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Ergonomics principles in the design of work systems

Principes ergonomiques de la conception des systèmes de travail

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Foreword

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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TC 159, *Ergonomics*, Subcommittee SC 1, *General ergonomic principles*.

This third edition cancels and replaces the second edition (ISO 6385:2004), which has been technically revised with the following changes:

— terms were aligned with the terms given in ISO 26000;

— 3.2, 3.7 and Clause 4 have been technically revised;

— life cycle of a work system was introduced in 3.2;

— principle of adjustment was added to 3.7 and validation replaced by verification;

— new subclause on conformity was added to Clause 4;

— examples were added in several clauses.

Introduction

Technological, economic, organizational and human factors affect the work behaviour and well-being of people as part of a work system. Applying ergonomic knowledge in the light of practical experience in the design of a work system is intended to satisfy human requirements.

This International Standard provides a basic ergonomic framework for professionals and other people who deal with the issues of ergonomics, work systems and working situations. The provisions of this International Standard will also apply to the design of products for use in work systems.

Following the principles and requirements described in this International Standard will support management in making better decisions, for instance related to the sustainability of investments in work system innovation.

In the design of work systems in accordance with this International Standard, the body of knowledge in the field of ergonomics is taken into account. Ergonomic evaluations of existing or new work systems will show the need for, and encourage attention to, the role of the worker within those systems.

ISO 26800 provides a general starting point for thought on ergonomics and determines the essential general principles and concepts. This International Standard presents these in the context of the design and evaluation of work systems.

This International Standard is also valuable in the application of management systems such as OHSAS 18001. Besides guidelines for processes, it also offers guidance for achieving good human performance.

Ergonomics principles in the design of work systems

1 Scope

This International Standard establishes the fundamental principles of ergonomics as basic guidelines for the design of work systems and defines relevant basic terms. It describes an integrated approach to the design of work systems, where ergonomists will cooperate with others involved in the design, with attention to the human, the social and the technical requirements in a balanced manner during the design process.

Users of this International Standard will include executives, managers, workers (and their representatives, when appropriate) and professionals, such as ergonomists, project managers and designers who are involved in the design or redesign of work systems. Those who use this International Standard can find a general knowledge of ergonomics (human factors), engineering, design, quality and project management helpful.

The term "work system" in this International Standard is used to indicate a large variety of working situations, including permanent and flexible work places. The intention of this International Standard is to assist in the improvement, (re)design or change of work systems. Work systems involve combinations of workers and equipment, within a given space and environment, and the interactions between these components within a work organization. Work systems vary in complexity and characteristics, for example, the use of temporary work systems. Some examples of work systems in different areas are the following:

— production, e.g. machine operator and machine, worker and assembly line;

— transportation, e.g. driver and car or lorry, personnel in an airport;

— support, e.g. maintenance technician with work equipment;

— commercial, e.g. office worker with workstation, mobile worker with a tablet computer, cook in a restaurant kitchen;

— other areas like health care, teaching and training.

The observance of ergonomic principles applies to all phases throughout the life cycle of the work system from conception through development, realization and implementation, utilization, maintenance and support to decommissioning.

The systems approach in this International Standard gives guidance to the users of this International Standard in existing and new situations.

The definitions and ergonomic principles specified in this International Standard apply to the design of optimal working conditions with regard to human well-being, safety and health, including the development of existing skills and the acquisition of new ones, while taking into account technological and economic effectiveness and efficiency.

The principles in this International Standard are applicable to many other human activities, e.g. in the design of products for domestic and leisure activities. A more general description of the principles in this International Standard can be found in ISO 26800.

NOTE 1 This International Standard is considered to be the core ergonomic standard for work systems from which many others on specific issues are derived.

Note 2 Although elements of the system can be the same, this International Standard is not intended to be applied to systems used in a non-work context (e.g. the use of a vehicle for private purposes).

2 Terms and definitions

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

2.1
well-being
<work system> sustainable internal state resulting from satisfaction of the physical and cognitive needs of the *worker* (2.4) during his/her activity

Note 1 to entry: Well-being can contribute to the quality of working life.

2.2
work system
system comprising one or more *workers* (2.4) and *work equipment* (2.6) acting together to perform the *system function* (2.21), in the *workspace* (2.9), in the *work environment* (2.8), under the conditions imposed by the *work tasks* (2.17)

2.3
ergonomics
human factors
scientific discipline concerned with the understanding of interactions among human and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human *well-being* (2.1) and overall system performance

[SOURCE: ISO 26800:2011, 2.2]

2.4
worker
person performing one or more activities to achieve a goal within a *work system* (2.2)

[SOURCE: ISO 26800:2011, 2.11, modified — synonym “operator” omitted]

2.5
work organization
interacting *work systems* (2.2) acting to produce a specific overall outcome

Note 1 to entry: The process of work organization includes coherent actions in relation to establishing the form and mode of organization to be adopted (e.g. individual or collective work, teams working separately or interdependently, etc.). It is also necessary to define and allocate resources and determine the means and channels of communication. All these actions lead to the definition and assignment of prescribed tasks to the operators involved.

2.6
work equipment
tools, including hardware and software, machines, vehicles, devices, furniture, installations and other components used in the *work system* (2.2)

2.7
work process
sequence in time and space of the interaction of *workers* (2.4), *work equipment* (2.6), materials, energy and information within a *work system* (2.2)

2.8
work environment
physical, chemical, biological, organizational, social and cultural factors surrounding a *worker* (2.4)

2.9
workspace
volume allocated to one or more persons in the *work system* (2.2) to complete the *work task* (2.17)

2.10
external work load
work stress
external conditions and demands in a *work system* (2.2) which influence a person's physical and/or mental internal load

Note 1 to entry: In some countries, "external work load" is referred to as "work stress".

Note 2 to entry: Compare ISO 26800:2011, 2.4.

2.11
work strain
internal response of a *worker* (2.4) to being exposed to *external work load* (2.10) depending on his/her individual characteristics (e.g. body size, age, capacities, abilities, skills, etc.)

Note 1 to entry: In ISO 26800, "work strain" is called "internal load".

Note 2 to entry: Compare ISO 26800:2011, 2.6.

2.12
usability
extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use

Note 1 to entry: Systems, products or services are part of *work systems* (2.2) and used by *workers* (2.4) within those systems.

Note 2 to entry: In this International Standard, the context of use is within a work system.

[SOURCE: ISO 9241-210:2010, 2.13]

2.13
human-centred design
approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying *human factors/ergonomics* (2.3) and *usability* (2.12) knowledge and techniques

[SOURCE: ISO 9241-210:2010, 2.7, modified — Notes 1 and 2 to entry omitted]

2.14
accessibility
extent to which products, systems, services, environments and facilities can be used by people from a population with the widest range of characteristics and capabilities to achieve a specified goal in a specified context of use

[SOURCE: ISO 26800:2011, 2.1, modified — Notes 1 and 2 to entry omitted]

Note 1 to entry: Products, systems, services and facilities are part of *work systems* (2.2) and used by *workers* (2.4) within those systems.

Note 2 to entry: In this International Standard, the context of use is within a work system.

2.15
allocation of functions
process of deciding whether *system functions* (2.21) will be implemented by humans, by equipment and/or hardware and/or software

2.16
job
organization and sequence in time and space of an individual's *work tasks* (2.17) or the combination of all human performance by one *worker* (2.4) within a *work system* (2.2)

2.17
work task
activity or set of activities required of the *worker* (2.4) to achieve an intended outcome

2.18
workstation
combination and spatial arrangement of *work equipment* (2.6), surrounded by the *work environment* (2.8) under the conditions imposed by the *work tasks* (2.17)

2.19
work fatigue
impairing non-pathological manifestation of *work strain* (2.11), completely reversible with rest

Note 1 to entry: Work fatigue can be mental, physical, local and/or general.

Note 2 to entry: Compare ISO 26800:2011, 2.5.

2.20
target population
people for whom the design is intended, specified according to the relevant characteristics

Note 1 to entry: Relevant characteristics include, for example, the skill level, intelligence or physical characteristics, such as anthropometric dimensions, of these people. Gender and age can be related to variations in these characteristics. In addition to these intrinsic characteristics, extrinsic factors (e.g. cultural differences) could also be relevant.

[SOURCE: ISO 26800:2011, 2.8]

2.21
system function
broad category of activity performed by a system

3 Designing work systems

3.1 General principles

Work system design considers human beings as the main factor and an integral part of the system to be designed, including the work process, as well as the work environment.

In the design process of work systems, the major interactions between one or more people and the components of the work system, such as tasks, equipment, workspace and environment, shall be considered.

These interactions create demands on the worker that together constitute the external work load. This will result in reactions within the worker, depending on her/his individual characteristics (e.g. size, age, capacities, abilities, skills, etc.) called work strain. Work strain will result in impairing effects (e.g. fatigue generated by work), or facilitating effects (e.g. skill development), thus affecting the individual characteristics of the worker in a feedback loop.

Ergonomic work system design aims at optimizing work strain, avoiding impairing effects and promoting facilitating effects. Unimpaired human performance at the same time will often improve system effectiveness and efficiency, thus contributing to another important goal of ergonomic work system design.

Ergonomics shall be used in a preventive function by being employed from the beginning rather than being used to solve problems after the design of the work system is complete. However, ergonomics can be successfully employed in the redesign of an existing, unsatisfactory work system. Furthermore, in a risk assessment process, the interaction between work system design and the worker's foreseeable behaviour should be considered in order to secure their safety and health.

The most important decisions that have consequences in the design are made at the beginning of the design process. Therefore, particular attention should be paid to the application of ergonomics principles at this stage. Ergonomic contribution to the work system design shall continue throughout the design process. However, the level of input can vary from being fundamental and extensive during the analysis of the system needs ("formulation of goals") to fine-tuning when the completed system is being implemented ("realization, implementation and verification"). Sufficient attention shall continue to be given to the application of ergonomic principles until late in the design process in order to prevent negative effects such as delays in projects, extra costs for adaptation, a lower design quality, and reduced usability.

In accordance with a human-centred approach, workers should ideally be involved in and should participate in the design of work systems during the process in an effective and efficient manner. Workers include those responsible for constructing, maintaining, operating, and supervising, each of which requires different considerations. In work system design, a participatory approach is essential in order to avoid sub-optimal solutions, because the experience of workers provides an indispensable knowledge base. The design process shall therefore, wherever possible, involve workers in all stages.

NOTE 1 Detailed information about the human-centred approach can be found in ISO 9241-210.

It is recommended that a work system be designed for a broad range of the target population (see ISO 26800:2011, 4.2.2). In particular, the designer should consider the needs of people with special requirements and apply ergonomic principles to ensure that work systems are accessible to them. Thus, the need for the development of special solutions for individual workers can be minimized and the accessibility of the work system improved.

NOTE 2 Special requirements include limitations to sensory abilities such as vision, tactile and acoustic input, and physical abilities such as dexterity, manipulation, movement, voice, strength and endurance, cognitive abilities such as intellect, memory, language and literacy. For further guidance, see ISO/IEC Guide 71 and ISO/TR 22411.

In ergonomics, the variation within the target population is commonly accounted for by using the 5th and/or 95th percentiles of important design characteristics, with the intention of accommodating at least 90 % of the target population.

NOTE 3 In some circumstances, a different percentile range is used. For example, the 1st and 99th percentiles are used for many safety-related applications.

In designing the work system, a variety of conditions should be considered, e.g. normal, disturbed and degraded functioning.

The work system design process (3.2) can be divided into the following phases:

— formulation of goals (requirements analysis) (3.3);

— analysis and allocation of functions (3.4);

— design concept (3.5);

— detailed design (or development) (3.6);

— realization, implementation, adjustment, verification and validation (3.7);

— evaluation and monitoring (Clause 4).

These phases will be explained in the relevant clauses or subclauses.

3.2 Work system design process

"Designing" refers to an iterative and structured process of a number of design phases, which results in a new design or a redesign. The work system design process should include all phases throughout the life cycle of the work system from conception through development, realization and implementation, utilization, maintenance and support to decommissioning. Verification should be performed in each of

these phases to confirm that the specified requirements are being fulfilled. A multidisciplinary design team best accomplishes this process. Activities involved in the phases of the design process are analysis, synthesis, simulation and evaluation (see EN 16710-2).

NOTE 1 A multidisciplinary design team can include engineers, operators, ergonomists, occupational health and safety specialists, management, financial services and purchasers.

Each of the many variables described in the following subclauses is likely to influence others. Decisions concerning, for instance, the allocation of different functions to people or equipment, the design of any interface, and the training requirements, all interact to an extent which will make it necessary for the system designer to evaluate alternatives before reaching the final decision.

This process of evaluating suitable alternatives is likely to be iterative until sufficient information is gathered for each area. The marshalling and final consideration of the information is then conducted in the following stages of the design process. It is important to ensure that appropriate methods and techniques are applied in the realization of a new work system design.

NOTE 2 ISO 26800 lists the basic requirements for ergonomics-oriented design.

NOTE 3 See ISO/TR 16982 on usability methods supporting human-centred design.

NOTE 4 A work system can change or evolve over time and is not necessarily static and unchanging.

3.3 Formulation of goals (requirements analysis)

In the case of a new design, the analysis of system requirements will involve the acquisition of information regarding the production or performance requirements of the work process, together with the characteristics and limitations of the people who will be working in the new system (including user needs) and the environment in which they will work. Where equivalent or similar systems already exist, this will also entail the identification of information regarding ergonomic*s* issues and problems occurring with these existing work systems, either from existing sources or from studies conducted for the purpose. Appropriate ergonomic methods and techniques for this purpose imply the use of evaluation tools for working conditions, observations on the spot, interviews, etc.

After gathering and analysing this information, a set of demands, requirements and specifications shall be created, which includes work system specifications relating to the performance, safety, health and well-being of the workers as well as the technical performance requirements for the new system.

EXAMPLE One design goal of a dedicated voice recognition system to be designed is to allow surgeons to verbally dictate a report about an operation they have just carried out, with a voice recognition accuracy greater than 98 %.

Each aspect, element and component (see 3.6) of the work system which can influence the human or system performance shall be described, including both operation and maintenance.

3.4 Analysis and allocation of functions

Having established the requirements for the new system, the first step in this stage is to establish those functions which are to be fulfilled by the work system in order to meet these requirements. Once these have been established, decisions shall be taken about how to allocate these between worker(s) and equipment. This is to ensure that each function is performed in an effective and efficient manner with due regard to the work system design considerations previously identified (see 3.3).

This will involve analysing the capabilities and limitations in fulfilling the requirements of the system of both the human and technical components of the planned system. This analysis and the subsequent allocation of functions to workers or equipment should create tasks and jobs, which have a positive effect on health, well-being and safety, as well as achieving the desired level of performance.

Appropriate ergonomic methods and techniques for this purpose include schemes, evaluation tools, human models and laboratory tests. Function allocation leads to tasks and jobs, which are in accordance with the ergonomic principles specified in this International Standard.

EXAMPLE The list of functions of an automatic mail-sorting machine includes those of (a) feeding letters into the machine, (b) address reading, (c) sorting of letters into destination slots, (d) emptying letters from destination slots for further transport. The analysis results in a recommendation for (a) and (d) to be allocated to human operators and (b) and (c) to be performed automatically by the machine.

NOTE Besides principles of work task design, EN 614–2 contains guidelines on function analysis and function allocation for machinery.

3.5 Design concept

Once such decisions have been made, the functions allocated to either humans or to technical solutions shall be transformed into an initial conceptual design for the work system (design concept), which shows the structure of the system and the interactions between its components. Any such concept shall be developed with due regard to a human-centred approach.

Those functions, which are allocated to workers, should be transformed into a list of demands for the design of tasks, jobs and work organization. These demands form the basis for the design of these components.

Those functions allocated to equipment should be transformed into a list of demands for the design of work equipment, work tools (including software), workstation and work environment. These demands form the basis for their design or selection.

Ergonomic methods and techniques that can be used for this purpose include simulation and task analysis techniques, scale models and mock-ups, and group discussions.

3.6 Detailed design (or development)

3.6.1 General

The following subclauses examine the design of the components, which together form the developed work system, in order to provide for a better understanding of the range and needs of ergonomic work system design.

In the design of a work system, the design of the following components shall be addressed:

— design of work organization (3.6.2);

— design of work tasks (3.6.3);

— design of jobs (3.6.4);

— design of work environment (3.6.5);

— design of work equipment and interfaces (3.6.6);

— design of workspace and workstation (3.6.7).

The components should be designed with due regard to the interdependencies among them. The above-mentioned sequence does not imply that this is a mandatory sequence for the design process. Iterations are normally required to achieve optimal solutions.

System design is a flexible process. The work system inevitably changes from its conception to its first use.

The design process is not limited to the design phase (development) itself, but extends to implementation and especially to the initial period of use.

3.6.2 Design of work organization

Individual jobs and work systems have effects on each other. The extent to which various work systems, e.g. within companies, create constraints and pressures on other work systems shall be determined and the impact which these can have on the performance of the work organization and all the work systems, as well as on workers, taken into account.

Where appropriate, consideration should also be given to the implications of wider systems of the organization (e.g. company or production) or external influences (e.g. social, cultural, regulatory aspects).

The extent to which the relationships between the different elements in a work system affect the external work load acting on the individual shall be determined. Thus, many of the factors described in 3.6.7 can also have a significant influence when considered as part of the way the combination of work processes is organized.

If these constraints and pressures result in undesirable outcomes relative to system requirements, alternative design solutions shall be sought.

3.6.3 Design of work tasks

When transforming functions allocated to the human into work tasks, the designer shall achieve the following goals:

— ensure that the work tasks performed make a significant contribution to the total work system, which can be understood by the people involved;

— ensure that the work tasks performed are identifiable as whole units of work rather than fragments;

— recognize the experience and capabilities of the working population;

— provide for the application of an appropriate variety of skills, capabilities and activities;

— provide people with an appropriate degree of autonomy in deciding priority, pace and procedure;

— provide opportunities for the development of existing skills and the acquisition of new skills with respect to the work tasks concerned;

— avoid isolating individual workers such that opportunities do not exist for social and functional contacts;

— avoid overload, as well as underload of the worker, which can lead to unnecessary or excessive work strain, work fatigue or to errors;

— avoid repetitiveness, which can lead to unbalanced work strain and thus to physical disorders, as well as to sensations of monotony, satiation, boredom or to dissatisfaction;

— provide sufficient feedback in meaningful terms to those performing the work task.

EXAMPLE 1 The tasks for the workers in a call centre are designed in order to optimize the work flow and call centre efficiency while minimising work fatigue and monotony for the workers.

EXAMPLE 2 A growing population of office workers do knowledge work. They are often free to do their tasks at the time and in the place they prefer, at home or in the office. Additional education may be required to ensure the correct implementation of ergonomic principles into the home work place.

NOTE See also ISO 9241-2, ISO 10075-2 and EN 614–2.

3.6.4 Design of jobs

Jobs shall be designed to facilitate the goals of the work system while achieving a level of demands on the workers which optimises performance. If, due to design restrictions, individual tasks cannot be designed in accordance with 3.6.3, job design shall be used to achieve this outcome.

Job design shall, where possible, be used to correct any imbalance between external work load and the capacities of the target population and thus avoid impairing effects.

NOTE See also ISO 9241-2 and ISO 10075-2.

The overall external work load depends not only on the factors considered in other subclauses, e.g. 3.6.3, but also on the combination of the individual tasks within a job, the content and repetitiveness of operations and the workers' control over the work process.

If task design and job design do not result in an optimal level of demand, then one or more of the following methods shall be implemented in order to improve the quality of the job:

— adequate breaks, organized or non-organized;

— change of activities as, for example, job rotation among people on an assembly line or in a team working within a group;

— having one person (instead of several people) perform several successive tasks belonging to the same system function (job enlargement), for example, performing different assembly operations in a sequence;

— having one person (instead of several people) perform successive tasks belonging to different system functions (job enrichment), for example, assembly operations followed by quality checks performed by the person who also removes defects.

EXAMPLE A bank introduces a new system of job rotation allowing their workers to perform a number of different tasks while allowing sufficient time for breaks.

3.6.5 Design of work environment

The work environment shall be designed and maintained to minimize the adverse effects of social, physical, chemical and biological conditions on the health, safety and well-being of workers, as well as on their capacity and willingness to perform the tasks under consideration.

Wherever possible, both objective and subjective assessments should be used to determine conditions. As well as ensuring that environmental conditions remain within recognized limits for the maintenance of health, safety and well-being, attention should also be given to the extent to which the design of the environment can influence safe and efficient task performance. For example, inappropriate acoustical background can mask an acoustical signal whereas appropriate lighting can enhance the performance of visual inspection tasks. Wherever possible, the worker should be able to influence the conditions in her/his work environment (e.g. lighting, temperature, ventilation).

It should be recognized that social, cultural and ethnic factors can influence the acceptability of work and work organization. These influences can be wide-ranging, including such diverse issues as dress requirements; substances used in the work process and the hours and days of work. Wherever possible, these should be taken into account in designing the work system. Social and family pressures can also influence safety and performance. Possible avenues for amelioration include designing workplaces to minimize the potential for human error or, where concentration is vital, providing additional social support.

NOTE 1 Concerns over private problems can cause distraction, predisposing workers to errors.

NOTE 2 Some religious requirements impose constraints on dress or on contact with certain animals.

3.6.6 Design of work equipment and interfaces

When designing work equipment psychological aspects shall be considered in addition to physical and/or mechanical factors.

In general, interfaces provide for decision-making, information transfer or communication between people and equipment. Their main components are displays and controls. These may be conventional devices or computer hardware and software. Interfaces to support human-system interaction shall be designed to match human characteristics.

— Interfaces shall provide adequate information to allow a rapid overview, as well as providing information concerning detailed parameters.

— Those elements which most need to be reached shall be where they can most easily be reached and operated and those which most need to be seen shall be where they can most easily be seen.

  There may be an exception for certain controls, e.g. emergency stop buttons.

— Signals and displays shall be selected, designed and laid out in a manner compatible with the characteristics of human perception and the task to be performed.

— Signals, displays and controls shall function in a manner likely to minimize the probability of human error.

— Controls shall be selected, designed and laid out in such a way as to be compatible with the characteristics (particularly of movement) of that part of the body by which they are to be operated and the task to be performed. Skill, accuracy, speed and strength requirements should be taken into account.

— Controls shall be selected and laid out in a manner compatible with population stereotypes, the dynamics of the control process and its spatial representation. In particular, controls shall be sufficiently close to each other to facilitate correct operation where they are to be operated simultaneously or in quick succession.

— Controls shall be located so as to avoid inadvertent operation.

— Controls shall be close enough to each other to facilitate correct operation where they are to be operated simultaneously or in quick succession.

— The layout of software information displays and the design and function of screen-based controls, e.g. touch screens, should also reflect the principles above, where appropriate.

NOTE 1 For information regarding the design of displays and control actuators, see ISO 9355 (all parts) and ISO 1503.

NOTE 2 For the human-system interaction, see also ISO 9241 series.

NOTE 3 For control centres, see also ISO 11064 series.

3.6.7 Design of workspace and workstation

3.6.7.1 General

The design shall be such as to allow people both postural stability and postural mobility.

People shall be provided with a base, which is as safe, secure and stable as possible from which to exert physical energy.

Workstation design, including work equipment and devices, shall include considerations of body dimensions, posture, muscular strength and movement. For example, sufficient space should be provided to allow the task to be performed with good working postures and movements, opportunities for variations in posture, and to allow for easy access.

Body postures shall not cause fatigue from prolonged static muscular tension. Alterations in body postures shall be possible.

NOTE Some work practices, such as home working, can provide particular challenges in that the designer can have little control or influence over the design of the home workspace and workstation.

3.6.7.2 Body dimensions and body posture

The design of the workstation should take into account any constraints imposed by the body dimensions of those likely to use it together with any clothing or other necessary items.

For prolonged tasks, the worker shall be able to vary their posture, for example, changing between sitting, standing or an intermediate posture (e.g. using a sit/stand chair). Sitting is normally preferable, although standing may be necessitated by the work process. For prolonged tasks, crouching or kneeling postures shall be avoided.

If high muscle strength should be exerted, the chain of force or torque vectors through the body shall be kept short and simple by allowing suitable body posture and providing appropriate body support. This applies in particular for tasks requiring high precision of movements.

EXAMPLE Height-adjustable work surfaces can be adapted to the body dimensions and enable various workers to work while standing or sitting.

NOTE Changes in posture and movement during the task, if necessary, through the provision of work breaks, are valuable in preventing work fatigue.

3.6.7.3 Muscular strength

Strength demands shall be compatible with the physical capacities of the worker and should take into account scientific knowledge on the relationships between strength, frequency of exertion, posture, work fatigue, etc.

The design of the work shall be such as to avoid unnecessary or excessive strain in muscles, joints, ligaments, and on the respiratory and circulatory systems.

Muscle groups involved shall be strong enough to meet the strength demands. If strength demands are excessive, auxiliary sources of energy should be introduced into the work system or the task should be redesigned to use more powerful muscles.

EXAMPLE 1 Nurses are assisted by lifting devices to move patients.

EXAMPLE 2 Construction workers are assisted by manipulators to transport and assemble heavy components.

3.6.7.4 Body movement

A good balance shall be established among body movements; motion is preferred to prolonged immobility.

The frequency, speed, direction and range of body or limb movements shall be within anatomical or physiological limits.

Movements with great accuracy requirements, particularly for a long duration, shall not entail exertion of considerable muscular strength.

The execution and sequencing of movements should be facilitated by guiding devices, as appropriate.

NOTE An absence of body movement can lead to muscle discomfort and pain. Workers in sedentary jobs are encouraged to change position from time to time.

3.7 Realization, implementation, adjustment, verification and validation

The term realization includes the building, production or purchase of the new technical design of the work system and its installation in the place where it will be used.

Implementation shall include a careful introduction of the new work system to all people concerned, especially the (potential) workers, including the provision of information and training, where appropriate. A clear procedure for the change from the old to the new situation shall be incorporated, if possible, including a back-up system.

The initial period of use should be considered as the final phase (adjustment) and should be seen as the final design phase.

It is therefore important to identify the changes necessary (their origins, effects and associated risks) to improve the design process and optimize work system performance.

NOTE 1 Failure to implement this phase is often the root cause of some accidents and industrial disasters.

Adjustments could be as follows:

— technical, related to the adjustment of the work system to the final location;

— organizational, taking into account the management and allocation of resources and means and the design of local procedures and different organizational levels;

— worker-related, giving workers the opportunity to apply their experience, training and coping skills to manage risks and unanticipated circumstances.

It is therefore important to support this adjustment phase to obtain acceptable performance.

Documentation, which is usable by the intended user population, should be available and instruction and training of the workers helps to ensure a quick and reliable change to the new situation.

The application of ergonomic principles during the design process minimizes the need for training. Where necessary in order for any design to achieve its full potential, adequate and appropriate, training shall be given in the functioning of the new work system.

Verification activities shall be conducted to ensure that work system meets the required characteristics. These can include, but are not limited to, specified requirements, design description and the work system itself.

The validation process shall demonstrate that the new work system performs as intended without any harmful effects on the workers' health, well-being or safety. If system performance is inadequate or the workers' health, well-being or safety is negatively affected, the work system shall be redesigned as described in this International Standard. Workers should be involved and participate in the validation of the work system. If, during the validation process, a work system achieves its performance criteria at the expense of the health, well-being or safety of the workers, it fails to meet the requirements of this International Standard.

NOTE 2 Further information on the verification and validation process is given in ISO/IEC/IEEE 15288:2014, 6.4.9 and 6.4.11.

4 Evaluation and monitoring

4.1 General

Properly applied, ergonomics optimizes the performance and effectiveness of the work system, including the workers without detriment to their health, well-being or safety.

After realization and implementation of the work system, processes of evaluation and monitoring of the work system should be established. Besides evaluation during the development process (see 3.7), an

overall evaluation of the design of a work system is useful in order to get a total view on the results of the project and to learn from it, by comparing the intended outcome at the beginning of the project with the final result. It is also necessary to continue to monitor the effect of the system in order to safeguard against longer-term deterioration in the performance or health of the users. The overall evaluation shall be carried out when the process is stabilized.

This evaluation should consider the quality of work in order to create a healthy basis within working situations for long-term effective performance of workers.

Evaluation and monitoring should include criteria relating to the following:

— health and well-being (4.2);

— safety (4.3);

— system performance (4.4);

— usability (4.5);

— cost-benefit (4.6).

In practice, this will include recording of problems and experiences for analysis as a basis for corrective, adaptive and preventive actions or further development of work systems.

NOTE For additional information, see also ISO 10075-3, ISO 11226, ISO 11064-7, EN 614–2, EN 1005–4 and EN 1005–5.

4.2 Health and well-being

Examples for approaches for the evaluation of workers' health and well-being in the work system are as follows:

— medical surveillance;

— physiological measurements;

— subjective assessment;

— measurement by psychological instruments.

4.3 Safety

Examples for approaches for the evaluation of safety in the work system are as follows:

— reliability of system related to safety;

— incidence of errors;

— observation of unsafe behaviour;

— incidence of near-misses;

— incidence of accidents;

— hazard identification and risk assessment.

4.4 System performance

Examples for approaches for the evaluation of performance of the worker and the work system are as follows:

— qualitative evaluation as a check for defective products;

— quantitative evaluation of productivity.

4.5 Usability

Usability is a criterion against which a work system can be evaluated. In applying the concept of usability within the work system, all relevant system components should be identified.

To evaluate usability, it is normally necessary to use at least one measure for each of effectiveness, efficiency and satisfaction.

NOTE For a detailed description of usability measures and definitions of effectiveness, efficiency and satisfaction, see ISO 9241-11.

4.6 Cost-benefit

Cost-benefit models can be used for semiquantitative evaluation about the effect of the new design, for instance, costs can be diminished by a reduction in average sickness absence, of production loss, or of maintenance. Good work situations can have many comparable positive side effects that can be translated into cost-benefits.

4.7 Conformance

As well as by having met the requirements of the document itself, conformance with this International Standard is achieved by

a) satisfying the set of demands, requirements and specifications (3.3),

b) identifying applicable recommendations,

c) stating whether or not these recommendations have been followed, and

d) if any have not been followed, explaining why.

If a work system is claimed to have met the requirements, and if the applicable recommendations are considered to have been followed, the procedure used to determine how they have been met/followed should be specified.

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