INTERNATIONAL STANDARD

ISO 11226

First edition
2000-12-15

Ergonomics — Evaluation of static working postures

Ergonomie — Évaluation des postures de travail statiques

Reference number
ISO 11226:2000(E)

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Foreword

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International Standard ISO 11226 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 3, *Anthropometry and biomechanics*.

Annexes A and B of this International Standard are for information only.

Introduction

Pain, fatigue and disorders of the musculoskeletal system may result from sustained inadequate working postures that may be caused by poor work situations. Musculoskeletal pain and fatigue may themselves influence posture control which can increase the risk of errors and may result in reduced quality of work or production, and in hazardous situations. Good ergonomic design is a basic requirement to avoid these adverse effects.

This International Standard contains an approach to determine the acceptability of static working postures. The content of the standard is based on current ergonomic knowledge, and is subject to changes according to future research.

It is connected with ISO 11228-1, ISO 11228-2 and ISO 11228-3 (see [1], [2] and [3] in the Bibliography).

INTERNATIONAL STANDARD ISO 11226:2000(E)

Ergonomics — Evaluation of static working postures

1 Scope

This International Standard establishes ergonomic recommendations for different work tasks. This standard provides information to those involved in design, or redesign, of work, jobs and products who are familiar with the basic concepts of ergonomics in general, and working postures in particular.

It specifies recommended limits for static working postures without any or only with minimal external force exertion, while taking into account body angles and time aspects.

It is designed to provide guidance on the assessment of several task variables, allowing the health risks for the working population to be evaluated.

It applies to the adult working population. The recommendations will give reasonable protection for nearly all healthy adults. The recommendations concerning health risks and protection are mainly based on experimental studies regarding the musculoskeletal load, discomfort/pain, and endurance/fatigue related to static working postures.

2 Terms and definitions

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

2.1
extreme body-joint position
towards the end of the range of motion, where there is a substantial mechanical load on the passive structures such as ligaments

2.2
Frankfurt plane
standard horizontal plane at the level of the upper edge of the opening of the external auditory meatus (external ear opening) and the lower border of the orbital margin (lower edge of the eye socket); the median plane of the head is held vertically

NOTE The Frankfurt plane is associated with the normal line of sight (relaxed extraocular muscles).

2.3
full arm support
support of the upper arm segment weight by the workplace (e.g. by the elbow/forearm on a table desk)

2.4
full head support
support of the head segment weight by the workplace (e.g. by a headrest)

2.5
full trunk support
support of the trunk segment weight directly by the workplace (e.g. by a high chair backrest in the case of trunk inclination backwards) or indirectly (e.g. through arm support at the workplace in the case of trunk inclination forwards)

2.6
holding time
duration that a static working posture is maintained

2.7
maximum holding time
maximum duration that a static working posture can be maintained continuously from a rested state (maximum remaining endurance capacity)

2.8
neutral posture for the trunk, upper arms, and head
upright trunk, upper arms hanging freely, and head posture according to the Frankfurt plane

2.9
recovery time
time available for recovering, i.e. the duration that a body segment is either fully supported or maintained in a neutral posture

2.10
reference posture
sitting or standing posture with a non-rotated upright trunk and the arms hanging freely, while looking straight forward along the horizontal

2.11
remaining endurance capacity
percentage of the maximum holding time that a static working posture can still be maintained continuously

2.12
static working posture
working posture maintained longer than 4 s; this applies to slight or non-existant variations around a fixed force level delivered by muscles and other body structures

2.13
working posture
position of body segments and joints while executing a work task

3 Recommendations

3.1 Introduction

Work tasks and operations should provide sufficient physical and mental *VARIATION.* This means a complete job, with sufficient *VARIATION* of tasks (for instance, an adequate number of organizing tasks, an appropriate mix of short, medium and long task cycles, and a balanced distribution of easy and difficult tasks), sufficient autonomy, opportunities for contact, information and learning. Furthermore, the full range of workers possibly involved with the tasks and operations should be considered, in particular their body dimensions.

With respect to working postures, the work should offer sufficient variation between and within sitting, standing and walking. Awkward postures, such as kneeling and crouching, should be avoided, whenever possible.

It is stressed that measures meant to induce variations of posture should not lead to monotonous repetitive work (for more information, refer to [4] in the Bibliography).

3.2 Evaluation procedure

The approach described below can be used to determine the acceptability of static working postures. The evaluation procedure considers various body segments and joints independently in one or two steps. The first step considers only the body angles (recommendations are mainly based upon risks for overloading passive body structures, such as ligaments, cartilage and intervertebral disks). An evaluation may lead to the result "acceptable", "go to step 2" or "not recommended".

An "acceptable" evaluation result means that a working posture is acceptable only if *VARIATIONS* of posture are also present (see 3.1). In any eventuality, every effort should be made to obtain a working posture closer to the neutral posture, if this is not already the case.

NOTE 1 The concept "reference posture" is used for determination of working postures (see 3.3).

An evaluation result "go to step 2" means that the duration of the working posture will also need to be considered (recommendations are based upon endurance data).

Extreme positions of joints should be evaluated as "not recommended".

NOTE 2 Only those extreme joint positions that are most commonly found in practice are mentioned.

3.3 Determination of working postures

There are various ways to determine working postures, e.g. observation, photography/video, 3-dimensional opto-electronic or ultrasound measuring systems, body-mounted measuring devices such as inclinometers and goniometers. The appropriate method depends, amongst other things, on the accuracy of determination required by the evaluation. In most cases, direct observation (without measuring systems/devices) will do. However, for more precise determination of working postures, measuring systems/devices may be necessary (for an overview and detailed descriptions, see [5] in the Bibliography). Informative annex A describes the procedure for determining particular posture parameters appearing in 3.4 to 3.7, i.e. trunk inclination, head inclination, neck flexion/extension, upper arm elevation, and extreme joint positions.

3.4 Trunk posture

3.4.1 Step 1

Trunk posture should be evaluated by considering items 1, 2 and 3 in Table 1. Item 3 refers only to sitting.

3.4.2 Step 2

The holding time for trunk inclination is evaluated using Table 2.

It is recommended to provide adequate recovery time following the holding time for a certain trunk inclination. Informative annex B provides recommendations for evaluating holding time/recovery time regimes based on endurance data.

3.5 Head posture

3.5.1 Step 1

Head posture should be evaluated by considering head inclination (item 2 in Table 3), as well as head posture with respect to trunk posture (items 1 and 3 in Table 3).

3.5.2 Step 2

The holding time for head inclination is evaluated using Table 4.

It is recommended to provide adequate recovery time following the holding time for a certain head inclination. Informative annex B provides recommendations for evaluating holding time/recovery time regimes based on endurance data.

Table 1 — Trunk posture

Postural characteristic	Acceptable	Go to step 2	Not recommended
1) Symmetrical trunk posture [a]			
No			X
Yes	X		
2) Trunk inclination α [b]			
$> 60°$			X
$20°$ to $60°$ without full trunk support		X	
$20°$ to $60°$ with full trunk support	X		
$0°$ to $20°$	X		
$< 0°$ without full trunk support			X
$< 0°$ with full trunk support	X		
3) For sitting: convex lumbar spine posture [c]			
No	X		
Yes			X

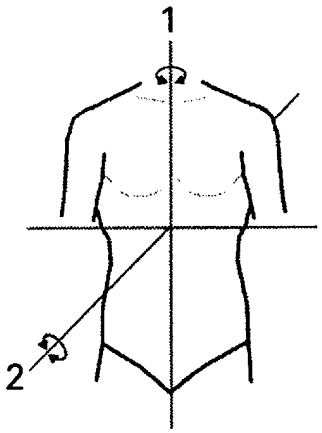
[a] With a symmetrical trunk posture, there is neither axial rotation nor lateral flexion of the upper part of the trunk (thorax) with respect to the lower part of the trunk (pelvis) (see Figure 1).

[b] Posture during task execution (dark body segment, solid line) with respect to the reference posture (white body segment, broken line) when viewed from the side of the trunk (for α see Figure 2, where forward inclination is given a positive sign). Annex A describes the procedure for determining trunk inclination.

[c] Convex curvature of the lumbar part of the spine (see Figure 3). This posture is more likely to occur

— when the lumbar spine is not supported by a backrest, and

— when a small hip angle is adopted (see 3.7).



Key

1 Axial rotation

2 Lateral flexion

Figure 1 — Trunk posture (axial rotation/lateral flexion of thorax vs. pelvis)

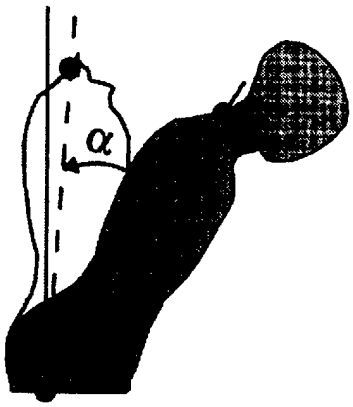
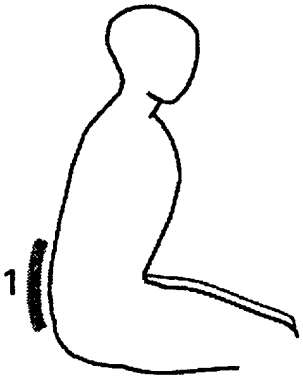


Figure 2 — Trunk inclination



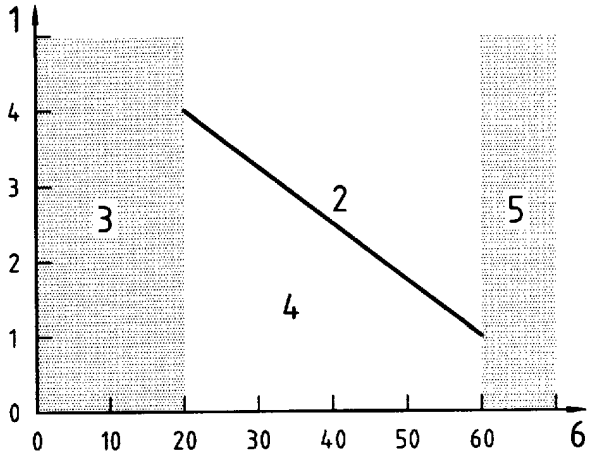
Key

1 Convex lumbar spine posture

Figure 3 — Convex lumbar spine posture

Table 2 — Holding time for trunk inclination

Holding time	Acceptable	Not recommended
> maximum acceptable holding time [a]		X
⩽ maximum acceptable holding time [a]	X	
[a] Taken from Figure 4.		



Key

1 Maximum acceptable holding time (minutes)
2 Not recommended
3 See 3.4.1, step 1
4 Acceptable
5 See 3.4.1, step 1
6 Trunk inclination α (degrees vs. reference posture)

Figure 4 — Maximum acceptable holding time vs. trunk inclination

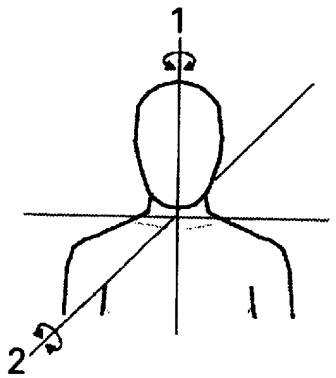
Table 3 — Head posture

	Postural characteristic	Acceptable	Go to step 2	Not recommended
1)	Symmetrical neck posture [a]			
	No			X
	Yes	X		
2)	Head inclination β [b]			
	$> 85°$			X
	25° to 85° without full trunk support: [c] go to item 3			
	25° to 85° with full trunk support		X	
	0° to 25°	X		
	$< 0°$ without full head support			X
	$< 0°$ with full head support	X		
3)	Neck flexion/extension $\beta - \alpha$ [b]			
	$> 25°$			X
	0° to 25°	X		
	$< 0°$			X

[a] With a symmetrical neck posture, there is neither axial rotation nor lateral flexion of the head with respect to the upper part of the trunk (thorax) (see Figure 5).

[b] Posture during task execution (dark body segment, solid line) with respect to the reference posture (white body segment, broken line) when viewed from the side of the head (for β see Figure 6, where forward inclination is given a positive sign; for α see 3.4 on trunk posture). Positive values for $\beta - \alpha$ are called neck flexion. Negative values for $\beta - \alpha$ are called neck extension. Annex A describes the procedure for determining head inclination and neck flexion/extension.

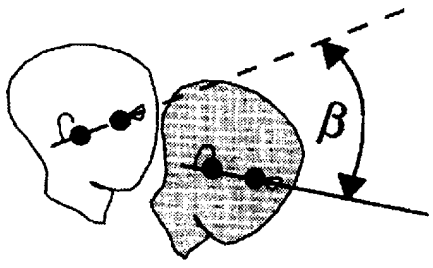
[c] At about the same head and trunk inclination, the holding time for the trunk is critical, because the maximum acceptable holding time for the trunk is lower than the maximum acceptable holding time for the head. In the case of full trunk support, the holding time for head inclination is critical, and should be evaluated (see 3.5.2).



Key

1 Axial rotation
2 Lateral flexion

Figure 5 — Neck posture (axial rotation/lateral flexion of head vs. thorax)

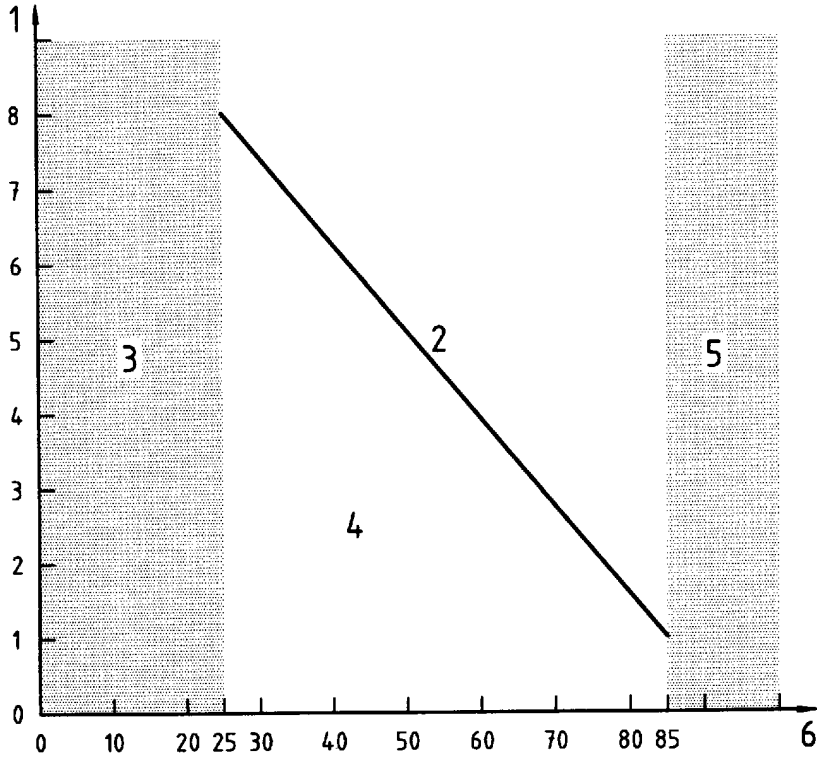


NOTE The straight lines are not lines of sight, but lines through the points used for measurement.

Figure 6 — Head inclination

Table 4 — Holding time for head inclination

Holding time	Acceptable	Not recommended
> maximum acceptable holding time [a]		X
⩽ maximum acceptable holding time [a]	X	
[a] Taken from Figure 7.		



Key

1 Maximum acceptable holding time (minutes)
2 Not recommended
3 See 3.5.1, step 1
4 Acceptable
5 See 3.5.1, step 1
6 Head inclination β (degrees vs. reference posture)

Figure 7 — Maximum acceptable holding time vs. head inclination

3.6 Upper extremity posture

3.6.1 . Shoulder and upper arm posture

3.6.1.1 Step 1

Shoulder and upper arm posture should be evaluated by considering items 1, 2 and 3 in Table 5 for both sides of the body.

3.6.1.2 Step 2

The holding time for upper arm elevation is evaluated using Table 6.

It is recommended to provide adequate recovery time following the holding time for a certain upper arm elevation. Informative annex B provides recommendations for evaluating holding time/recovery time regimes based on endurance data.

3.6.2 Forearm and hand posture

Forearm and hand posture should be evaluated by considering items 1, 2 and 3 in Table 7 for both sides of the body.

3.7 Lower extremity posture

Lower extremity posture should be evaluated by considering items 1, 2, 3 and 4 in Table 8 for both sides of the body. Item 3 refers only to standing (except when using a buttock rest). Item 4 refers only to sitting. Special consideration should be given to

— an even distribution of the body weight over both feet when standing or using a buttock rest,

— a proper body support by means of a stable seat, footrest, or buttock rest, whichever applies, and

— a favourable position of the knee and ankle when operating a pedal in a sitting posture.

For the hip angle in Figure 12, refer to 3.1.

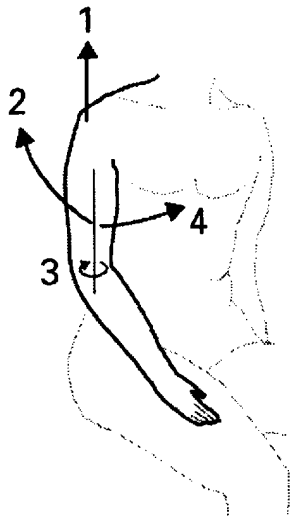
Table 5 — Shoulder and upper arm posture

	Postural characteristic	Acceptable	Go to step 2	Not recommended
1)	Awkward upper arm posture [a]			
	No	X		
	Yes			X
2)	Upper arm elevation γ [b]			
	$> 60°$			X
	$20°$ to $60°$ without full arm support		X	
	$0°$ to $60°$ with full arm support	X		
	$20°$ to $20°$	X		
3)	Raised shoulder [c]			
	No	X		
	Yes			X

[a] Either upper arm retroflexion (i.e. elbow behind the trunk when viewed from the side of the trunk), upper arm adduction (i.e. elbow not visible when viewed from behind the trunk), or extreme upper arm external rotation ("external" refers to an outward rotation around the long axis of the upper arm with respect to the trunk). For all three terms, see Figure 8. For "extreme", refer to clause A.4.

[b] Posture during task execution (dark body segment, solid line) with respect to the reference posture (white body segment, broken line) (for γ see Figure 9). Annex A describes the procedure for determining upper arm elevation.

[c] The evaluation procedure refers to the awkward posture indicated by the vertical arrow in Figure 8, but not to the natural raising of the shoulder top as a consequence of upper arm elevation.



Key

1 Raised shoulder
2 Upper arm retroflexion
3 Upper arm external rotation
4 Upper arm adduction

Figure 8 — Shoulder and upper arm posture

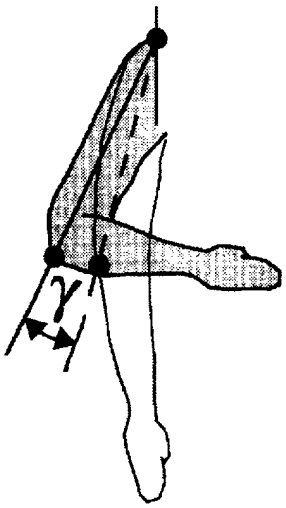
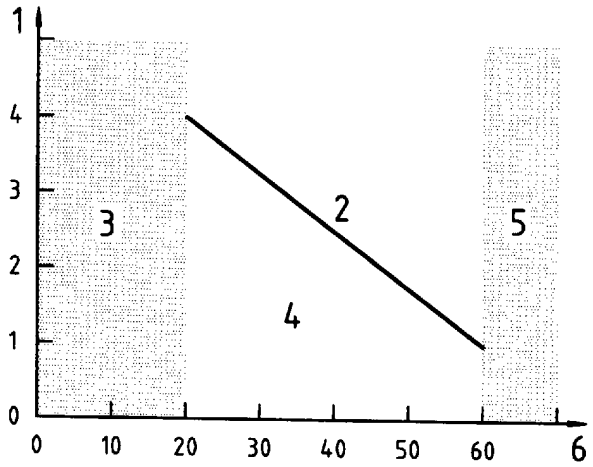


Figure 9 — Upper arm elevation

Table 6 — Holding time for upper arm elevation

Holding time	Acceptable	Not recommended
> maximum acceptable holding time [a]		X
⩽ maximum acceptable holding time [a]	X	
[a] Taken from Figure 10.		



Key

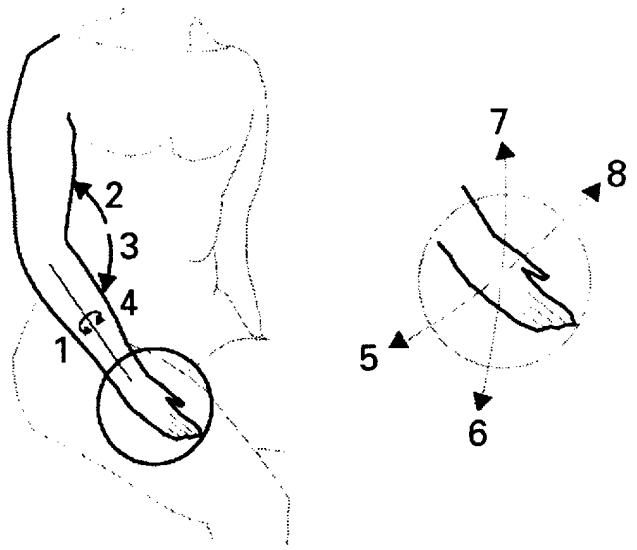
1 Maximum acceptable holding time (minutes)
2 Not recommended
3 See 3.6.1.1, step 1
4 Acceptable
5 See 3.6.1.1, step 1
6 Upper arm elevation γ (degrees vs. reference posture)

Figure 10 — Maximum acceptable holding time vs. upper arm elevation

Table 7 — Forearm and hand posture

Postural characteristic	Acceptable	Not recommended
1) Extreme elbow flexion/extension [a, b]		
No	X	
Yes		X
2) Extreme forearm pronation/supination [a, b]		
No	X	
Yes		X
3) Extreme wrist posture [b, c]		
No	X	
Yes		X

[a] See Figure 11.
[b] For "extreme", refer to clause A.4.
[c] Radial/ulnar abduction and/or flexion/extension (see Figure 11).



Key

1 Forearm supination: palm of the hand up
2 Elbow flexion
3 Elbow extension
4 Forearm pronation: palm of the hand down
5 Wrist ulnar abduction: little finger moved towards the forearm (ulnar bone)
6 Wrist flexion: palm of the hand moved towards the forearm
7 Wrist extension: back of the hand moved towards the forearm
8 Wrist radial abduction: thumb moved towards the forearm (radial bone)

Figure 11 — Forearm and hand posture

Table 8 — Lower extremity posture

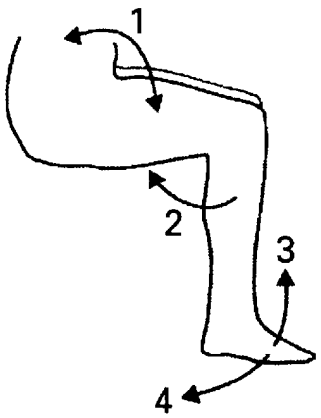
Postural characteristic		Acceptable	Not recommended
1)	Extreme knee flexion [a]		
	No	X	
	Yes		X
2)	Extreme ankle plantar flexion/dorsiflexion [a]		
	No	X	
	Yes		X
3)	For standing (except when using a buttock rest): flexed knee [b]		
	No	X	
	Yes		X
4)	For sitting: knee angle [c]		
	$> 135^\circ$		X [d]
	90° to 135°	X	
	$< 90^\circ$		X

[a] See Figure 12. For "extreme", refer to clause A.4.

[b] Any joint position other than 180° (the upper leg in line with the lower leg).

[c] 180° = the upper leg in line with the lower leg.

[d] Acceptable with a backward inclined trunk.



Key

1 Hip angle
2 Knee flexion
3 Ankle dorsiflexion
4 Ankle plantar flexion

Figure 12 — Lower extremity posture

Annex A
(informative)

Determination of working postures

A.1 Introduction

Clauses A.2 and A.3 contain the procedure for measuring trunk inclination, head inclination and neck flexion/extension (A.2), and upper arm elevation (A.3). This procedure is based on the use of photography/video (2-dimensional measurement) and/or 3-dimensional opto-electronic or ultrasound measuring systems. Clause A.4 contains the procedure for determining extreme joint positions.

For the measurement procedures described in clauses A.2 and A.3, two points should be marked on each body segment involved. For this, the following requirements apply:

— the points should be related to the body segment;

— the points should be detectable by the measuring system;

— the points should not be too close together (in order to reduce measurement error).

It is most important that the same points are used for measuring both the reference posture, and the posture during task execution. Particular points are recommended below on the basis of past experiences. However, any other set of points may be picked, provided the above mentioned requirements are met.

A.2 Trunk inclination, head inclination and neck flexion/extension

Two body segments are distinguished, i.e. the trunk and head. Each segment is defined as a straight line through two points on the segment when viewed from the side of the segment (i.e. perpendicular to the plane of symmetry of the segment).

The procedure starts by marking two points on the trunk, e.g. at the upper edge of the greater trochanter (denoted T1), and at the spinous process of the 7th cervical vertebra (denoted T2), along with two points on the head, e.g. close to the lobe of the ear (denoted H1) and close to the lateral corner of the eye (denoted H2).

The following three steps are executed for the trunk segment, as well as for the head segment. The first step involves measuring the angle between the vertical and the line through the body segment (T1-T2 for the trunk, H1-H2 for the head) in the reference posture (see Figure A.1). The second step involves measuring the angle between the vertical and the line through the same segment (T1-T2 for the trunk, H1-H2 for the head) in the posture during task execution. In the third step, the inclination of the body segment (denoted α for the trunk and β for the head in 3.4 and 3.5, respectively) is calculated as the difference between the angle in the reference posture and the angle in the posture during task execution.

NOTE The definition of reference posture includes "while looking straight forward along the horizontal". For this, first the eye height is measured, then a mark is placed on a wall at the eye height measured at a distance from the subject and the subject is asked to look at the mark.

Finally, neck flexion/extension (i.e. the position of the head with respect to the trunk) is calculated as the difference between head inclination and trunk inclination (denoted $\beta - \alpha$ in 3.5).

As an example, Figure A.1 shows the reference posture (white body, broken lines), as well as a posture during task execution (dark body, solid lines). Both also contain vertical lines for measurement purposes.

The angle between the vertical and the broken line T1-T2 in the reference posture is 4°, whereas the angle between the vertical and the solid line T1-T2 in the posture during task execution is 33°. Therefore, trunk inclination (denoted α in 3.4) is equal to 29° (i.e. 33° − 4°).

The angle between the vertical and the broken line H1-H2 in the reference posture is 71°, whereas, the angle between the vertical and the solid line H1-H2 in the posture during task execution is 140°. Therefore, head inclination (denoted β in 3.5) is equal to 69° (i.e. 140° − 71°).

Neck flexion (i.e. head inclination minus trunk inclination; denoted $\beta - \alpha$ in 3.5) is equal to 40° (i.e. 69° − 29°).

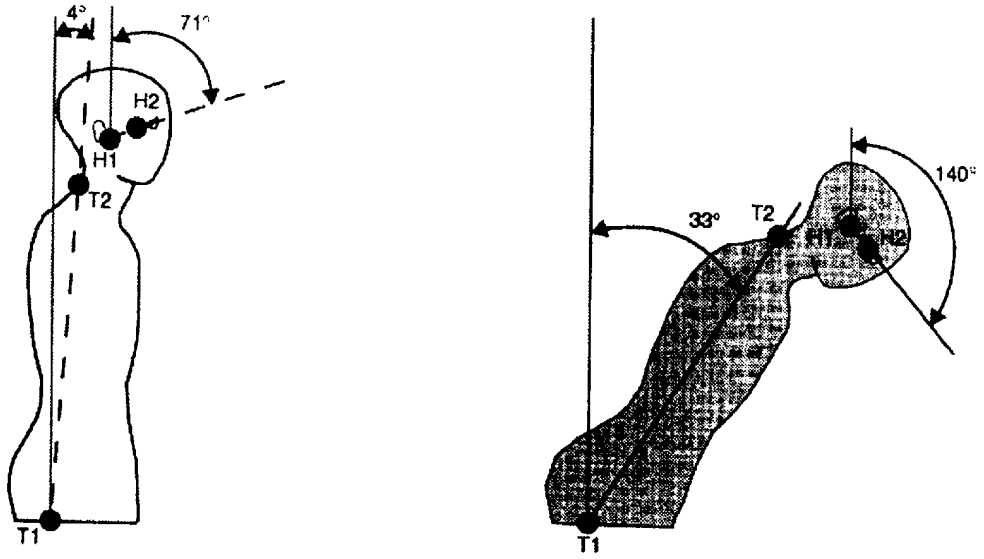


Figure A.1 — Determination of head and trunk inclination

A.3 Upper arm elevation

The procedure starts by marking two points on the upper arm, e.g. at the acromio-clavicular joint (denoted UA1) and at the humero-radial joint (denoted UA2). The upper arm is defined as a straight line through both points.

The following three steps refer to real angles, i.e. not depending on a viewing direction during measurement as in clause A.2. The first step involves measuring the angle between the vertical and the line through the upper arm (UA1-UA2) in the reference posture. The second step involves measuring the angle between the vertical and the line through the upper arm (UA1-UA2) in the posture during task execution. In the third step, the elevation of the upper arm is calculated as the difference between the angle in the reference posture and the angle in the posture during task execution (denoted γ in 3.6.1).

As an example, Figure A.2 shows the reference posture (white body, broken lines), as well as a posture during task execution (dark body, solid lines). Both also contain a vertical line for measurement purposes.

The angle between the vertical and the broken line UA1-UA2 in the reference posture is 13°, whereas the angle between the vertical and the solid line UA1-UA2 in the posture during task execution is 21°. Therefore, upper arm elevation (denoted γ in 3.6.1) is equal to 8° (i.e. 21° − 13°).

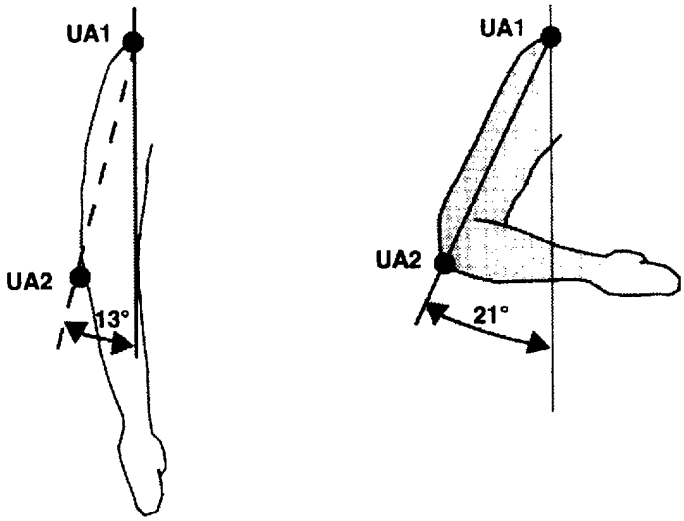


Figure A.2 — Determination of upper arm elevation

A.4 Extreme joint positions

For quite a number of joints, it can be observed whether extreme positions are adopted during task execution. Alternatively, the worker involved can be asked whether a resistance was felt at the joint during a particular operation, or whether it could still be moved further about the joint until resistance was felt, that is workers do feel very well when the task/operation forces a joint in an extreme position or not. Goniometers (angle-measuring devices) provide for more accurate measurement of joint angles. Such a device allows not only for measuring the actual joint position while executing a task, but also allows for quantifying the extreme joint positions of the worker involved.

The scientific literature with regard to group distributions of ranges of motion for joints shows considerable variability (refer to [6] to [9] in the Bibliography). On the basis of this literature, Table A.1 provides indications of the limit(s) of the range of motion for those extreme joint positions that are mentioned in clause 3.

Table A.1 — Indications of the limits of joint ranges of motion

Postural parameter	Range of motion limit	Reference	
		Table	Figure
Upper arm external rotation	90°	5	8
Elbow flexion	150°	7	11
Elbow extension	10°	7	11
Forearm pronation	90°	7	11
Forearm supination	60°	7	11
Wrist radial abduction	20°	7	11
Wrist ulnar abduction	30°	7	11
Wrist flexion	90°	7	11
Wrist extension	90°	7	11
Knee flexion	40°	8	12
Ankle dorsiflexion	20°	8	12
Ankle plantar flexion	50°	8	12
NOTE All the figures mentioned are with, respect to an upright standing posture with the arms hanging freely, and the palms of the hands facing the body.			

Annex B
(informative)

Evaluation of holding time/recovery time regimes

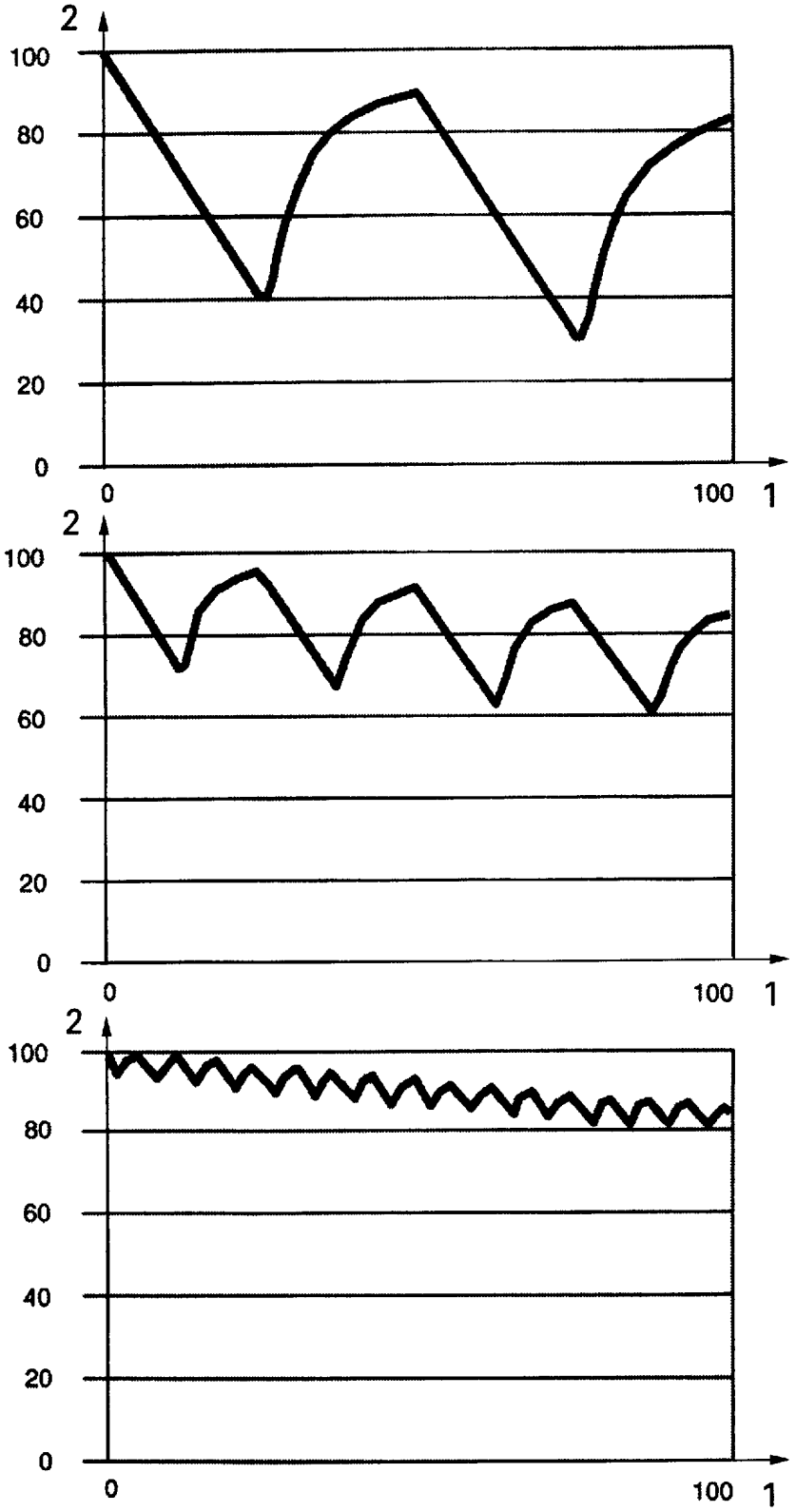
B.1 Introduction

There are various ways to evaluate holding time/recovery time regimes, e.g. based on endurance data; based on intervertebral disk physiology; or based on muscle physiology. It is recommended to consult an expert for evaluating holding time/recovery time regimes. Refer to the national standards bodies for up-to-date information on experts. Clause B.2 contains the background information needed by an expert for evaluating holding time/recovery time regimes based on endurance data.

B.2 Evaluation of holding time/recovery time regimes based on endurance data

Maximum holding times for trunk inclination, head inclination, and upper arm elevation were established on the basis of endurance data. From the various ranges of maximum holding times in these data, the lowest values were taken in order to give reasonable protection for nearly all healthy adults. The maximum acceptable holding times shown in Figures 4, 7 and 10 are equal to 20 % of the maximum holding times, that is a remaining endurance capacity of 80 %. Any maximum acceptable holding time can be considered as the equivalent of a score of 2 on a subjective rating scale ranging from 0 (no pain/discomfort) to 10 (maximum pain/discomfort). Any holding time should be followed by a recovery time, such that the remaining endurance capacity is not below 80 %. Refer to the following example.

As an example, the effects of three holding time/recovery time regimes on the remaining endurance capacity (REC) are shown in Figure B.1 and based upon an endurance model and a recovery model. The regimes are equal, as far as the same total holding time and total recovery time (in terms of minutes) is concerned. It can be seen that more (and shorter) holding time periods (i.e. more breaks) result in a higher average REC.



Key

1 Time, %

2 REC, %

Figure B.1 — Effects of three holding time/recovery time regimes on remaining endurance capacity (REC)

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1) To be published.

2) To be published.

3) To be published.

ICS 13.180

Price based on 19 pages