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Wheelchair seating —

Part 14:
Concepts related to managing external forces to maintain tissue integrity

Sièges de fauteuils roulants —

Partie 14: Concepts liés à la gestion des forces externes pour maintenir l'intégrité des tissus

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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 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 173, *Assistive products*, Subcommittee SC 1, *Wheelchairs*.

A list of all parts in the ISO 16840 series can be found on the ISO website.

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

The influence of pressure on the health of skin tissues has been acknowledged for some time: what used to be called "bed sores" or "decubitus ulcers" became renamed "pressure ulcers" in Europe and "pressure injuries" in much of the rest of the world. However, in recent years, greater awareness of other extrinsic factors affecting the health of skin tissues has led to increased reference to the more general term of tissue integrity. The current pressure injury definition from the 2019 International Guideline Prevention and Treatment of Pressure Ulcers/Injuries[1] highlights this new understanding. Pressure injury is referred to in Reference [1] as “localized damage to the skin and/or underlying tissue, as a result of pressure or pressure in combination with shear.” “The tissue damage occurs as the result of intense and/or prolonged exposure to sustained deformations in compression (perpendicular to the tissue surface), tension or shear (parallel to the tissue surface), or a combination of these loading modes. The tolerance of soft tissue for sustained deformations differs by tissue type and may also be affected by microclimate, perfusion, age, health status (either chronic or acute), comorbidities, and conditions of the soft tissues”.

The current NPIAP/EPUAP/PPPIA Guidelines[1] note the changing views on pressure injury staging. Stages 1 and 2 are described as “partial-thickness tissue loss” and having the strongest connections to superficial microclimate (temperature, humidity, altered pH due to incontinence), shear, and friction effects. Stage 1 and 2 pressure injuries are also described as ‘outside in’ skin damage[2]. Stages 3 and 4, Unstageable, and Suspected Deep Tissue Pressure Injury are categorized in the Guidelines as “full-thickness skin and tissue loss”. Deep tissue injury is an ‘inside out’ skin damage, which usually originates in deep soft tissues subjected to external pressure and shear forces and subsequent deformations around the bony prominences[2]. Suspected deep tissue injury is one of the most challenging pressure injuries for accurate identification: it can present as an intact non-blanchable red, maroon, or purple discolouration that can quickly evolve to reveal a full tissue loss[3]. Current guidelines advise clinicians not to think of the numbered stages as linear progression of the wound towards improvement/healing or worsening, but rather use the stage descriptions to note the maximum depth of a wound at a single point in time[3].

While the characteristics of an ideal microclimate (skin temperature and humidity) are still being researched, it is recognized that there are strong connections between microclimate and friction, and hence surface and internal tissue loads. This is relevant for all pressure injuries, not just the superficial ones[1].

It is the materials closest to the skin, be they clothing, continence products, and/or the materials in the cover of the support surface that the person is sitting or lying on that often have the most impact on microclimate, friction, and shear effects on the surface of the skin.

Stage 3 and 4, Unstageable and Suspected Deep Tissue, Pressure Injuries affect the deeper layers of the skin and around bony tissues and are currently thought to derive from the effects of external pressure, external shear forces, and the resulting internal shear stresses and strains.

Both short-term high pressure and long-term moderate pressures can be harmful for soft tissues. Internal muscular, adipose, and dermal tissue deformations are linked to multitude of damaging effects: partial or total occlusions of microvascular and lymphatic network, tissue ischemia, direct cell deformations with cytoskeleton distortions and breakdown, cellular DNA damage, tissue inflammation and necrosis, pH changes in interstitial fluids, altered orientation of collagen fibres, and subepidermal separation[2][4][5][6].

Combined effects of shear and pressure can be more damaging than effects of pressure and gravity forces alone. These effects can be ameliorated or exacerbated by the materials and construction of support surfaces.

The accompanying effects of shear strain alongside the pressures introduced by the effects of gravity creating areas of pressure on the body, have a more damaging effect on the tissues themselves, than pressure alone.

Frequently the terms discussed in this document are misused or confused in general usage. This document has been created to aid in understanding the differences between the defined extrinsic elements and their respective effects on human tissues.

Wheelchair seating —

Part 14: Concepts related to managing external forces to maintain tissue integrity

1 Scope

This document describes common terms related to forces and their effects as experienced by human bodies and their support surfaces. It provides further information on concepts around how these forces affect the human body's response to postural support systems, and particularly highlights the impact of the interface between tissues and postural support devices (PSD) on the maintenance of tissue integrity. It provides a general introduction to biomechanical concepts, phenomena, and vocabulary. This will facilitate effective understanding and sharing of information between a range of disciplines/ stakeholders involved in providing equipment to manage tissue integrity.

Representative stakeholders include people with a disability, occupational therapists, physical therapists, biomedical engineers, nurses, medical and para medical personnel, device manufacturers, and other professionals facilitating development, provision, and access to seating and mobility equipment.

This document does not provide detailed information that is currently available in physiological text books or scientific literature.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7176-26, *Wheelchairs — Part 26: Vocabulary*

ISO 16840-1, *Wheelchair seating — Part 1: Vocabulary, reference axis convention and measures for body segments, posture and postural support surfaces*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7176-26 and ISO 16840-1 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
perpendicular force
force occurring at 90° to an element's surface

Note 1 to entry: It is measured in newtons (N).

3.2
shear force
F_s
force occurring parallel with an element's surface

Note 1 to entry: It is measured in newtons (N).

3.3
pressure
p
force per unit area in a direction perpendicular to the surface

$$p = X / A$$

where

p is the pressure (MPa);

X is the perpendicular force (N);

A is the area (mm^2);

1 MPa = 1 000 kPa.

Note 1 to entry: It is measured in pascals (Pa) or equivalent units.

3.4
shear stress
τ
shear force divided by the area of the element's surface to which the shear force is applied, parallel with the slope or plane in which it lies

$$\tau = F_s / A$$

where

τ is the shear stress (MPa);

F_s is the shear force (N);

A is the area (mm^2);

1 MPa = 1 000 kPa.

Note 1 to entry: It is measured in pascals (Pa) or equivalent units.

3.5
axial strain
normal strain
ε
change of dimension due to the action of pressure

Note 1 to entry: Axial strain is dimensionless.

EXAMPLE Compressive effects from pressure are illustrated in Figure 1.

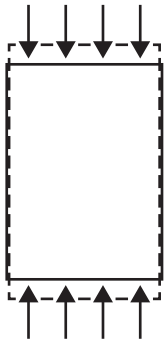


Figure 1 — Axial strain effects from the compressive effect of pressure

3.6
shear strain
γ
change in the shape of an element due to the action of shear stress

Note 1 to entry: Shear strain is dimensionless.

Note 2 to entry: See Figure 2.

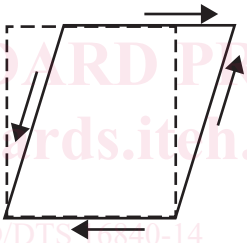


Figure 2 — Shear strain effects

3.7
shear modulus
G
ratio of shear stress to shear strain

Note 1 to entry: It is measured in pascals (Pa).

3.8
friction
force resisting the relative motion of two objects with surfaces in contact

3.8.1
static friction
friction force resisting the initial relative motion

3.8.2
dynamic friction
friction force resisting the motion while motion is in process

4 Effects on human tissues from interaction with a support surface

4.1 General principles

When any surface comes into direct contact with a user's body, then there will be a number of effects:

a) the skin surface is subject to complex pressure distributions;

b) the pressure distribution gradient at the interface surface, and friction forces, induce internal tissue deformation;

c) tissue deformation from the skin to the bony prominences produces an overall tissue displacement with respect to the unloaded tissue condition;

d) tissue deformation comprises internal axial strain and shear strain:

   1) axial strain and shear strain induce modification of internal blood and lymphatic circulation;

   2) blood vessel occlusion can lead to cellular death due to lack of oxygen and nutrients;

   3) high levels of cell strain can lead to cellular death due to disruption of the cytoskeleton.

e) there is modification of thermal exchange;

f) there is modification of moisture exchange;

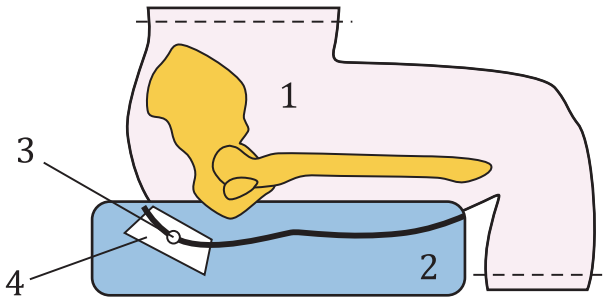
g) there is influence on the posture adopted by the body.

4.2 Phenomenological description

4.2.1 General

When a person sits on a seat cushion, there are two primary objects in contact with each other, as shown in Figure 3: the human body (key 1) and the cushion (key 2). There can be multiple interfaces between these two primary objects (e.g. clothes, cushion covers, sheets, continence products, etc).

Gravitational forces applied to the static human body are transmitted to the cushion through a contact surface whose complex shape can depend on the stiffness and shape of the human body and of the cushion. At any location of the contact surface (key 3), a tangential plane can be ideally defined (key 4).



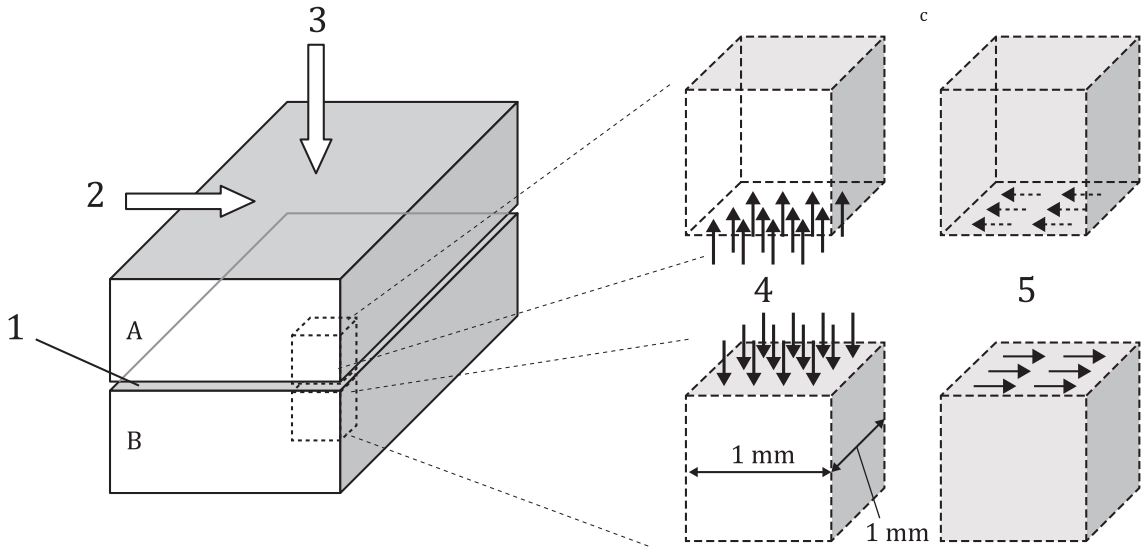
Key

1 human body
2 cushion
3 contact surface
4 tangential plane

Figure 3 — Human body in contact with a cushion

4.2.2 Pressure and shear

With reference to a given plane, two types of forces can be defined. The force at right angles to the plane is a perpendicular force. The force parallel with the plane is the shear force. This is described in part a of Figure 4 where the two objects are simplified as Object A and Object B. In Figure 4, the two objects are in contact at a common flat surface with an area A.



Key

1 contact surface
2 shear force
3 perpendicular force
4 pressure
5 shear stress
A object A
B object B

NOTE Object A can represent the skin of a seated person and Object B a support surface under a seated person.

a Forces acting on Object A and transmitted to Object B.

b Pressure and shear stress acting on the upper surface of a unit volume of Object B at the Object A-Object B contact surface.

c Pressure and shear stress acting on the lower surface of a unit volume of Object A at the Object A-Object B contact surface.

Figure 4 — Forces and stresses acting between two objects.

When the perpendicular force is distributed over the contact surface of area A, the pressure can be quantified. When the shear force is distributed over the contact surface of area A, the shear stress can be quantified, as described in parts b and c of Figure 4. These quantities can be extended also at any location of a curved contact surface, as local forces per unit area referenced to the local tangential plane (see Figure 5).