PD ISO/TR 16840-9:2015

BSI Standards Publication

Wheelchair seating

Part 9: Clinical interface pressure mapping guidelines for seating

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee CH/173/1, Wheelchairs.

A list of organizations represented on this committee can be obtained on request to its secretary.

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ISBN 978 0 580 87406 2

ICS 11.180.10

Compliance with a British Standard cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 July 2015.

Amendments issued since publication

Date	Text affected

PD ISO/TR 16840-9:2015

TECHNICAL REPORT

ISO/TR 16840-9

First edition
2015-07-01

Wheelchair seating —

Part 9: Clinical interface pressure mapping guidelines for seating

Sieges de fauteuils roulants —

Partie 9: Lignes directrices pour l'utilisation d'un système de mappage de pression

Reference number
ISO/TR 16840-9:2015(E)

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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 173, *Assistive products for persons with disability*, Subcommittee SC 1, *Wheelchairs*.

ISO 16840 consists of the following parts, under the general title *Wheelchair seating*:

— *Part 1: Vocabulary, reference axis convention and measures for body segments, posture and postural support surfaces*

— *Part 2: Determination of physical and mechanical characteristics of devices intended to manage tissue integrity — Seat cushions*

— *Part 3: Determination of static, impact and repetitive load strengths for postural support devices*

— *Part 4: Seating systems for use in motor vehicles*

— *Part 6: Simulated use and determination of the changes in properties of seat cushions*

— *Part 9: Clinical interface pressure mapping guidelines for seating* [Technical Report]

— *Part 10: Resistance to ignition of non-integrated seat and back support cushions — Requirements and test methods*

— *Part 11: Determination of perspiration dissipation characteristics of seat cushions intended to manage tissue integrity* [Technical Specification]

— *Part 12: Apparatus and method for cushion envelopment testing* [Technical Specification]

Introduction

The purpose of this Technical Report is to provide information as to where interface pressure mapping (IPM) can fit into a clinical assessment of an individual and their seating system, to highlight what can be achieved, and bring awareness of the limitations.

The use of IPM in the clinic is increasingly used to support clinicians in the evaluation of individual seating systems for individual clients. To get the best value from IPM requires a knowledge of the basic concepts of the interface pressure distribution (see Clause 2), the ability to define and apply a correct protocol for the application of IPM (see Clause 4), the ability to prepare correct documentation of the IPM (see Clause 5), and the skill in interpreting the collected data (see Clause 6).

The aim of an IPM test session can be different in a clinical or rehabilitation environment. In some cases, it can be a tool to compare the behaviour of different pressure care or postural cushions. It can also be used to support the clinician in finding the best match between cushion and client. Various applications looking at the broader picture are covered in Clause 3. Whichever the application, the main objective behind using an IPM needs to be clear from the beginning.

Wheelchair seating —

Part 9:
Clinical interface pressure mapping guidelines for seating

1 Scope

This Technical Report has been produced to guide users in the performance of the tasks that are directly involved in the clinical use of interface pressure mapping (IPM) or are synergistic with its use in a comprehensive wheelchair seating evaluation.

This Technical Report does not cover other aspects of the clinical assessment process (e.g. taking a medical history), nor the prescription or treatment process which might arise from an assessment. These guidelines are not meant to be a substitute for clinical reasoning and judgement within the context of a complete assessment.

This Technical Report refers to the state of the art of IPM experiences in a seating scenario. Most of the principles covered can be extrapolated to whole body (in bed) or to foot assessments, for example.

2 Definitions and glossary

2.1 Calibration

Calibration is a process wherein the sensing mat is subjected to known forces. The sensor responses are monitored and modelled in the software.

NOTE A record is kept of the responses (called a calibration file) and whenever the sensors output a similar response, the result is related to the previously known forces. In most cases, this is done by placing the mat in a purpose-built chamber with an air-filled bladder. The bladder is inflated and the pressure in the bladder is measured. It is assumed to be evenly pressurized over the mat.

Calibration allows for the software to accommodate changes with time (creep) or pressure (hysteresis) exhibited by the sensors.

Recalibrate the mat whenever the readings look unreliable, after excessive use, or at the manufacturer's recommended interval. Keep track of the uses of the mat and the date of the last calibration. Old calibration files should be retained (old calibration files can be loaded for comparison to determine change over a period).

2.2 Coefficient of Variation (CoV)

The CoV is expressed as a percentage:

$$\textit{Coefficient of Variation} = \frac{\textit{Standard deviation}}{\textit{Mean}} \quad (1)$$

NOTE This is one of the statistical measures available to assess how evenly the pressure is distributed across a support surface. The lower the CoV, the lower the variability in the data set.

2.3 Conformity

The ability of the IPM mat to adapt to irregular shapes without creasing.

2.4 Contact area

Contact area is the area under load

NOTE 1 The contact area is approximated by the total number of sensors under load.

NOTE 2 Contact area is representative of the aim to distribute the body weight over as large an area as possible. Given the defining equation of pressure (pressure = force/area) the larger the area, the lower the pressure given a constant load. Reference[8] recommended that the minimum threshold to be used should be 5 mmHg to avoid inclusion of fluctuating non-zero values and minimize the effect of noise.

2.5 Creep

There are three different manifestations of creep that are of concern: sensor creep, cushion creep, and tissue creep. Sensor creep, inherent in most IPM sensor technology, is the tendency for the sensors to change their reading (output) over time given a constant load (input).

NOTE Most IPM systems, for which this is a factor, have built-in software correction for sensor creep. Creep is normally only corrected for during the time the mat is reading. Stopping and starting the readings may interfere with the creep corrections.

2.6 Dispersion Index (DI)

The DI is defined as the sum of pressure distributed over the ischial tuberosity (IT) and sacral-coccygeal region divided by the sum of pressure readings of loaded sensors over the entire sensor mat, expressed as a percentage.

$$\text{Dispersion Index} = \Sigma A/(\Sigma A + \Sigma B) \tag{2}$$

where

A is the pressures of the IT and sacral-coccygeal area;

B is the pressures outside the IT and sacral-coccygeal area.

NOTE The DI represents the concentration of pressure in high risk areas versus low risk areas and can be indicative of a support surface's ability to redistribute pressures. DI is also a metric reported to have good reliability in Reference.[7] In Reference [4] it was found that interface pressures were "unacceptable" when >55 % of the pressure was at the IT/sacral regions. DI, as compared with pure contact area, may be a more useful metric when performing relative comparisons between cushions. Effective pressure distribution can be achieved either via envelopment or off-loading of the high risk sites. If one cushion off-loads and the other envelops, DI may offer a better "apples to apples" method of comparison than contact area alone.

2.7 Envelopment

The ability of a support surface to conform so to fit or mould around the irregular shape of the body.

2.8 Fomite

An inanimate object or substance (such as clothing, furniture, or soap) that is capable of transmitting infectious organisms from one individual to another.

2.9 Hysteresis error

Hysteresis error is the difference in two measurements of the same quantity when the measurement is approached from opposite directions.

NOTE 1 Hysteresis generally manifests itself in IPM applications as the difference in a given pressure reading depending on whether that pressure was reached by increasing from a lower pressure or decreasing from a higher pressure.

NOTE 2 Hysteresis is a natural phenomenon which occurs in all types of electrical, magnetic, and mechanical devices. A hysteresis loop is generally used to characterize hysteresis. If a sensor is held at a constant pressure, there is a corresponding electrical output value for that pressure. It would be expected that if that applied pressure rose or fell, the corresponding electrical output value would rise or fall in synchronicity with the applied pressure. Sensor hysteresis is a dynamic effect where the sensor output "lags" behind the corresponding applied pressure as the applied pressure rises or falls (i.e. for a rising pressure, the displayed pressure will be lower than the pressure applied at the sensor and vice versa).

NOTE 3 Hysteresis can be reduced in two ways: by selecting a material which will be used in the sensor which inherently possesses less hysteresis or by compensating for hysteresis via a calibration algorithm in the software.

2.10 Immersion

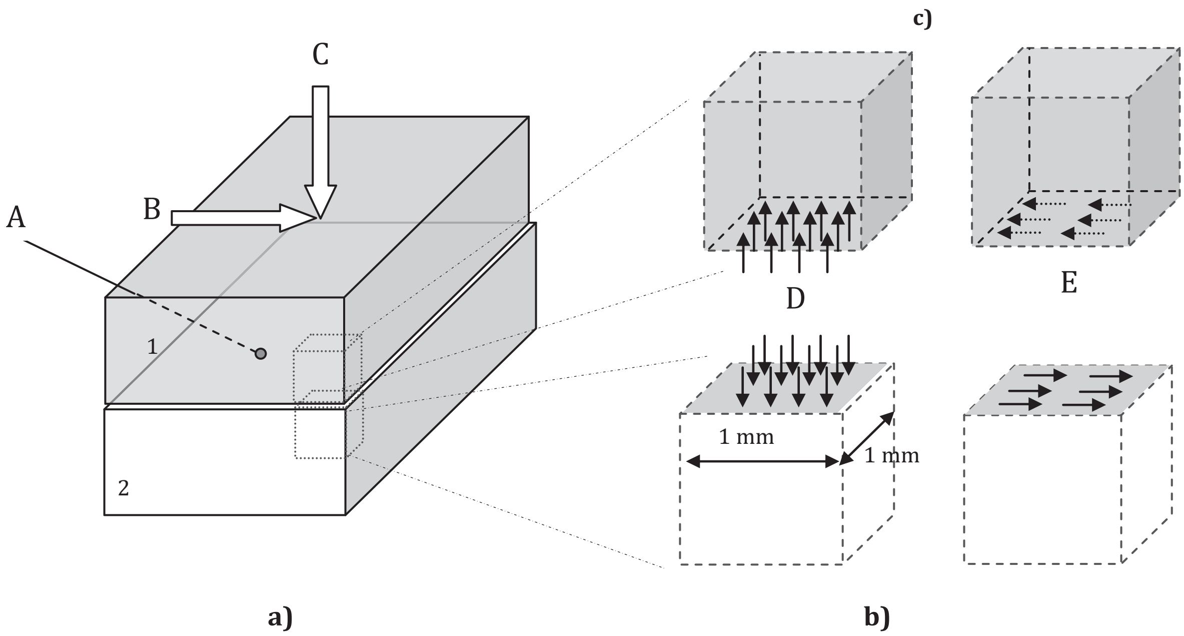
The depth of penetration into a support surface measured in the vertical plane.

NOTE 1 This is how far the body sinks into the cushion.

NOTE 2 It is important to immerse without bottoming out.

2.11 Pressure, stresses, and forces

For the seated person, the person's tissues and the support surface the person is seated on undergo potential deformations due to the effects of perpendicular and horizontal stresses and forces as summarized in Figure 1.



Key

A contact surface

B shear force

C perpendicular force

D pressure

E shear stress

Figure 1 — Forces and stresses acting between two objects a) forces acting on object 1 and transmitted to object 2 b) pressure and shear stress acting on the upper surface of a unit volume of object 2 at the 1-2 contact surface c) pressure and shear stress acting on the lower surface of a unit volume of object 1 at the 1-2 contact surface

2.11.1 Axial strain (ε)

The deformation (relative change of dimension) due to the action of stress in the stress direction (see Figure 2).

NOTE Axial strain is dimensionless.

2.11.2 Perpendicular force (FP)

A force occurring at right angles (90°) to an element's surface.

NOTE FP is measured in Newtons (N).

2.11.3 Pressure (p)

Pressure is the perpendicular force (FP) divided by the area of the element's surface to which the perpendicular force is applied.

$$\textit{Pressure [MPa]} = \textit{Normal force [N]/Area [mm}^2\textit{]} \quad (3)$$

NOTE 1 The units of pressure used in most applications are pounds per square inch (PSI), Pascals (N/m^2), or millimetres of mercury (mmHg).

NOTE 2 Unit conversions

1 Pa = 1 N/m^2

1 kPa = 1 000 Pa

1 MPa = 1 000 kPa

1 mmHg = 133,322 Pa

1 PSI = 6 894,757 Pa

NOTE 3 An IPM image is a visual representation of the normal pressures between two contact surfaces of two (usually deformable) bodies such as the top surface of a cushion cover and the material covering a person's backside.

2.11.3.1 Average pressure

Average pressure is defined as the average value of the pressure recorded by a group of sensors of predefined location and disposition around a significant landmark.

NOTE 1 The predefined groups of sensors can be called control areas or masks. As an extreme case, the overall average pressure can be calculated over the contact area.

NOTE 2 Overall average pressure across the whole cushion is not of clinical relevance because it is too general a metric for differentiating cushions.

2.11.3.2 Peak pressure

Peak pressure is the highest value of the pressures recorded by the sensor units in the mat.

NOTE 1 From a general view point, there can be a single absolute peak pressure as well as several relative peak pressures.

NOTE 2 If data collection is taken over time, there will also be a maximum peak pressure over a given time interval.

NOTE 3 The location of the peak pressure on an image can change over time in the case of a dynamic recording.

2.11.3.3 Peak pressure index (PPI)

PPI is the pressure average value calculated within a 10 cm^2 area (i.e. the approximate contact area of an ischial tuberosity) around the highest recorded peak pressure values).

NOTE 1 A high gradient from peak to adjacent sensors indicates poor envelopment of the bony prominence.

NOTE 2 Historically, single peak pressures were used to rate cushions. Reference[7] studied reliable metrics for IPM, and single peak measures were not repeatable. The result was that researchers recommended the use of a peak pressure index.

2.11.4 Shear force (FS)

A force occurring parallel with an element's surface.

NOTE FS is measured in Newtons (N).

2.11.5 Shear stress (τ)

The shear force divided by the area of the element's surface to which the shear force is applied.

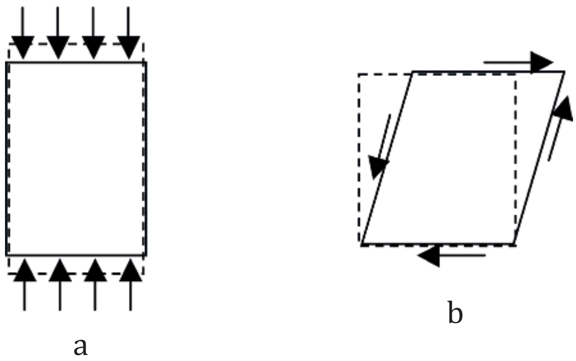
NOTE Shear stress is measured in kiloPascals [kPa] or equivalent units.

$$\textit{Shear stress [MPa] = Shear force [N]/Area [mm}^2\textit{]} \quad (4)$$

2.11.6 Shear strain (γ)

The distortion (change in the shape) of an element due to the action of shear stress.

NOTE Shear strain is dimensionless.



Key

a axial strain

b shear strain

Figure 2 — Axial and shear strain of a unit surface due to pressure and shear stress

2.11.7 Friction force

Friction is the force resisting the relative motion of two objects with surfaces in contact.

2.12 Sensor saturation

Sensor saturation is the point at which the individual sensor's output cannot increase any further with continuing increase in applied pressure.

NOTE Sensor saturation may be due to either the physical restraints of the sensor or the constraints imposed by the software, e.g. if the sensor is calibrated to a maximum pressure of 200 mmHg, the maximum pressure it will indicate will be 200 mmHg, regardless if the applied pressure is greater than 200 mmHg. Some IPM systems can extrapolate to pressures above the maximum calibration value to allow the operator to see if the pressure values are just slightly over the maximum threshold or considerably higher.

3 Applications

This section is intended to guide the operator through possible choices of IPM as a tool for clinical and rehabilitation applications. The list is not necessarily exhaustive. Please note that there are limitations of which the operator should be aware and various of these are listed in Clause 7.

3.1 Cushion comparison

The most common use of IPM is to compare cushions for prescription for a client. The value is for comparison of each cushion's ability to distribute pressure evenly across the body and minimize pressure at the bony prominences. This application can demonstrate that a less expensive cushion can be as effective for that client for static pressure redistribution as a more expensive one, for example, but it may not indicate which cushion would provide greater protection in dynamic situations.

An IPM image should not be the sole deciding factor. Additional considerations for cushion selection include the following:

— form, fit, and function;

— postural stability;

— functional mobility – transfers;

— weight of cushion;

— microclimate (heat/moisture transfer);

— perceived comfort;

— complexity - maintenance and set-up requirements;

— client's ability to perform, or direct, care;

— ability to provide client and caregiver education;

— number of caregivers/staff turnover.

IPM has its limitation since the readings taken are usually in a static situation, whereas the client usually uses sitting as a dynamic activity (see 3.4).

3.2 Wheelchair set-up

Using an IPM is an essential tool for setting up the adjustable parts of the wheelchair while observing the effects on the distribution of pressures across either a seat or back support surface. Reference[10] showed that the most effective means of redistributing pressures across a cushion is by adjusting the height of the foot supports. Remember that the foot and arm supports will need to be adjusted for different cushions with differing thickness or adjustability/compressibility.

NOTE You may find that the optimal pressure distribution will be achieved with a different position of parts of the body than you expect, for example, aiming to have the top of the thigh parallel with the seat base does not provide the optimum angle for pressure distribution under the thigh since the femur does not usually run parallel with the skin surfaces.

3.3 Client/caregiver education

IPM is useful as a visual feedback mechanism for client education. Seeing one's own pressure distribution and peak areas drives home the message of the importance of pressure management. It is also a very valuable tool to demonstrate the effectiveness of manual or power-assisted pressure relief techniques. Use the tool to teach movement or help the client find alternative pressure redistributing positions in their seating, e.g. use IPM as a biofeedback tool to educate a person with a spinal injury to discover how much (little) they have to move to achieve significant pressure reduction for their at risk areas. Pressure mapping is also a visual tool to show caregivers the consequences of setting up the cushion and chair incorrectly for the client. Likewise, it can be used to show the effects of different degrees of tilt or recline.

3.4 Dynamic activity

Current generation IPM systems provide instant feedback as to the impact of changing position on pressure distribution and therefore, just using mapping to look at non-representative static positions is wasting its potential. Allowing the client time on the mat to move into a natural position that they are likely to adopt when they leave the clinic is advisable (this may occur as the client relaxes while the therapist is nearby writing notes, for example). Record what the client is doing over time while they arrive at that position and see how long the client stays in that chosen position or if it is one of a selection of preferred positions (see also 4.3.5).

The non-wheelchair population moves about once every 6 min when seated while observations of wheelchair occupants indicates they move a tenth of this and therefore are putting their buttock tissues at greater risk.[6],[9] Thus, it can be seen as beneficial to prescribe cushions that allow the client to move comfortably from one position to another more frequently.

With various IPM systems, it is possible to record sessions either by storing data in the interface module or by wireless transmission of the client self-propelling their wheelchair. This will provide information as to whether left-right strength differences, for example, result in the client rotating in the seat to accommodate the differences. Comparing a 10 m run on a tiled surface, with a 10 m run on a carpeted surface, with a figure of eight run, with a run up a slope, will inform about the effects, if any, of the seating system in applied dynamic circumstances.

One protocol that has been suggested for assessing the individual on a range of seating scenarios is to take images with the client at maximum reach to left, to right, and forward. The image linked to the range of movement achieved can be more informative as to the best seating option to prescribe. Reference[7] gives measures of postural stability: getting the right balance between stability and dynamic activity is very important for the functionality of the individual.

3.5 Relevance to activities of daily living

Ideally, the client should be assessed with the IPM in simulations of the activities of daily living (ADL) they are likely to undertake. The impact of the activity on the seating set-up or the seating set-up on an activity can be assessed for what are key elements for that individual client, e.g. sitting at a computer, feeding, self-propelling, toileting, in transport, relaxing in front of a television, etc.

4 Test protocol in a clinic

This section is intended to guide the operator through the IPM test protocol once their clinical objectives are clear and which applications, conditions, or set-ups need to be measured have been planned. This set of instructions has been prepared with the intention to answer to the question "how shall I perform the tests?". Basic explanations regarding the justification of the proposed actions are contained in NOTES.

The different steps of the protocol are accompanied by an introductory paragraph with the aim of explaining the ambit and some background to the instructions that are stated.

4.1 Infection control

Before starting an assessment, be aware of the risks to you and your client of cross-contamination. IPMs may function as a "fomite" (vector) transferring infectious agents from one client to the next. Recent research indicates that both sides of sensor mats used in pressure mapping are at risk from contamination acquired from seating cushions and other components of the seating system since these frequently contain significant microbial loads.[3] IPM covers do not necessarily offer sufficient protection, especially against microbes, body fluids, or blood. Isolation bags are the most efficient protection for the sensor mat and for the client. If the mat becomes contaminated with urine or faecal material, clean with disinfectant wipes. However, contamination with blood or tissue fluids may result in the mat needing to be disposed of.

NOTE Isolation bags may affect IPM sensor output readings. Thus, if used, use consistently across a given IPM session.[3]

4.1.1 Wash hands

Wash your hands before and after the evaluation.

NOTE Local infection control protocols may indicate using gloves when undertaking client assessments.

4.1.2 Avoid cross-infection

Don't touch the computer until you have cleaned your hands or removed your gloves.

4.1.3 Protect the mat

Make sure you use an isolation bag if you wish to protect the mat.

4.2 Setting up

The success of the test session with the client is based on the ability of using the available time in the most effective and efficient way. All arrangements that can be prepared in advance to the client's arrival should be carried out. All the materials and instrumentation should be checked out, and all the testing and the combination of seating elements to be explored should be planned in advance, whenever possible.

4.2.1 Set up mat

Before the client arrives, ensure that the mat is working (by sitting on it yourself), that the correct mat has been selected in the software, and the most recent calibration file selected.

4.2.2 Prepare test protocol

Have a protocol prepared to be followed during the session. List the type of cushions/seats/postures/activities to be tested and their order in such a way as to minimize client discomfort.

4.2.3 Prepare client file

To save the assessment time with the client, have a mapping client file prepared and open into which you can add the session's readings. These might be adding to a previous session's records or might be a new file for a new client.

4.2.4 Be consistent

Be consistent with the orientation of the IPM on the surface to be evaluated during the client session. The IPM cable should be placed in the same orientation (e.g. front, right) for all readings and all sessions. Consistent placement of hands and feet during repeat testing will ensure more consistent results.

4.2.5 Check mat orientation

Make sure the IPM is square on the seat.

4.2.6 Check mat position

Place the IPM on the cushion to ensure that the buttocks will be fully captured by the active sensing area of the mat. This usually is accomplished by having the rear row of the IPM behind the posterior edge of the seating surface.

The mat may be significantly larger than the surface being studied if the wheelchair is small. If so, take care to avoid the formation of large folds in the IPM at the edges of the cushion or surface.

4.2.7 Smooth mat into cushion

Make sure the mat is relaxed into any contours of the cushion to avoid hammocking. Use your hands to smooth the mat into contours as needed.

NOTE The ability of the IPM to conform to these contours is essential for understanding the surface's ability to redistribute pressures.

4.2.8 Acclimatize test cushions

Ensure all cushions are at room temperature before they are used in an IPM assessment.

NOTE Variations in temperature can affect certain cushion materials' response to loading. For example, a viscoelastic foam or a gel cushion which has been stored in cold temperatures may initially be stiffer and take longer for the individual to achieve immersion.

4.3 Transferring the client and getting the client into position

Some clients will need assistance in transferring onto the mat. Adequate help may be required to transfer the client safely into position for the IPM session, e.g. assisting with lifting the patient using safe and appropriate lifting techniques to minimize shear and friction forces on the mat and client during transfer. Not obtaining adequate clearance can not only create harmful shear stresses, but also cause the mat to wrinkle, fold, or misalign during the transfer.

4.3.1 Transfer boards

Avoid the use of transfer boards if there is risk of damaging the sensors.

4.3.2 Remove unnecessary items

Place the mat as close to the skin as possible by, where feasible, removing unnecessary items such as slings, pads, etc. which may have been employed while bringing a client into interaction with the mat.

Consideration should be made about mapping an individual in the normal set-up in which the individual exists from day to day, e.g. if the sling is normally left in place during the day, if possible, map the individual with the sling in place, but with the IPM between the sling and the individual.

4.3.3 Post-transfer checks

Make sure the sensor mat is still in place after the transfer – squared on the seat, without wrinkles. Readjust the mat as needed.

NOTE Use of a plastic isolation bag often contributes to the mat sliding out of place during the transfer. The isolation bag may cause the client to slide on the seat. Be extremely cautious with clients who may be predisposed to sliding forward such as those with poor balance, low muscle tone, posterior pelvic tilt, and/or an open hip angle.

4.3.4 Consistency between tests

Make sure the client is in a seated position from which you can compare one set-up or surface with another. Use standard protocols for describing the patient posture on the wheelchair.[11]

4.3.5 Settling time

Allow time to sit prior to recording the session. This takes into account the time to settle into the cushion (accommodating the effects of tissue and cushion material creep).

NOTE Settling time varies based on differences in tissue and cushion material. Cushions composed of time-dependent materials take longer to settle into. Cushions which are air-filled or comprised of elastic foam have a short settling time (3 min–5 min) in contrast with cushions made with viscous materials (viscous fluid or viscoelastic foam) which take longer (5 min–7 min) to adjust.[3]

For client safety, total maximum sitting time during the IPM evaluation should not be exceeded if sitting duration limits are in place (e.g. due to current pressure injury).

4.4 Introducing pressure mapping to the client

Many clients and caregivers will be intrigued by the IPM and the information they see on the screen. Take this into account and possibly take advantage of this attitude by providing information to the client about IPM. Conversely, they may be apprehensive about what is going on. Explaining the equipment to the client can also be advantageous in this case.

4.4.1 Position of the screen

It is useful to have the IPM mat under the person at the beginning of the session so the client can get used to it while the therapist is getting organized. Having the screen out of sight of the client while you are taking readings reduces the effects of the client twisting to see the screen or adjusting their position to affect the readings. Alternatively, for education purposes, images on the screen can be used to demonstrate points to the client or caregiver.

4.5 Capturing data

Data may validate or challenge initial assessments, but should not be used exclusively for making decisions. Clinical observation and expertise should always be part of the assessment process.

4.5.1 Identify position of bony prominences

As a prelude to assessing the client on their existing cushion (if they have one), if possible, have the client sit upright on the IPM mat on a firmer surface like an assessment table or a foam cushion. Scan, store, and describe where the bony prominences are confirming their existence with your hands and noting the on-screen coordinates. This will help answer the questions below.

— What is the client’s bony architecture like?

— Is it all there?

— Flexible?

— Is there an obvious obliquity?

— How rotated is the pelvis, etc.?

4.5.2 Record one or more images

After reading(s) of the first set-up (4.5.1) have been taken, document (see Clause 5) the details of the set-up before moving to the next scenario (which could be the seating set-up that the client came in with). There are options of taking a single 'snap shot' of the set-up, or take continuous recordings over a period of time. The latter will be of more value for assessing dynamic sitting and seated activities.

4.5.3 Repeat the process

Repeat as above until all required set-ups have been recorded.

4.5.4 Check the images

While the client is in the set-up being recorded, the therapist should check the mat and the client's contact with the mat to cross check the sources of any high or unexpected aspects in the IPM reading. Unexpected pressure points may be caused by wrinkles in the mat or clothing or items in pockets (see 6.1).

4.5.5 Validate the images

Use the collected data in combination with your professional experience to validate your original clinical judgement.

NOTE One mistake new users of IPMs make is to stand back and attempt to let the system make decisions for them. Another is to throw out their years of experience and start from scratch with all the solutions at their disposal.

5 Documentation

Good documentation is key to the effective use of IPM. The first level is to record information about the client.

NOTE This could include (in no particular order of importance) and depending on local protocols:

— ID#/name (observe privacy guidelines);

— date;

— equipment set-up (baseline);

— cushion model, age, width × depth, thickness;

— back support model;

— wheelchair model, width × depth;

— seat to back angle;

— seat sagittal angle;

— foot support position (thigh loading/distribution of pressure);

— posture: note postural deformities or asymmetries; express the posture with a repeatable method using quantitative values;[11]

— upper and lower extremity position as pertinent for pressure redistribution;

— risk level on a standardized scale (e.g. Braden or Norton) or use low, medium, high based on sensation, mobility, history of pressure injury, and frequency of pressure relief;

— clinicians and carers as appropriate.

5.1 File naming protocol

Use a consistent file naming protocol for each client and for all IPM sessions.

5.2 File location

Determine the IPM session save-to location. This can be configured in many different ways. The goal is for an orderly, easily retrievable file.

5.3 Make notes immediately

Record notes alongside the images at the time the data are captured, of the set-up, position, posture, and circumstances existing at that time as these are the most important things when taking pressure readings and may not be easily recalled some minutes, hours, or days later. Use standard protocols for describing the patient posture on the wheelchair.[11] Keep your comments related just to the specific scan and store these with that scan.

NOTE Make notes that can assist review several months in the future. This will help answer the questions below.

— Why did we need to make changes or spend money?

— Why wouldn't a simple solution be sufficient?

— How well did the usual solution perform?

— How well did the alternative solution perform for your client?

5.4 Reporting

Most IPM software provides the opportunity to print a report or export the data or a set of readings into Microsoft Office software, for example, Word, Excel, PowerPoint, or similar. Alternatively, consider copying a specific screen shot into one of these applications. The report can also be saved as a PDF.

5.5 Photo documentation

Use correlative photo or video documentation to record posture and seating set-ups and label them accordingly. IPM software can insert the photos or videos into the sessions. It may be helpful to write the cushion or set-up under test on a board or label visible in the picture so as not to mismatch the video/picture with the data. Be sure to obtain a photo release statement and observe relevant local protocols/legal requirements.

5.6 Data back-up

Keep secure back-ups of records in case of computer hardware failure. Ensure that local record keeping protocols are observed.

6 Interpretation

Historically, single peak pressures were used as the primary interpretive tool for analysing IPM data. However, research has shown that single peak pressure values are not reliable and/or repeatable.[7] It is also important to know where the pressure has gone after an intervention to reduce the peak pressure (has a new peak pressure appeared where the client is more vulnerable to tissue damage?). Thus, the trend has shifted away from reporting single peak values to assessing the distribution of pressure over the entire support surface and relative comparisons thereof.

6.1 An unexpected image

If there is an unexpected image, consider if it is the tool. Unexpected readings can come from the following:

— wrinkles in the mat;

— wrinkles, seams, pockets, etc. in clothing;

— items left in pockets;

— poor placement of the mat;

— hammocking of the mat;

— out of date calibration;

— damaged mat.

Manually check and feel for any of the above possibilities. The IPM may be indicating something important that despite your years of experience, might have been overlooked or cannot be detected with the human eye/touch.

6.2 An image that is not ideal

Sometimes, the picture may not be ideal, but the best advice could be to leave “well enough alone”, for example, a client’s right greater trochanter is reading at or above 200 mmHg and has been for some time without incident. If the only alternative is high pressure on an alternative proven risk area of, say the right ischial tuberosity, the best approach could be to leave things as they are, but monitor it over time.

6.3 The image shows nothing abnormal

Sometimes, the client has evidence of tissue damage, but everything in the seat looks good with the IPM. If it does, review the location of the wound and the clinical history. What is not obvious and unseen during the assessment? Activities away from the wheelchair may be the source of the problem. Some research and anecdotal evidence indicates that while the referral is for a perceived seating related pressure issue, much of the time the problem is in the bed and not the seat. It may therefore be necessary to conduct IPM assessments on other surfaces such as a bed or furniture in the home. Even if only a seat-sized mat is available, it can be used to pressure map the client in bed or other surfaces. Tissue problems may also be caused by microclimate issues of humidity or heat. Tissue problems may also be caused by shear forces which cannot be determined using the IPM. Shear stress forces could be generated in the seat (for example, due to sliding) or arising during activities such as reaching, propelling, or transferring.

6.4 IPM views and metrics

The metrics listed below can be used to guide the interpretation of the IPM images. Other possible measures are defined in Clause 2.

6.4.1 Isobar (2-D)/contour view

This type of view displays the pressures of the same or similar values as a single colour. The blue end of the spectrum represents lower pressures while the red end represents areas that are under higher pressures.

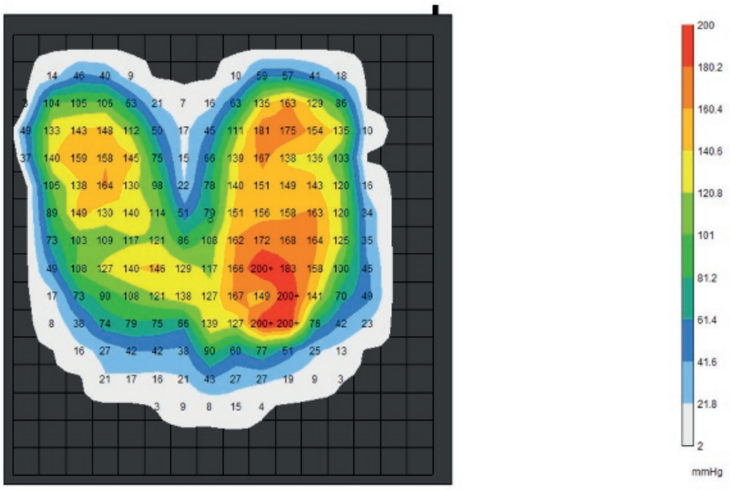


Figure 3 — Contour view

Most IPM systems allow the user to adjust the scale which correlates colour to a specific pressure range. Thus, great caution should be taken in automatically assuming a certain colour is good or bad. Therefore, always check the scale.

It is useful to set the minimum value a little above zero pressure to remove the background ”noise” levels that are not relevant to the seated individual.

Adjusting the scale so that the readings take up most of the scale has the benefits of differentiating more clearly what is happening under the client at different contact points. For lightweight clients, it is particularly useful to expand the scale for their readings: look to see what the maximum pressure is on any image for that client, and set the upper limit of the scale to slightly above that value.

NOTE Some clinicians reset the maximum value of the scale to an artificially low value to encourage clients to change their behaviour to lessen the “red” zones.

6.4.2 3-D/surface view

This view provides a “3-D” graphical representation of pressure in relation to its location on the mat. Higher pressures are represented by peaks in the 3-D display. What looks like a mountain range in this view is worse for the client than a collection of “foot hills’”. The mountain range appearance represents higher gradients or rate of change of pressure from one point to the next (see also 6.4.4 or 2.2).

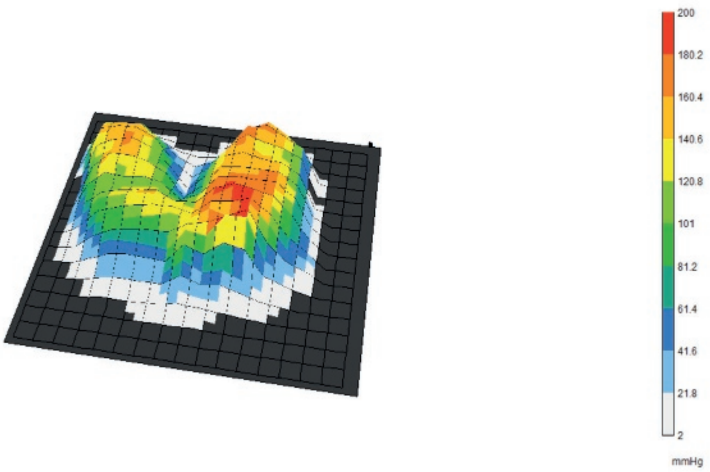


Figure 4 — Surface view

Please be aware that the shape of the 3-D view does not represent the profile of the client's anatomy and therefore cannot be used as a profile to contour a piece of foam, for example. It is a graph of the pressures across the IPM mat at each of the sensor points. Similar to the 2-D view, the 3-D view helps to bring out the areas of higher pressure and therefore, possible areas of greater risk of tissue breakdown.

6.4.3 Centre of pressure (CoP)

This feature displays a marker of the CoP which represents the location on the mat where the resultant load of all contact pressure (i.e. the portion of body weight that is being transferred to the seating through the mat) is applied as if it was a concentrated load instead of a distributed load. This marker can be used to assess asymmetry (see also 6.4.5). The CoP marker helps to assess whether an intervention has taken pressure forward from the ischial tuberosities and more under the thighs. On the other hand, where a client presents with a flexible left pelvic obliquity, the baseline map would likely show a shift in the CoP to the left. Different cushions and seating set-ups will have variable effectiveness in reducing the obliquity. Noting which intervention shifts the CoP towards a midline point can aid in choosing the best solution.

When taking continuous recordings of a dynamic activity, tracking the CoP will give an indication of how symmetry is affected by the activity.

NOTE The CoP location is mainly affected by the client's overall posture. Small changes in the subject's posture (e.g. head flexion or extension, foot placement, and arms or shoulder placement) can produce large changes in the CoP position. Make sure to have the client in a standardized and repeatable posture before taking the measure and before comparing two seating or two test sessions before and after a treatment.

6.4.4 Gradient

Gradient recordings reflect the spatial changes in pressure. High gradients occur where the pressures change quickly from low to high on neighbouring sensors. The 3-D view is useful in assessing gradient. The steeper the "slope of the hill" created by the peaks, the higher the gradient. High gradients are indicative of either poor envelopment or poor off-loading of the bony prominences. The higher the gradient, the higher the shear strain forces that the tissues are likely to be experiencing. The higher the gradient, the greater damage that will occur to the subcutaneous cells (especially around bony prominences) and the greater resistance to blood flow reaching the higher pressure points.

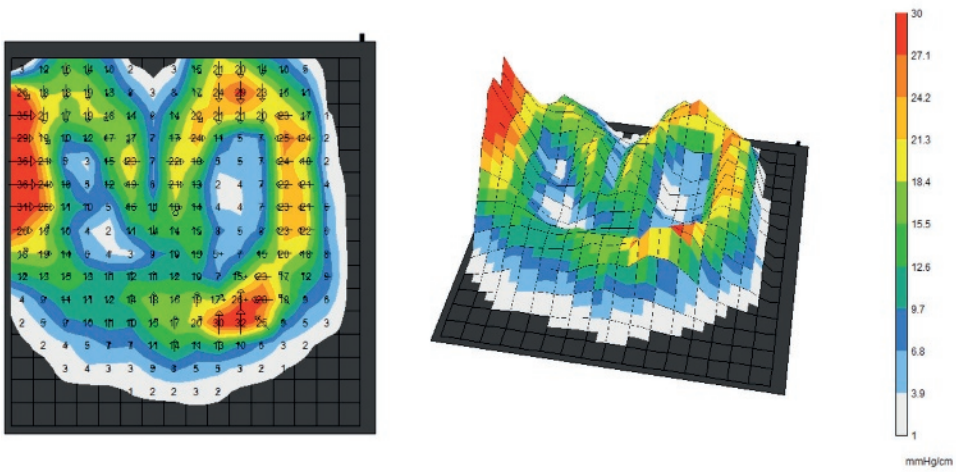


Figure 5 — Gradient contour and surface views for the pressure plots in Figure 3 and Figure 4

6.4.5 Asymmetry

This visual and numerical measure demonstrates a pressure or shape differential. This is usually referred to as the amount or direction of asymmetry. Asymmetry indicates a probable need for further postural evaluation and seating modifications. It is often reflective of an orthopaedic deformity (e.g.

pelvic obliquity, scoliosis, etc.), postural imbalance (e.g. functional lean), or improper seating set-up (e.g. incorrect foot support height). Asymmetry across the IPM is not always a "bad" thing. For some clients, asymmetry offers increased stability or allows a more functional position of other parts of the body such as the head or shoulder girdle.

6.4.6 Interpolation

Most people use an IPM display where the software is looking at each sensor's individual value and at the values of the neighbouring sensors and spreads the differences into a number of steps as if there were more sensors across the area than what really exists. This produces a view that is more like that of a contour based map and is more intuitive for the user to understand. This software process is called interpolation.

The pressure values remain the same. The only thing that changes is how the 2-D pressure image is drawn. This can aid an experienced therapist to identify objects or other features in the display that might not be visible or obvious in the non-interpolated display.

6.4.7 Smoothing

Smoothing is a mathematical technique that attempts to capture important patterns in the data that may not be visible or obvious in the original data, while eliminating noise. In other words, the software identifies the values that are outliers and thus probable sources of error (smoothing involves fitting a 3-D spline to a 3-D set of points). From an isobar display perspective, smoothing blends the colours and margins of adjacent sensors. In some IPM systems, the smoothing preserves the highest value.

If the smoothing option for one cushion is chosen, use smoothing for all cushions in a given client evaluation session to perform a fair relative comparison of the cushions.

7 Limitations

This section considers the main factors that may influence the effectiveness of an IPM measuring session or its clinical relevance in the assessment of wheelchair seating systems.

7.1 Prediction of pressure injuries

A vast majority of papers on the aetiology of pressure injuries have attempted to identify the level of sustained mechanical loading on skin and soft tissue beyond which the tissue will break down. This has led to a number of qualitative observations that can be summarized as follows.

As pressure and shear forces are applied, tissue damage occurs. There is a relationship between time and magnitude of an externally applied load and the risk of acquiring a pressure injury. It is generally accepted that a high magnitude requires less time to cause a pressure injury. Low loads can also lead to a pressure injury, but may require a longer time.

In certain cases, muscle is more susceptible to breakdown than skin or adipose tissue.

Externally applied shear forces are more damaging than normal forces (however, shear forces cannot occur in the absence of normal forces).

The highest stresses and strains can be found internally (i.e. adjacent to bony prominences) leading to deep tissue injury.[5]

Pressure will be a factor in combination with other factors leading to tissue breakdown, but at the surface (most NPUAP/EPUAP Stage 1 and 2 pressure injuries), other elements are most likely to be the primary cause such as microclimate (7.2), friction, or shear strain. Stage 3 and 4 pressure injuries are more likely to be caused by pressure and frequently this has been the result of damage to tissue adjacent to bony prominences and working outwards.

Thus, whereas IPM is used as a tool to help in the prediction of pressure ulceration, it has to be used with caution and awareness of the other factors involved.

7.2 Microclimate

Microclimate, namely local temperature and moisture, has an important impact on skin integrity at the surface and is considered by some to be the primary cause of Stage 1 and 2 pressure injuries alongside friction and shear strain damage. IPM will not provide any guidance as to the influences any of these factors may have, but all of them need pressure for their influences to apply.

7.3 Clothing

Clothing does have an impact on tissue integrity and most people are assessed with the clothing they are wearing when they attend a clinic. For those who are concerned about any hammocking affects the IPM may have between the cushion and the client, most clothing is going to have more of a hammocking affect than a modern IPM mat. Furthermore, if the clothing and the mat are not changed during the assessment, comparisons under these conditions can be made between surfaces or positions.

Do watch out for “artefacts” that will appear on the picture arising from studs and seams in jeans, for example. If they show on the image, they are possibly affecting the client. Various objects such as keys, combs, wallets, etc. in back pockets often show up well on images and the client should be advised of the potential harm these objects may be causing them.

7.4 Repeatability and relative values

IPM shows values of pressures taken at a certain time within a certain set-up. However, if reproducible absolute values are sought, there are better engineering tools for this purpose than IPM such as strain gauges. Clinically, it is the distribution of pressures that is more important than the individual pressure values. Equally, as pressure is redirected from one place to another, is the new place better or worse for the client? There is no right or wrong pressure, though there may be better or worse values for an individual client. Values for the individual will change and will not be repeatable due to creep in the person’s tissues and their cushion, changing position, fatigue, etc.

7.5 Influence of posture

An “ideal” posture for an individual of, say a neutral pelvis may be a posture that increases forces through the ischial tuberosities. The “best” pressure map may have the client in a non-functional position. It is therefore essential that all aspects are taken into consideration and the image alone is not used to determine whether a cushion or the posture is the right one or not.

7.6 Sampling frequency

The inbuilt sampling rate (rate of data collection) of an IPM system is not usually greater than 100 Hz at best. This will not be enough to collect significant data regarding, say the vibrational behaviour of a wheelchair or seating set-up, as the frequency of vibrations can be higher than the sampling frequency of the system. On the other hand, taking three readings a second (3 Hz) is usually sufficient for use in the seating environment to get the balance between identifying changes with time and obtaining more data than will be useful.

Bibliography

[1] ISO 7176-5, *Wheelchairs — Part 5: Determination of dimensions, mass and manoeuvring space*

[2] ISO 7176-26, *Wheelchairs — Part 26: Vocabulary*

[3] Davis K., & Call E. (2013) Evidence-based guidelines for IPM: final research findings *Proceedings of the International Seating Symposium* March 7-9, Nashville, TN p101

[4] Drummond D. et al. Relationship of spine deformity and pelvic obliquity on sitting pressure distributions and decubitus ulceration. J Ped Orthoped. 1985, **5** pp. 396-402

[5] Gawlitta D. et al. The relative contributions of compression and hypoxia to development of muscle tissue damage: an *in vitro* study. Ann. Biomed. Eng. 2007, **35** pp. 273–284

[6] Linder-Ganz E. et al. (2005) Frequency and extent of spontaneous motion to relief tissue loads in normal individuals seated in a wheelchair *Summer Bioengineering Conference*, June 22-26, Vail, CO

[7] Sprigle S. et al. Reliability of bench tests of interface pressure. Assist. Technol. 2003, **15** pp. 49–57

[8] Sprigle S. et al. Development of valid and reliable measures of postural stability. J. Spinal Cord Med. 2007, **30** pp. 40–49

[9] Stockton L., & Parker D. Pressure relief behaviour and the prevention of pressure ulcers in wheelchair users in the community. J. Tissue Viability. 2002, **12** pp. 84, 88–90, 92

[10] Swain I.D., & Peters E. (1997) The effects of posture, body mass index and wheelchair adjustment on interface pressures *Evaluation Report* **MDA/97/20** Medical Devices Agency, Department of Health

[11] Waugh K. et al. A clinical application guide to standardized wheelchair seating measures of the body and seating support surfaces Assistive Technologies Partners. University of Colorado, 2013

ICS 11.180.10

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