TECHNICAL REPORT

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Mechanical vibration — Description and determination of seated postures with reference to whole-body vibration

Vibrations mécaniques — Description et détermination des postures assises en référence à des vibrations transmises à l'ensemble du corps

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Foreword

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In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TR 10687 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 4, *Human exposure to mechanical vibration and shock*.

Introduction

Seated persons exposed to whole-body vibration carry a risk for low-back pain and for spinal degeneration which is most likely increased by unfavourable postures. However, the biomechanical mechanism of this increase is not fully understood.

It is therefore necessary, as a first step, to determine the posture and ergonomic environment of a seated person with special focus on the spine.

To this end, this Technical Report summarizes descriptive quantities that

— are likely to be relevant for the assessment of adverse health effects due to whole-body vibration and unfavourable seated posture;

— can be determined using a variety of methods;

— are in accordance with the description of static, unfavourable seated postures as far as angles of body segments are concerned;

— include additional information, e.g. the presence of arm- or backrests.

It is recommended that the whole set of quantities be reported in order to

— facilitate the comparison of seated postures;

— be able to compare different methods for the determination of the seated posture;

— permit further investigation, e.g. in biomechanical laboratories, on the basis of the determined seated postures.

Due to limitations of the applied assessment methods, it might be necessary to combine different methods in order to be able to report a complete list of quantities.

This Technical Report does not recommend sampling strategies or evaluation methods.

Mechanical vibration — Description and determination of seated postures with reference to whole-body vibration

1 Scope

This Technical Report summarizes descriptive quantities for those responsible (e.g. scientists, safety engineers) for determination of postures for a seated person who is exposed to whole-body vibration. It is the intention that the results of different methods which also are summarized can be easily related to these quantities and that they allow for a common terminology between practitioners. The postures determined can also be used as a basis for further investigation or as a means of comparison for different methods. Although some of the approaches described here can be applied to standing or recumbent positions, additional considerations are likely to be required in these cases.

NOTE 1 This work is closely related to International Standards which focus on static postures (ISO 11226[4]) or on radiologically accessible landmarks, i.e. points on the body (ISO 8727[3]).

Additionally, this Technical Report deals with dynamic postures where body angles or associated movements are determined visually or by measuring points on the skin or clothing.

NOTE 2 Nevertheless, ISO 8727[3] and ISO 11226[4] put forward principles for further extensions which are followed in this Technical Report, in particular for measurements of body angles.

This Technical Report does not recommend sampling strategies or evaluation methods.

2 Description of posture quantities

2.1 General

This clause summarizes the description of measurable quantities used in 5.2. The basis of the descriptions is the points on the body as shown in Figure 1.

2.2 Points on the body

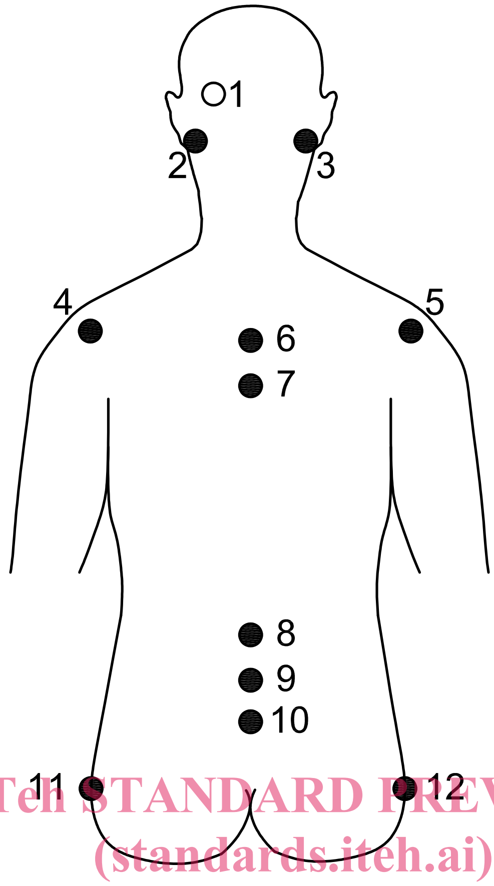
With the help of the points on the body presented in Figure 1, lines and planes can be defined, which in turn define a posture. They are chosen in such a way that their position in space is relevant for the strain on the spine.

A line between two points is represented by the respective normalized vector, $\boldsymbol{v}_\mathrm{l}$. A plane is represented by three points and a normalized vector, $\boldsymbol{v}_\mathrm{pl}$, perpendicular to that plane.

Their angles with respect to the coordinate system can in turn be correlated to movements of parts of the spine that are considered to be independent from one another.

A general vector in the coordinate system described in Clause 4 is represented in Figure 2.

Having defined suitable points on the body, two markers for optical measurement systems determine a line, $\boldsymbol{v}_\mathrm{l}$, and three markers are needed for a plane, $\boldsymbol{v}_\mathrm{pl}$. Triaxial accelerometers, on the other hand, combined with, e.g. gyroscopes or magnetic sensors, offer a possibility to measure a (local) line, $\boldsymbol{v}_\mathrm{l}$, with only one sensor unit.



Key

1 left lateral canthus
2 left tragus
3 right tragus
4 left acromion
5 right acromion
6 C_7 (spinous process)
7 T_3 (spinous process)
8 L_5 (spinous process)
9 L_3 (spinous process)
10 L_1 (spinous process)
11 left greater trochanter
12 right greater trochanter

Figure 1 — Sketch of the human body with landmarks, i.e. points on the body that should be monitored if using a marker-based measurement system

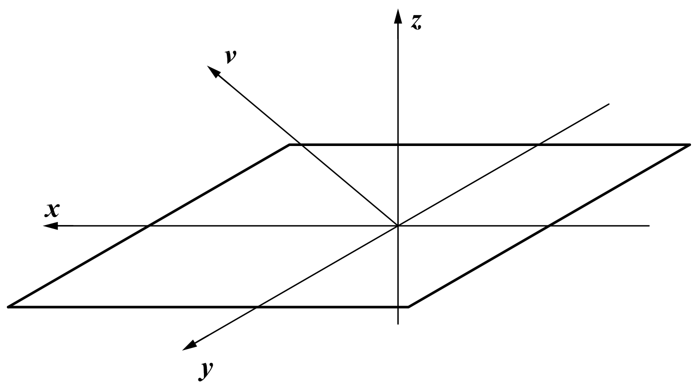


Figure 2 — Cartesian coordinate system for a general vector, *v*

Experiments that do not measure the absolute posture in space, but a relative posture, should measure the reference (the upright standing or seated posture) in the Cartesian coordinate system of Clause 4 in order to be able to transform their data later.

2.3 Flexions and axial rotations

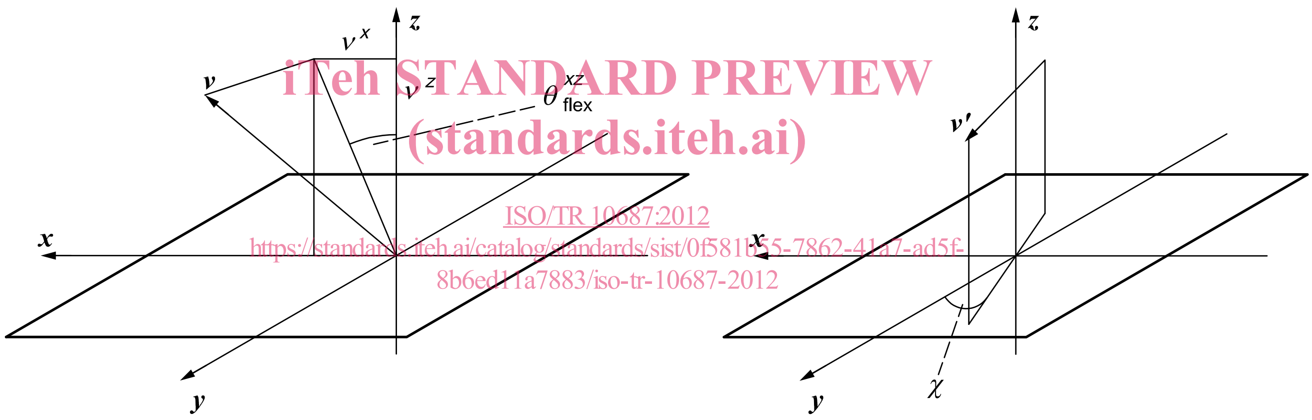
Once the posture of a part of the body is defined by a vector, $\boldsymbol{v}$, its sagittal flexion can be defined by the angle $\theta_{\text{flex}}^{xz}$ of the projection of $\boldsymbol{v}$ on to the xz-plane and the z-axis:

$$\theta_{\text{flex}}^{xz} = \arctan\frac{v^x}{v^z} \tag{1}$$

This is shown in Figure 3 a). A sagittal extension is given by $v^x < 0$. The lateral flexion is defined accordingly by the angle of the projection of $\boldsymbol{v}$ on to the yz-plane and the z-axis:

$$\theta_{\text{flex}}^{yz} = \arctan\frac{v^y}{v^z} \tag{2}$$

Here, the sign of v^y determines left and right lateral flexion.



a) Sagittal flexion of a vector *v* **b) Rotation of a vector *v***

Figure 3 — Sagittal flexion and rotation of a vector *v*

The effects of flexions and extension on a given vector $\boldsymbol{v}_{\text{rot}}'$ parallel to z can be described by applying a rotary matrix to that vector $\boldsymbol{D}^{-1}(\theta,\phi)\boldsymbol{v}_{\text{rot}}' = \boldsymbol{v}_{\text{rot}}$ where θ, ϕ are the polar angles of $\boldsymbol{v}_{\text{rot}}$. Consequently, the effects can be eliminated by the inverse rotary matrix $\boldsymbol{v}_{\text{rot}}' = \boldsymbol{D}(\theta,\phi)\boldsymbol{v}_{\text{rot}}$. This is used to describe axial rotation independently from flexions and extension.

If $\boldsymbol{v}_{\text{rot}}$ is the rotation axis around which another unit vector $\boldsymbol{v}$ is rotated, and if $\boldsymbol{v}_{\text{rot}}' = \boldsymbol{D}(\theta,\phi)\boldsymbol{v}_{\text{rot}}$ is parallel to z, then $\boldsymbol{v}' = \boldsymbol{D}(\theta,\phi)\boldsymbol{v}$ defines the vector $\boldsymbol{v}'$ which in this Technical Report is always chosen to be orthogonal to $\boldsymbol{v}_{\text{rot}}'$ and z, see Figure 3 b).

This defines the rotation angle of $\boldsymbol{v}$ around $\boldsymbol{v}_{\text{rot}}$, independent from flexions and extension, with respect to $\boldsymbol{y}$ by the scalar product

$$\chi = \arccos(\boldsymbol{v}' \cdot \boldsymbol{y}) \tag{3}$$

This is illustrated in Figure 3 b).

Annex A gives examples for the application of these definitions to different body segments. Angles pertinent to different body segments are shown in 5.2.2 to 5.2.10.

2.4 Symbols

C_1 to C_7	vertebrae of the cervical spine
$\boldsymbol{D}$	rotary matrix
L_1 to L_5	vertebrae of the lumbar spine
N	normalization constant
T_1 to T_{12}	vertebrae of the thoracic spine
th, ls	subscripts indicating the thoracic and lumbar spine
$\boldsymbol{v} = \overrightarrow{AB}$	vector between points A and B
$\boldsymbol{v} = (v^x, v^y, v^z)$	vector, represented by its Cartesian coordinates
$\boldsymbol{v}' = \boldsymbol{Dv}$	vector without influence of flexion and extension
$\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{z}$	unit vectors of the Cartesian coordinate system
χ	angle between two vectors
θ, ϕ	polar angles, the z-axis of the coordinate system as polar axis

3 Biomechanical background

3.1 General

This clause provides the biomechanical background for the selection of relevant quantities with respect to the spinal load of seated persons subject to whole-body vibration.

3.2 Spinal segments

In order to describe the spinal load as closely as possible, the range of motion of different parts of the spine in flexion, extension, and axial rotation has to be considered. A summary is given in Table 1 which indicates that the lumbar, thoracic and cervical spine show different mobility and should, therefore, be treated separately.

Table 1 — Maxima and minima of spinal tolerances towards movement according to Reference [6]

Type of movement	Maxima (vertebrae)	Minima (vertebrae)
Sagittal flexion	C_0/C_1, C_4/C_5, L_4/L_5	T_9/T_{10}
Sagittal extension	C_0/C_1, C_4/C_5, L_5/S_1	T_9/T_{10}
Lateral flexion	C_1/C_2, C_7/T_1, L_3/L_4	T_5/T_6
Axial Rotation	C_1/C_2, T_{12}/L_1	T_5/T_6
NOTE C_0 is the occiput.		

Due to the large mobility in the cervical spine (vertebrae C_1 to C_7), it is more feasible to describe its movement by the position of the head (sagittal flexion/extension, lateral flexion, axial rotation).

The thoracic spine (vertebrae T_1 to T_{12}) is separated from the lumbar spine by a distinct minimum for all types of movement. Therefore, the axial rotation, sagittal flexion/extension and lateral flexion of the thoracic spine are investigated separately.

The lower part of the lumbar spine is closely connected to the pelvis. The forward and backward tilting of the pelvis leads concomitantly to the lordosis or kyphosis of the lumbar spine (vertebrae L_1 to L_5). This is an additional degree of freedom which has already been addressed in ISO 11226.[4] As for the other degrees of freedom of the lumbar spine, it is sufficient to measure the sagittal flexion/extension and lateral flexion, since the axial rotation is negligible for the seated person.

3.3 Body segments apart from the spine

Appendicular body segments (i.e. the upper and lower limb) are known to affect the biomechanical response of the seated body. The position of the lower limb can affect the apparent mass and transmissibility as can the position of the upper limb. For drivers, the position of the upper limb can be dictated by the nature of the driving task, the nature and position of controls. The position of the lower limb can be dictated by the presence of pedals, the seat height, and upholstery in the vehicle.

In order to fully describe the position and loading on the spine of the seated subject, it is necessary to consider the position of all body segments as this affects the position of the centre of mass which the musculoskeletal system is required to support.

3.4 Other quantities

Detailed segmental positions alone do not fully describe the loading on the body. For example, one set of segment angles could be stable or unstable depending on whether a seat was present or not. Similarly, they do not allow for a description of the biomechanical response as it is known that the presence of a backrest affects the apparent mass and transmissibility.

4 Coordinate system

In most cases, the person is seated in a vehicle with the position of the pelvis in the seat pointing forward. Because the direction of the seat might not correspond to the direction of motion of the vehicle, the seat might not have a clear front (e.g. a stool) or the coordinate systems used in other whole-body vibration standards, e.g. ISO 2631-1,[1] may not match this coordinate system; consequently, appropriate transformations can be necessary.

A suitable coordinate system resembles an external polar coordinate system. It consists of orthogonal unit vectors $\boldsymbol{x}$, $\boldsymbol{y}$, and z. The vector $\boldsymbol{x}$ is fore-aft at the pelvis; $\boldsymbol{y}$ is lateral and left at the pelvis and z is vertical at the pelvis (Figure 4). For upright seated persons, the vector z opposes gravity. The y-axis of the coordinate system is parallel to the y-axis of the pelvis, given by the line that connects the greater trochanters. This coordinate system is the basis for all variables concerning the movements of the spine described in Clause 5.

NOTE 1 The line that connects the greater trochanters is not necessarily the rotational axis of the pelvis. Within the levels of accuracy of this Technical Report, this is acceptable.

If the pelvis orientation does not correspond to the seat orientation, the coordinate system rotates with the pelvis. This might be the case, e.g. when the driver is leaning out of the window or is driving backwards for a longer time. Then the coordinate system should be transformed in such a way that the transformed coordinate system's new y-axis is again parallel to the y-axis of the pelvis and the angle of old and new z-axis is minimal. If there is spinal axial rotation, the origin is defined at the pelvis.