vertical interpolation is useful to analyse values at the border of a force range.

Assignment of static and dynamic actions to the respective level of force as in [Figure A.39](#):



Key

STEP 4a → Find force level for the static actions (max. 7 force levels)

STEP 4b → Find force level for the dynamic actions (max. 7 force levels)

NOTE See [Figure A.63](#) for detail

Figure A.39 — Classification of dynamic and static actions to the respective force level

STEP 5:

Calculate the percentage (%) of actions for each force level. For the static actions (% FLS) the total percentage equals 100 %. For the dynamic actions (% FLD) the total percentage is to be equal % DA. See [Figure A.40](#)

If dynamic and static actions are involved, the frequencies utilized to select the Force-Frequency score (Step 3) are based just on the dynamic portion of the cycle, the %FLD (Force Level for Dynamic actions) smooth values by multiplying the scores by %DA, (otherwise FFGD would be overestimated). If we based the calculation of action frequency on the total cycle duration, we would under-estimate FFD score, since during the static portion of the cycle, there is a load generated by static actions (not a recovery period), which is to be compounded with the dynamic load.

5a

$$\sum_{i=1}^7 \text{FLSi} = 100 \%$$

$$\% \text{FLS}_3 : 25/25 = 100 \%$$

5b

$$\sum_{j=1}^7 \text{FLDj} = \% \text{DA}$$

$$\% \text{FLD}_1 : 8/17 \times 72,2 \% = 34,0 \%$$

$$\% \text{FLD}_2 : 5/17 \times 72,2 \% = 21,2 \%$$

$$\% \text{FLD}_3 : 4/17 \times 72,2 \% = 17,0 \%$$

72,2 %

Key

- STEP 5a → %FLSi: Percentage of static actions at force level i (*) = [duration stat. act. at force level i / total duration of stat. act.]
- STEP 5b → %FLDj: Percentage of dynamic actions in the cycle at force level j (*) = [(# dyn. act. at force level j / # dyn. act. in the cycle) × %DA]

Figure A.40 — Classification of each percentage of static and dynamic actions

STEP 6:

Find the FDS/FFD points for each force level at the intersection of the frequency/duration column and the force level line (see Figure A.41).

6a

DSA = 16,7 s/min

↓

6b

FDA = 15,7/min

↓

Force [N]	Calc Stat				Static actions (s/min)						Grip			Dynamic actions (real actions/min)								Calc Dyn				
	FDS	GS'	%FLS	SC	≥45	30	20	10	5	3	0	2	4	2-5	10	15	20	25	30	35	≥40	FFD	GD	%FLD	DC	
0 – 5					1	1	0	0	0	0	abc			0	0	0	1	2	3	4	7	0,1		34		
> 5 – 20					4	2	1	1	0	0	ab	bc		0	0	1	2	3	4	6	9	1,1		21,2		
> 20 – 35	2,7		100 %		7	5	3	2	1	1	ab	b	c	0	1	2	3	4	6	8	12	2,1		17,0		
> 35 – 90					11	8	5	3	2	1	a	b	b	1	2	3	5	7	9	12	18					
> 90 – 135					16	11	7	4	3	2	a	ab	b	2	3	5	7	9	12	15	24					
> 135 – 225					21	14	10	6	4	3	a	a	b	4	5	6	8	11	14	20	32					
> 225 – 300					28	18	12	8	5	4	a	a	b	5	6	7	9	12	16	26	40					
20a	FDGS = ∑ SC _i			100%	FFG = FDGS + FFGD						FFG			%DA = ∑ FLD _j								FFGD = ∑ DC _j				%DA

Key

- STEP 6a → FDSi: Force-Duration points for Static actions at force level i
- STEP 6b → FFDj: Force-Frequency points for Dynamic actions at force level j

NOTE See Figure A.63 for detail

Figure A.41 — Classification of Force-Frequency/duration points of static and dynamic actions

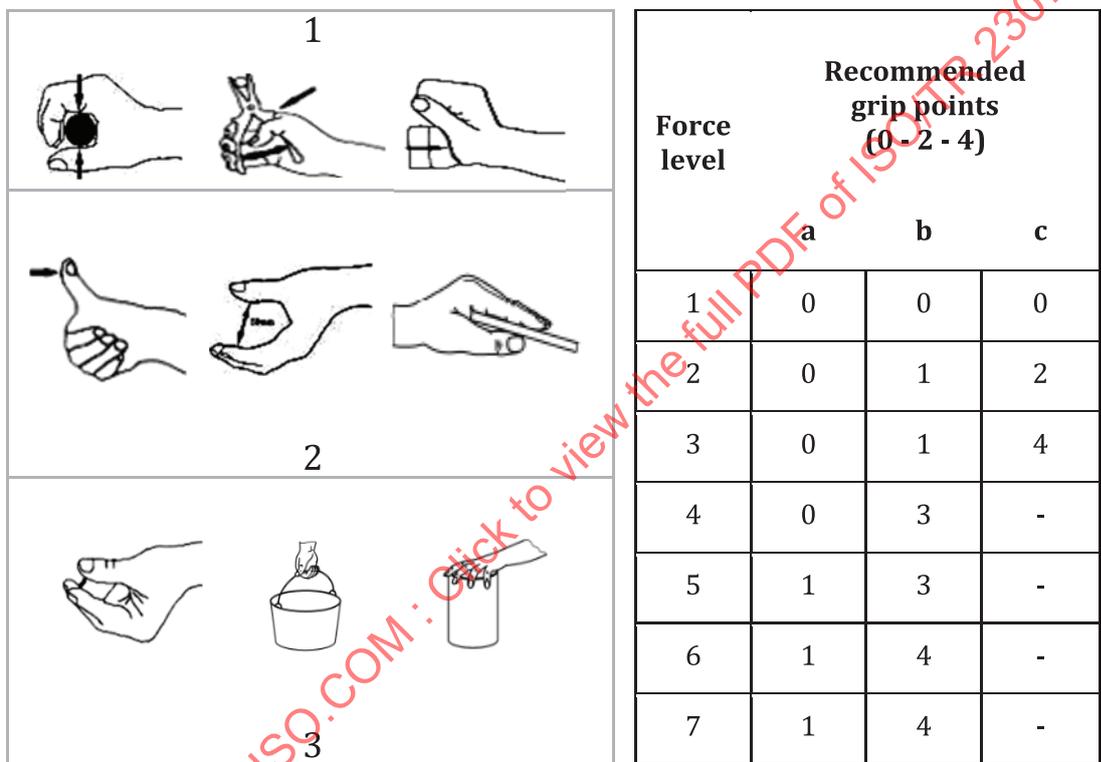
To determine the points: use the interpolation, e.g.

$$FDS3 = 2 + ((16,7 - 10) \times (\frac{3 - 2}{20 - 10})) = 2,7 \text{ Points}$$

STEP 7:

For each force level, it is necessary to determine the average grip mode and calculate a score (grip points). The average grip mode of a given force level j (GD_j/GS_j) is defined as the grip which generates a score corresponding to the weighted average of all the individual grip points, where the weights are the frequencies/durations of actions belonging to a given force level (see [Figure A.42](#), [Figure A.43](#) and [Figure A.44](#)).

With the aim of reducing the applicator deviation, the following grip points in the chart are recommended for each force level:



Key

- 1 power grip or contact grip
- 2 finger press or moderate pinch thumb to > 2 fingers or thumb to 2 fingers with object larger than 3 mm × 3 mm × 3 mm
- 3 strong pinch: thumb to 1 finger or thumb to 2 fingers with object smaller than 3 mm × 3 mm × 3 mm hook and palmar grip (use of the last phalanx)

Figure A.42 — Gripping examples and the recommended grip points, depending on the level of force

7a

Static Actions	s	Force level	Grip mode	Grip points (at force lv)
Fastening	20	3	a	0
Push button	5	3	b	1
Duration of static actions	25			

Average grip points at force level 3:

$$GS_3 = \frac{(20s \times 0) + (5s \times 1)}{20s + 5s} = 0,2$$

$$GS'_3 = GS_3 \times \%SA$$

$$= 0,2 \times 27,8\%$$

$$= 0,05 - > 0,1$$

Key

STEP 7a

→ GSi: Grip points for Static actions at force level i

→ GS'i: GSi × %SA

Figure A.43 — Grip point calculation of static actions

7b

Dynamic Actions	#	Force level	Grip mode	Grip points (at force lv)
Bolt to threaded hole	2	1	c	0
Turn in bolt	6	1	c	0
Handling screwdriver	5	2	a	0
Assembly covers	4	3	c	4
Frequency of dynamic actions	17			

$$GD_1 = 0 \quad GD_2 = 0 \quad GD_3 = 4$$

Key

STEP 7b → GDj: Grip points for Dynamic actions at force level j

Figure A.44 — Grip point calculation of dynamic actions

STEP 8:

Calculation of the force-frequency/duration-grip points for static and dynamic actions (see [Figure A.45](#))

- Step 8a: Calculate the force-duration-grip points of static actions (SC_i) for each force level:
 $SC_i = \%FLSi \times (FDSi + GS'i)$
- Step 8b: Calculate the force-frequency-grip points of dynamic actions (DC_j) for each force level:
 $DC_j = \%FLDj \times FFG'j = \%FLDj \times (FFDj + GDj)$

8a

$$SC_3 = 100 \% \times (2,7 + 0,1) = 2,8 \text{ Points}$$

8b

$$DC_1 = 34,0 \% \times (0,1+0) = 0,0 \text{ Points}$$

$$DC_2 = 21,2 \% \times (1,1+0) = 0,2 \text{ Points}$$

$$DC_3 = 17,0 \% \times (2,1+4) = 1,0 \text{ Points}$$

Force [N]	Calc. Stat				Static actions (s/min)						Grip			Dynamic actions (real actions/min)										Calc. Dyn				
	FDS	GS'	%FLS	SC	≥45	30	20	10	5	3	0	2	4	2-5	10	15	20	25	30	35	≥40	FFD	GD	%FLD	DC			
0 – 5					1	1	0	0	0	0	abc			0	0	0	1	2	3	4	7	0,1	0	34	0			
> 5 – 20					4	2	1	1	0	0	ab	bc		0	0	1	2	3	4	6	9	1,1	0	21,2	0,2			
> 20 – 35	2,7	0,1	100 %	2,8	7	5	3	2	1	1	ab	b	c	0	1	2	3	4	6	8	12	2,1	4	17	1,0			
> 35 – 90					11	8	5	3	2	1	a	b	b	1	2	3	5	7	9	12	18							
> 90 – 135					16	11	7	4	3	2	a	ab	b	2	3	5	7	9	12	15	24							
> 135 – 225					21	14	10	6	4	3	a	a	b	4	5	6	8	11	14	20	32							
> 225 – 300					28	18	12	8	5	4	a	a	b	5	6	7	9	12	16	26	40							
20a	FDGS = Σ SC _i			100 %	FFG = FDGS + FFGD						FFG			%DA = ΣFLD _j										FFGD = Σ DC _j				72,2 %DA

Key

STEP 8a:

- SC_i: Static Contribution at force level i
- SC_i = %FLSi × (FDSi + GS'i)

STEP 8b → FFGD: Force-Frequency-Grip points for Dynamic actions “FFGD=” Σ_{j=1}⁷ “DC_j”

- DC_j: Dynamic Contribution at force level j
- DC_j = %FLDj × (FFDj + GDj)

Figure A.45 — Calculation of the force-frequency/duration-grip points for each force level

STEP 9:

Add the total force-frequency-grip points of each force level for dynamic actions (DC_j) and static actions (SC_i). See [Figure A.46](#).

Force [N]	Calc Stat				Static actions (s/min)						Grip			Dynamic actions (real actions/min)							Calc Dyn					
	FDS	GS'	%FLS	SC	≥45	30	20	10	5	3	0	2	4	2-5	10	15	20	25	30	35	≥40	FFD	GD	%FLD	DC	
0 – 5					1	1	0	0	0	0	abc			0	0	0	1	2	3	4	7	0,1	0	34	0	
> 5 – 20					4	2	1	1	0	0	ab	bc		0	0	1	2	3	4	6	9	1,1	0	21,2	0,2	
> 20 – 35	2,7	0,1	100%	2,8	7	5	3	2	1	1	ab	b	c	0	1	2	3	4	6	8	12	2,1	4	17	1,0	
> 35 – 90					11	8	5	3	2	1	a	b	b	1	2	3	5	7	9	12	18					
> 90 – 135					16	11	7	4	3	2	a	ab	b	2	3	5	7	9	12	15	24					
> 135 – 225					21	14	10	6	4	3	a	a	b	4	5	6	8	11	14	20	32					
> 225 – 300					28	18	12	8	5	4	a	a	b	5	6	7	9	12	16	26	40					
20a	FDGS = $\sum SC_i$				FFG = FDGS + FFGD						FFG			%DA = $\sum FL_{Dj}$							FFGD = $\sum DC_j$				72,2	1,2

Key

STEP 9a: FDGS: Force-Duration-Grip points for Static actions “FDGS=” $\sum_i i = 1 \text{ } ^{7} = \text{“} SC_i \text{”}$

STEP 9b: FFGD: Force-Frequency-Grip points for Dynamic actions “FFGD=” $\sum_j j = 1 \text{ } ^{7} = \text{“} DC_j \text{”}$

Figure A.46 — Sum of the force-frequency/duration-grip points for static and dynamic actions

STEP 10:

Sum the force-frequency/duration-grip points of static (FDGS) and dynamic (FFGD) actions. See [Figure A.47](#).

Force [N]	Calc Stat				Static actions (s/min)						Grip			Dynamic actions (real actions/min)							Calc Dyn					
	FDS	GS'	%FLS	SC	≥45	30	20	10	5	3	0	2	4	2-5	10	15	20	25	30	35	≥40	FFD	GD	%FLD	DC	
0 – 5					1	1	0	0	0	0	abc			0	0	0	1	2	3	4	7	0,1	0	34	0	
> 5 – 20					4	2	1	1	0	0	ab	bc		0	0	1	2	3	4	6	9	1,1	0	21,2	0,2	
> 20 – 35	2,7	0,1	100%	2,8	7	5	3	2	1	1	ab	b	c	0	1	2	3	4	6	8	12	2,1	4	17	1,0	
> 35 – 90					11	8	5	3	2	1	a	b	b	1	2	3	5	7	9	12	18					
> 90 – 135					16	11	7	4	3	2	a	ab	b	2	3	5	7	9	12	15	24					
> 135 – 225					21	14	10	6	4	3	a	a	b	4	5	6	8	11	14	20	32					
> 225 – 300					28	18	12	8	5	4	a	a	b	5	6	7	9	12	16	26	40					
20a	FDGS = $\sum SC_i$				FFG = FDGS + FFGD						4			%DA = $\sum FL_{Dj}$							FFGD = $\sum DC_j$				72,2	1,2

Key

STEP 10: FFG = FDGS + FFGD

Figure A.47 — Sum of static and dynamic force-frequency-grip points

— LINE 20b: Assigning posture points to wrist, arm and shoulder

To determine the posture points for wrist/forearm/shoulder, it is necessary to consider all instances during the cycle, in which the upper limb under analysis is in an awkward posture.

General posture definitions (see [Figure A.48](#)):

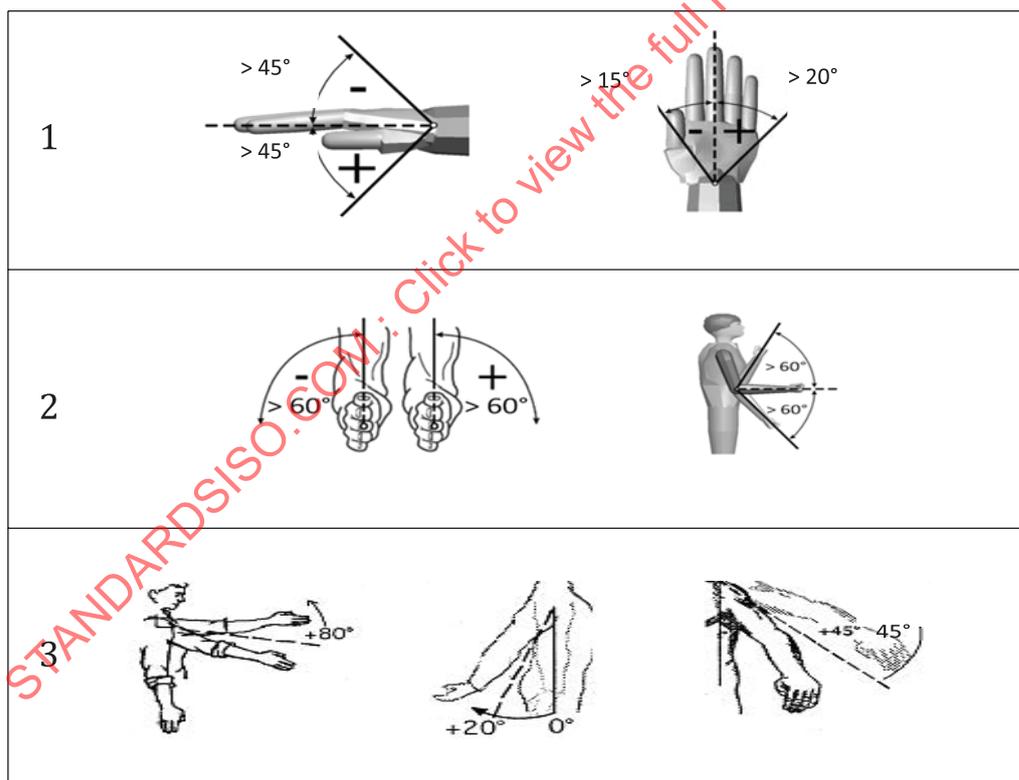
- Flexion is bending movement that decreases the angle between two parts. Bending the elbow, or clenching a hand into a fist, are examples of flexion.
- Extension is the opposite of flexion; a straightening movement that increases the angle between body parts. In a conventional handshake, the fingers are fully extended.

- Abduction is a motion that pulls a structure or part away from the midline of the body. In the case of fingers and toes, spreading the digits apart, away from the centreline of the hand or foot. Abduction of the wrist is called radial deviation. Raising the arms laterally, to the sides, is an example of abduction.
- Adduction is a motion that pulls a structure or part towards the midline of the body, or towards the midline of a limb. Dropping the arms to the sides, or bringing the knees together, are examples of adduction. In the case of the fingers or toes, adduction is closing the digits together.
- Forearm-Pronation is a rotation of the forearm that moves the palm from an anterior-facing position to a posterior-facing position or palm facing down.
- Forearm-Supination is the opposite of pronation, the rotation of the forearm so that the palm is in an anterior-facing position or palm facing up.

In order to simplify the postural analysis, EAWS considers only the high joint stress, which occurs when the concerned joint segment exceeds 50 % of the total joint range of motion.

In this section (contrary to Section 1 definitions), as in the OCRA INDEX methodology, all awkward postures are considered independently if they are static (duration ≥ 4 s) or dynamic (duration < 4 s).

- The static awkward postures are accounted for according to their duration.
- The dynamic postures are accounted by considering the number of actions involving an awkward posture with respect to the total number of actions.



Key

- 1 wrist/hand: extension/flexion and radial/ulnar deviation
- 2 forearm/elbow: supination/ pronation, flexion/extension
- 3 shoulder: flexion/extension, abduction

Figure A.48 — Overview about hand/wrist/elbow/shoulder position

If, after summing all instances together, the duration of the awkward posture is at least 10 % of the cycle time, posture points PP are assigned. Interpolate if necessary.

- Dynamic actions (time factor < 4 s): extension of the joint segment

The actions, to be accounted for as awkward posture, are the real actions of the wrist, elbow and the shoulder, when the defined limits are overcome. For example, forearm-pronation greater than 60°.

- Static actions (time factor ≥ 4 s): holding time in an awkward posture

The time, to be accounted for as awkward posture, is the holding time of the wrist or the shoulder (elbow is not included), when the defined limits are overcome. For example, holding the hand above head level (flexion > 80°).

- Posture points calculation model

Awkward posture times, dynamic and static, are then added by upper limb sections (wrist/hand, forearm/elbow and shoulder) and compared to the whole duration of the cycle, giving as output three percentages: one per section. See [Figure A.49](#).

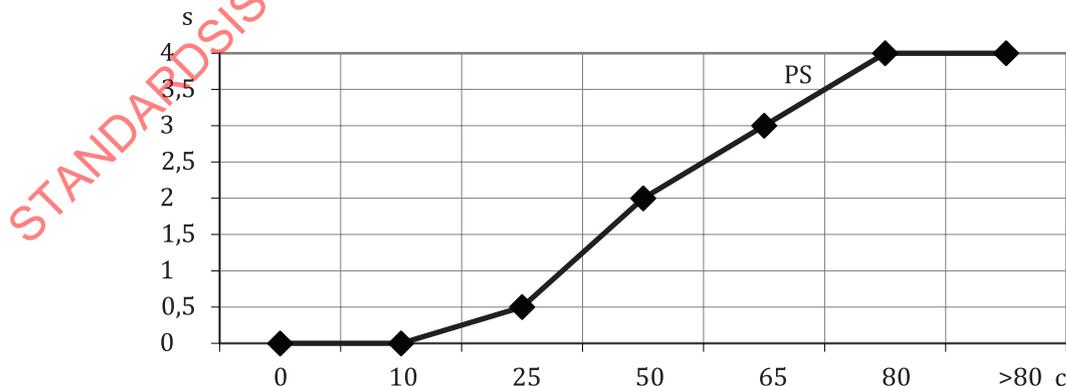
Hand / arm / shoulder postures (use duration for worst case of wrist / elbow / shoulder)							
Wrist (deviation, flex./extens.)		Elbow (pron, sup, flex./extens.)		Shoulder (flexion, extension, abduction)			
20b							
Posture points	10%	25%	33%	50%	65%	85%	PP
	0	0,5		2	3	4	

Figure A.49 — Awkward hand/forearm/shoulder postures

In case of awkward flexion of the shoulder, with non-suitable support, the shoulder posture score will be tripled. Shoulder extension and abduction scores are not influenced by this rule.

The scores are calculated with linear interpolation between the benchmark values printed on the EAWS form (10 %, 25 %, 50 %, 80 %). The minimum threshold value to obtain posture points is 10 %.

In [Figure A.50](#) the results of the interpolation are presented:



Key

- s score
- c % cycle
- PS posture score

Figure A.50 — Awkward posture scores - interpolation

The final posture score is the highest score generated by the three sections. The posture duration scale is represented in [Figure A.51](#):

Hand / arm / shoulder postures (use duration for worst case of wrist / elbow / shoulder)							
Wrist (deviaton, flex./extens.)		Elbow (pron, sup, flex./extens.)		Shoulder (flexion, extension, abduction)			
						If shoulders are involved close to or above shoulder height without support or in awkward postures, multiply score x 3	
Posture points	10 %	25 %	33 %	50 %	65 %	85 %	PP
	0	0,5	1	2	3	4	

Figure A.51 — Posture duration scale

The quantification of the durations of awkward posture of Section 4 is one of the most difficult parts in the EAWS evaluation.

The most efficient way to determine the percentage of awkward postures of each part of the body is to apply the following method:

- a) Sum of real actions generating awkward dynamic postures divided by the total number of dynamic actions.
- b) Sum of the duration of static awkward postures divided by the total duration of the part of the cycle with static postures.
- c) Weighted average of the two obtained percentages using as weights:

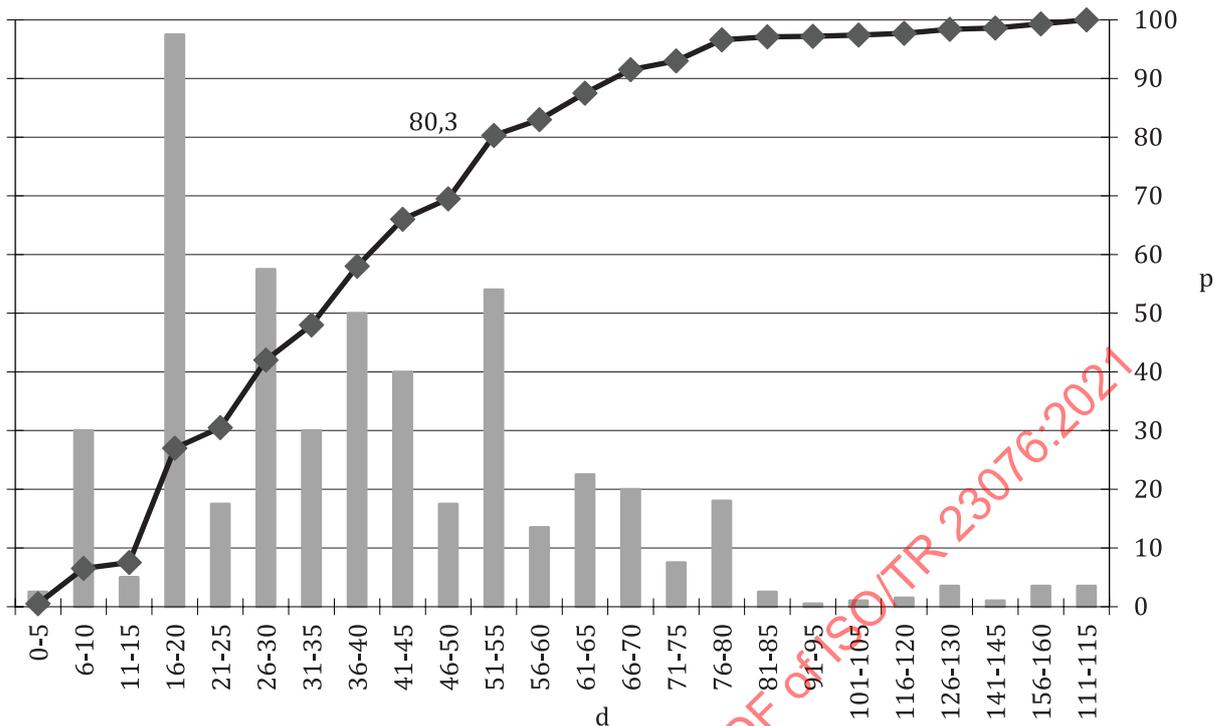
For static actions, that percentage of the cycle in which static actions occur, based on the total cycle duration.

For dynamic actions, that percentage of the cycle in which dynamic actions occur, 100 % of the cycle minus the static portion (%) and the idle time (%).

The idle time considered in the calculation is the macro-idle time related to the balancing of the workplace considered in the evaluation and it is not the micro-idle time measured at the single limb level. The idle time effect is to reduce the mean duration of dynamic actions and in this way also the posture score of dynamic actions.

In dynamic action, low frequency context, the percentage calculation of awkward postures during the dynamic portion of the cycle has to consider that the duration of the action cannot be more than a certain duration limit.

To support this, a study carried out by the International MTM Directorate created the following results, where the frequencies of actions occurrence were being calculated and classified based on their duration. The actions duration is the one calculated with MTM.

**Key**

d duration range of real actions (TMU)

p percentile

histogram bars is the frequency

points in the line are the percentile

Figure A.52 — Duration of Real Actions

From [Figure A.52](#), we see that a 2 seconds duration (about 56 TMU) represents the 80th percentile and that the average duration is about 1,3 seconds (35 TMU). Using the value of 2 seconds per action to estimate the awkward posture duration is therefore a conservative approach.

If the dynamic actions frequency, calculated in the cycle portion where there are no static actions or idleness (modified dynamic frequency - FDA'), is less than 30 times/min (the limit comes from $60 \text{ s} / 2 \text{ s} \times \text{action}$) it is necessary to calculate the percentage of awkward dynamic actions as the ratio between awkward dynamic actions quantity multiplied by 2 seconds and the dynamic cycle portion (cycle time without static actions and idleness). If FDA' is less than 30 actions/minute, the percentage of awkward dynamic actions is the ratio between awkward dynamic actions quantity and the total number of dynamic actions. This calculation is conservative, considering that 2 s/dynamic action represents the 80th percentile of the actions duration distribution.

[Table A.30](#) shows the flow diagram with the calculation process of the awkward posture percentage for the upper limbs:

Table A.30 — Upper limb awkward posture percentage calculation procedure

No.	Calculation process
1	$\%SA = \frac{\text{Duration of Static Actions [s.]}}{\text{Cycle time [s.]}} \times 100 \%$
2	$\%IDLE = \frac{\text{Idleness [s.]}}{\text{Cycle time [s.]}} \times 100 \%$
3	$\%DA' = \frac{\text{Cycle time [s.] - duration of static actions [s.] - idleness [s.]}}{\text{Cycle time [s.]}} \times 100 \%$
4	$\%AS = \frac{\text{Duration of awkward static postures [s.]}}{\text{Duration of all static postures [s.]}} \times 100 \%$
5	ASPC = %AS × %SA
6	$FDA' = \frac{\text{Number of real dynamic actions} \times 60 \text{ s}}{\text{(cycle time [s.] - Duration on static actions [s.] - Idleness [s.]}}$
7	if FDA' > 30: $\%AD = \frac{\text{Number of awkward dynamic actions}}{\text{Total number of dynamic actions}} \times 100 \%$
	if FDA' ≤ 30: $\%AD = \frac{\text{Number of awkward dynamic actions} \times 2 [s]}{\text{Cycle time [s.] - duration of static actions [s.] - idleness [s.]}} \times 100 \%$
8	ADPC = %AD × %DA'
9	APP = ASPC + ADPC
10	Interpolation of the corresponding point value for APP in line 20b
Key	
%SA% Static Actions	
%DA' % Dynamic Actions Modified	
%IDLE % Idleness	
FDA' Frequency Dynamic Actions Modified	
%AD Percentage of Awkward postures in Dynamic portion of the cycle	
%AS Percentage of Awkward postures in Static portion of the cycle	
ADPC Contribution of Awkward Dynamic Postures	
ASPC Contribution of awkward static postures	
APP Awkward Posture Percentage	
Phase components:	
1	Calculation of % Static Actions on the cycle time (%SA)
2	Calculation of % Idleness (%IDLE)
3	Calculation of % Dynamic Actions Modified (%DA')
4	Calculation of Percentage of awkward postures in static portion of the cycle (%AS)
5	Calculation of Contribution of awkward static postures on the cycle time (ASPC)
6	Calculation of Frequency Dynamic Actions Modified (FDA')
7	Calculation of Percentage of awkward postures in dynamic portion of the cycle (%AD)
8	Calculation of Contribution of awkward dynamic postures on cycle time (ADPC)
9	Calculation of Awkward Posture Percentage (APP)

EXAMPLE 6:

Awkward posture calculation for modified dynamic actions frequency $FDA' > 30/\text{min}$. (see [Table A.31](#))

a) $T_c = 60 \text{ s}$.

b) Total Static Actions = 20 s.

Whereof 5 s with wrist awkward posture

c) Dynamic Actions = 20

Whereof 12 actions with wrist awkward posture

d) Idleness = 10 s.

Calculate % of wrist awkward posture.

Table A.31 — Percentage calculation procedure of Example 6

No.	calculation process
1	$\%SA = \frac{\text{Duration of Static Actions [s.]}}{\text{Cycle time [s.]}} \times 100 \%$ $20/60 \times 100 \% = 33,3 \%$
2	$\%IDLE = \frac{\text{Idleness [s.]}}{\text{Cycle time [s.]}} \times 100 \%$ $10/60 \times 100 \% = 16,7 \%$
3	$\%DA' = \frac{\text{Cycle time [s.] - duration of static actions [s.] - idleness [s.]}}{\text{Cycle time [s.]}} \times 100 \%$ $(60 - 20 - 10)/60 \times 100 \% = 50 \%$
4	$\%AS = \frac{\text{Duration of awkward static postures [s.]}}{\text{Duration of all static postures [s.]}} \times 100 \%$ $5/20 \times 100 \% = 25 \%$
5	$\%AS \times \%SA = \text{ASPC}$ $25 \% \times 33,3 \% = 8,3 \%$
6	$FDA' = \frac{\text{Number of real dynamic actions} \times 60 \text{ s.}}{(\text{cycle time [s.] - Duration on static actions [s.] - Idleness [s.]})}$ $(20 / (60 - 20 - 10)) \times 60 = 40$
Key	
1	Calculation of % Static Actions on the cycle time (%SA)
2	Calculation of % Idleness (%IDLE)
3	Calculation of % Dynamic Actions Modified (%DA')
4	Calculation of Percentage of awkward postures in static portion of the cycle (%AS)
5	Calculation of Contribution of awkward static postures on the cycle time (ASPC)
6	Calculation of Frequency Dynamic Actions Modified (FDA')
7	Calculation of Percentage of awkward postures in dynamic portion of the cycle (%AD)
8	Calculation of Contribution of awkward dynamic postures on cycle time (ADPC)
9	Calculation of Awkward Posture Percentage (APP)