HEALTHCARE INNOVATIONS AUSTRALIA

Supporting your needs

What makes a good cushion?

by Dr Barend ter Haar


Canon

What makes a good cushion?

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This is a compilation of articles published in the journal THIIS, which is a series of occasional resumés of aspects in the world of posture and mobility where there are common misconceptions, and myths to be addressed, to help promote better practice. Further items can be found at: www.hiaus.net.au and www.beshealthcare.net.

Why cushions need to vary from user to user

This chapter aims to start getting people thinking more about what goes into a cushion that makes it 'good' for one person, but not necessarily for another. This sets the scene, whereas the various headings are teased out in greater detail in later chapters.

What makes a good cushion depends on the needs of the individual. These days we have many procurement departments which treat cushions as commodities and, under the misconception that all cushions are the same, look for what is the lowest price option. Cushions are prescription items, with different elements that are relevant to any one individual's needs. This kind of commodity-oriented generalisation is as useless to the individual as saying all white pills must do the same thing since they are all white.

Around reviewing the suitability of a cushion for an individual, the context in which the cushion is to be used needs to be taken into consideration, such as whether it is to be used in a wheelchair, and consequently whether the wheelchair is the right size and conformation. There are various recent publications[1,2,3] that cover these aspects in varying levels of detail, the more recent of which is the All Wales Best Practice Guidelines[4]. When considering which cushion meets the user's needs, we have three key criteria to consider. The most important for anyone who is sitting still for any length of time, is to look after the user's tissue integrity. The next is positioning:

What's in a name? Pressure ulcer?

Over the years what we in the UK currently call Pressure Ulcers have previously been known as Pressure Sores or Decubitus Ulcers. In North America and the Pacific regions, these are now referred to as Pressure Injuries, and as a result the likes of the North American Pressure Ulcer Advisory Panel (NPUAP) has renamed itself the North American Pressure Injury Advisory Panel (NPIAP). Europe has chosen to stay with ulcers and stay with the EPUAP name as the related body.

to what extent do the materials in the cushion assist in maintaining a healthy posture. The third is functionality. Over and above the provisions of the first two criteria listed: how well does the cushion enable the user to carry out as normal a daily life as possible? The user needs to be part of the prescription process, since if they are not happy with the prescribed solution, they are unlikely to use it, and risk their health as a result.
For tissue integrity, over the years we have been concerned about pressure, and we have tended to term much of the skin damage that occurs as pressure ulcers. However, for the health of the skin, there are other 'extrinsic' factors that may be as, or more, important. These include the microclimate adjacent to the skin, where temperature and moisture come into play – we all know the effect that having our hands in water for an extended period has on our skin. Even more potentially damaging to the skin are the additional effects of friction and shear forces. This leads us then not so much to the cushion, as to its cover. The majority of pressure ulcers recorded are Stage 1 or 2, and these occur at the epidermis and dermis, the outer layers of the skin (see Fig. 1). What affects these outer layers of the skin is what is closest to the skin i.e. one's clothing and the cover on the cushion. If these items can move with the skin as the person moves in their seat, there will be less risk of shear damage (from shear stress and shear strain) to the skin.
Likewise, if the person's clothing and cushion cover materials control the microclimate from temperature and

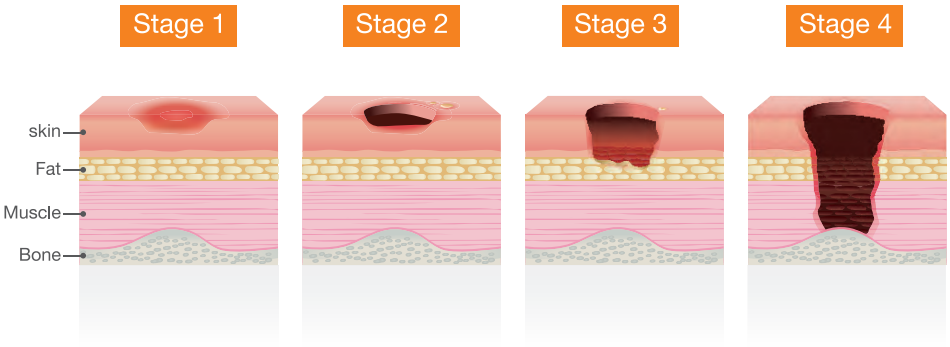


Figure 1. *The stages of a pressure ulcer*

humidity build up around the skin, there will be less risk of skin damage arising from maceration of the skin.
There's over thirty elements, falling under the tissue integrity, postural management, and functionality headings, that can be taken into account when assessing the properties of a cushion and its suitability for an individual.
We will be going into these different elements in more detail in the following chapters.

2

Pressure care

In later chapters, we address the benefits of a neutral pelvis and stability for posture management and contouring to optimise positioning. This chapter addresses the core issue of pressure management and distribution.

For the clinician, as well as for the client, tissue integrity around the buttocks may well come first when selecting the attributes of a cushion. This chapter covers strategies for getting forces away from the sharper bony parts of the pelvis i.e. the ischial tuberosities (ITs) – what we might call 'pressure management'. Pressure is considered to be a 'bad' thing since it is accompanied by shear and the two combined lead to cell damage and reduced blood flow. (Chapter 3 covers other influences than pressure alone on tissue integrity, such as shear forces and microclimate.) On the other hand, some pressure is a 'good' thing since without it, we would not stay in our seats. It's just where the pressure is that's critical.

The ITs present as quite rough and pointy bits of bone covered with relatively small amounts of flesh and people were not really designed to sit on these – by sitting on these, we are putting those thin tissues under high risk of damage from the pressures exerted on those tissues from the ITs. So, what can we do about this?

Pressure is force over area (P=F/A). The force comes from the pull of gravity on our body mass and the equal and opposite reaction from the surface we are sitting on. So the wider the area that we can spread that force, the less the maximum pressure over that area. Even better is if we can find less vulnerable areas of the body to redirect those forces towards. We will be covering aspects of cushion design that can assist with this redirection, but first let us look at what we can do under the ITs through the choice of suitable materials.

IMMERSION AND ENVELOPMENT

If we want to increase the area of the cushion that is in contact with the skin, we need to immerse the buttocks further into the cushion.

However, immersion on its own will not be enough (see Fig. 2)[6]. To get the cushion to interact with a larger area

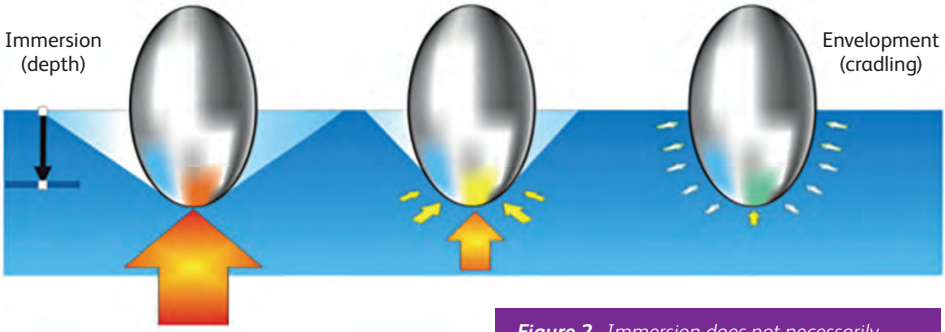


Figure 2. *Immersion does not necessarily equate with envelopment*

of the skin, the cushion materials need to allow the cushion to come into full contact with the skin to envelop it. Only then will you have the larger surface area over which to dissipate the forces and thereby reduce the pressure.

PRESSURE REDISTRIBUTION

Where and how can we unload pressures away from the ITs? Within the cushion, this can be under the trochanters, under the thighs, and/or under the gluteal muscles. Away from the cushion, the person's body mass can also be spread into the back support, arm supports, foot supports, and indeed head supports. A pressure mapping system is the ideal tool to check the optimal height of the foot supports to redistribute pressure evenly along the thighs.

Let's start with the greater trochanters, which are the bony protuberances at the top of our thigh bones, the femurs, roughly opposite where the hip joint is situated (Fig. 3).

As the pelvis' ITs sinks into the cushion (if the cushion is thick enough), eventually the sides of the cushion will come into contact with the trochanters, thereby bringing extra areas into play for spreading the forces.

Different densities of materials under the trochanters (firmer) as compared

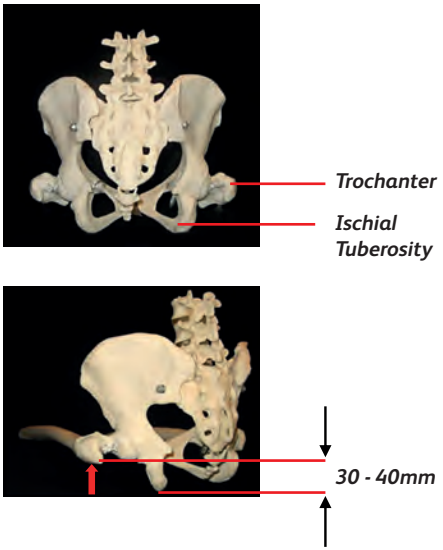


Figure 3. *The anatomical relationship between the ischial tuberosities and the trochanters*

with the ITs (softer) may facilitate this process. For most of us, the amount of immersion needed will be 30-40 mm. Note that too much redistribution of the forces towards the hip joint can damage the hip joint and lead to hip dysplasia, so don't leave the buttocks hanging off the trochanters over a large hole. You can have too much of a good thing!

To enable manufacturers to test the degree to which their cushions disperse the forces away from the ITs towards envelopment of the buttocks and off-loading onto the trochanters, a wooden indenter device with implanted pressure sensors has been designed[7] (Fig. 4).

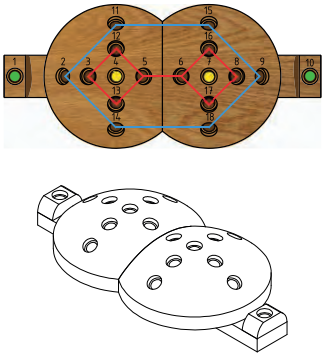


Figure 4. *Indenter with implanted pressure sensors – yellow positions replicate the position for the ITs and the green positions for the trochanters.*

THIGH OFFLOADING

In chapter 4 of this series, we look at aspects of cushion design to aid in the positioning of the pelvis.

In that chapter, we introduce a means towards both encouraging a neutral pelvis while simultaneously offloading the forces along the thighs: The solution is to have the seat plate horizontal, and therefore the pelvis neutral, but place a wedge under the cushion at the anterior part of the plate, thereby both elevating the knees and allowing pressure redistribution away from under the pelvis to below the thighs – to tissues more suited to carrying the pressures (Fig 5: 3). This wedge is best if placed inside the cushion cover. Lowering the foot supports may achieve the same effect but, for most chairs, this will result in the foot supports being too low for safe wheeling around.

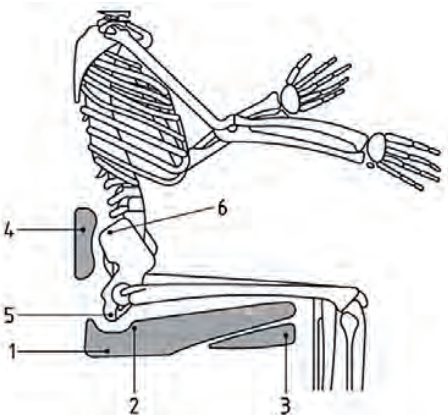


Figure 5. *Pressure redistribution under the thighs*

Key
1. Flat seat base under ischials
2. Pre-ischial ridge
3. Ramping wedge under thighs
4. PSIS block
5. Ischial tuberosity
6. PSIS

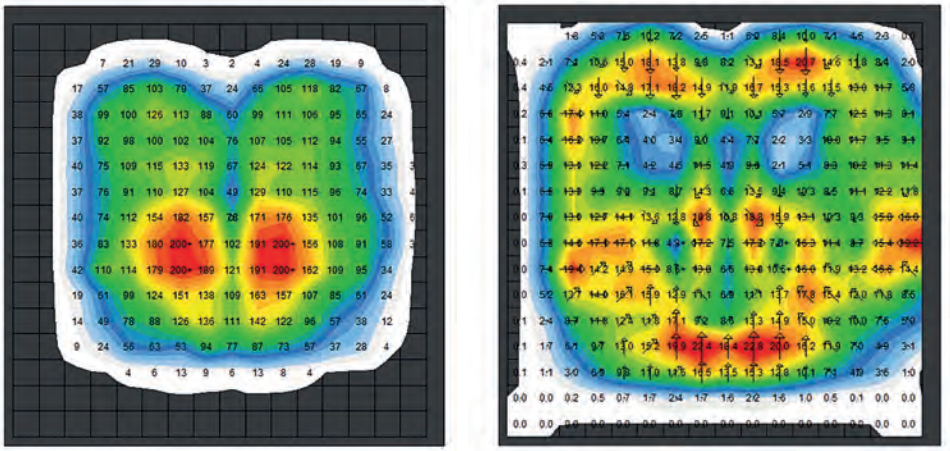


Figure 6. *Pressure map showing left: pressures, with highest pressures under the ITs, and right: the gradients from the same map, showing greatest gradients are occurring around the sacral/coccyx area.*

WHERE ELSE?

Many of us have more tissue than we feel we need around our buttocks. As we discuss in chapter 5, if we can spread the support of the body more widely over this area, we are taking the forces into tissues well away from inadequately covered bony prominences. Using a pressure mapping system which shows gradients as well as pressures can also show clearly the potentially damaging forces around areas which are normally out of sight to the naked eye - the sacrum (Fig. 6).

Where the maximum pressures occur are not where the largest rates of change occur and the greater the rate of pressure change, the greater likelihood of damaging shear strain – a topic we will come back to again in the next chapter. To what extent does your cushion provide contouring around this area (one area of contouring that, incidentally, will not have an adverse effect on transfers)?

All ways round, there's a lot we can do to take the pressures off the bony prominences of the ITs, sacrum, and coccyx.

ADDING PERIPHERAL SUPPORT TO A CUSHION

Adding, for example, a Varilite™ Contoured Positioning Wave Base (CPB) under a cushion, such as a Roho™ cushion, can provide additional offloading support laterally and posteriorly.

The benefits to skin care of the right cover

In the previous chapter we covered the challenges of pressure redistribution by a cushion. In this chapter we look at other aspects that can affect the health of the skin.

The cover of the cushion is arguably the most important element of a cushion for caring for the tissues of the skin, in that this is the part of the cushion closest to the skin. Therefore, the materials that the cover is made from will have an effect on the facility of immersion and envelopment, on friction and hence shear stresses on the skin, and on the microclimate at the skin's surface. In this chapter, we explore various elements to consider when selecting the most appropriate cover for a client's cushion.

IMMERSION AND ENVELOPMENT

In chapter 2, we covered the importance of envelopment of the buttocks for maximising pressure redistribution. To facilitate this, the cover has to have sufficient stretchability and flexibility to allow for full immersion into, and envelopment from, the cushion – any cover materials without these properties will lead to 'hammocking' and incomplete potential envelopment.
Any taut material is likely to have an adverse effect around the ischial tuberosities – the area most at risk from pressure damage.

FRICTION AND SHEAR

In this section we consider the differences between, pressure, shear, and friction. Static friction helps to keep us in our seats, but is also what grabs the skin and distorts it. These shear forces lead to distortion of the shape of the cells in our skin and also our blood capillaries (shear strain) - too much distortion for too long leads to cell death. This is on top of the damage from compression of the tissues and blood vessels from the pressures (axial strain) created by gravity pulling down on the mass of our bodies (Fig. 7).
For most people, there is more flesh under the thighs than under the bony bits of the pelvis. Thus, there is more tissue under the thighs than there is under the pelvis to take up the shear stresses

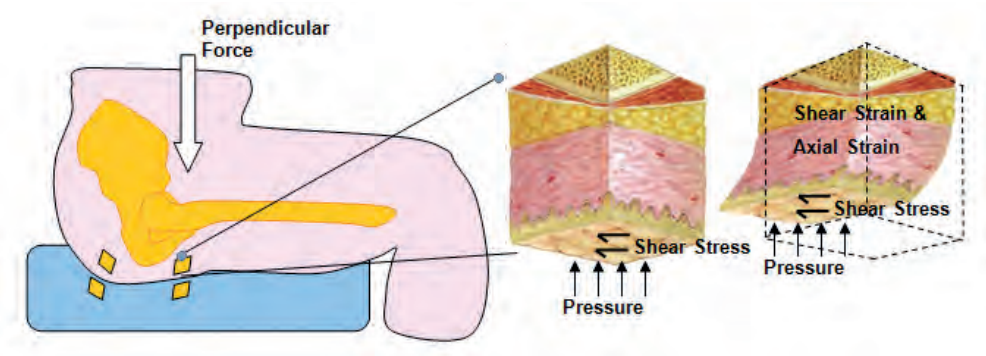


Figure 7. *Example of body tissue strains resulting from contact surface stresses when sitting on a cushion. Complex strains are developed inside the cushion as well.*

of sitting. With this in mind, it is ideal if the material under the pelvis can, to some degree, move with the skin, while having grippier material under the thighs (to stop us slipping into posterior pelvic tilt or out of the seat) (Fig. 8).

RISKS FROM TRANSFERS

During transfers, there are two key sources of risk to skin tissues from the design of a cushion. The first relates to the 'slipperiness' of the cover materials – the lower the level of friction, the easier to slide across it and the less 'grabbing' of the skin and therefore less shear strain on the skin tissue.
The second relates to the degree of contouring of the cushion – the greater the profile of any medial and lateral thigh supports, the greater the amount the user will need to lift or be lifted for a lateral (or forward) transfer.

MICROCLIMATE

Whereas pressure, friction, and shear can lead to pressure ulcers, there's another element that has an influence on skin health and that's the microclimate at the skin's surface. Microclimate covers the effects of temperature and moisture.
Taking temperature first: If a cushion has been stored overnight in a cold environment, then sitting on this cold surface could encourage capillary closure and therefore restrict the transfer of nutrients to the tissues. If the temperature is too high, this leads to the risk of sweating and moisture accumulation.
An important side-effect of higher temperatures is that each one degree centigrade of increase in temperature leads to 13 per cent more metabolic demand: 13 per cent more oxygen and nutrients needed, and 13 per cent more carbon dioxide and metabolites to be disposed of.

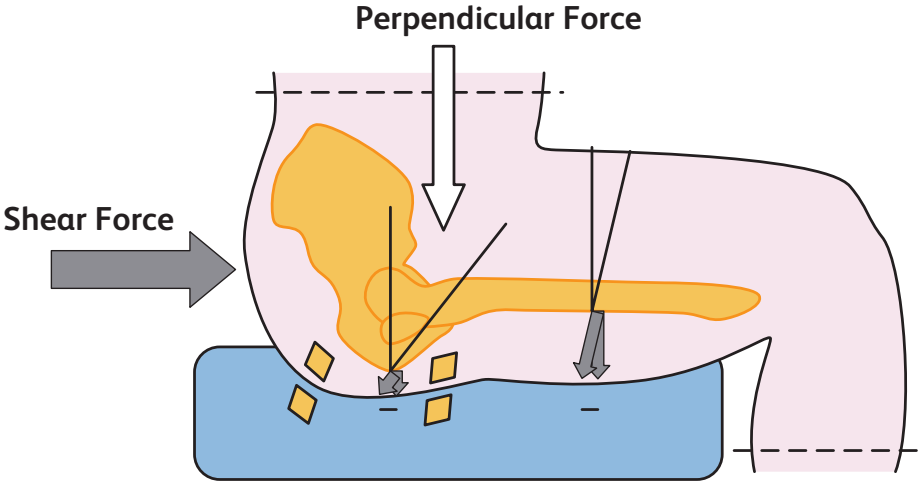


Figure 8. *Relative effects of shear strain on thinner tissues under a bony prominence (ischial tuberosity) as compared with deeper tissues (under the femur along the thighs).*

When we come to moisture, this can come from the skin as water vapour or as sweat. Non-breathable cover materials often lead to water vapour not being able to dissipate away and thus leads to moisture build up. Moisture on the skin leads to maceration (the wrinkling of the skin we get with having our hands in water for too long) and macerated skin is more susceptible to the effects of friction and shear. Further sources of moisture can come from leaking wounds and faecal or urinary incontinence.

The take home message is, again, that the material that the cushion cover is made from is critical to the health of the user's skin. Issuing a water-resistant or 'incontinence' cover may protect the cushion from the user's outputs, but the water vapour permeability will have a large influence on whether the water vapour will condense or wick away. So, how much do we want to protect the cushion versus protecting the user?

CUSHION ADDITIVES

Both cushions and covers may have additives to their materials, in particular to improve their resistance to ignition. Since cushions may be placed against bare skin, there are biocompatibility and REACH-related requirements for these chemicals.

Be aware that some of these chemicals will be removed in washing processes and cushions which pass flammability tests when new may lose some of this

protection after washing. However, the washability of covers is important. Users are recommended to have two covers so that when one is in the wash, the other is available to place on the cushion to protect the skin – see chapter 6.
The furnishing flammability standards and the REACH regulations had started to get in the way of designing good cushion and cover materials for optimal protection of the skin in medical products. For this reason, the flammability testing for cushions and other wheelchair postural support devices have been updated in the ISO 16840-10 flammability standard[8]. For more details, see the article in THIIS[9].

IN CONCLUSION

There are always elements of compromise for each user. The process of assessing the risk/benefit profile will indicate which cover solution is the most appropriate for each client. From the topics covered in this article, what the cover of a cushion is made from is critical for optimising tissue integrity, whether it is from enabling envelopment into the cushion, reducing the risks from friction and shear strain, or keeping air circulating to optimise temperature and moisture control at the microclimate level. The cushion's materials have more influence on positioning and pressure redistribution.

Stability and a neutral pelvis

This chapter reviews the first elements around the subject of posture and positioning, considering the role of 'stability', the health benefits of a neutral pelvis, and how this can be achieved.

For the clinician, as well as for the occupant, tissue integrity of the seated area may probably come first when selecting the attributes of a cushion. However, the construction and stability of the elements of the cushion's design will have major effects on the occupant's ability to carry out their normal activities while seated on their cushion. In addition, without appropriate support and stability at the pelvis, there are potential knock-on effects to the occupant's health, e.g. from misalignment of the spine leading to pain and to associated impacts on the physiological processes within the torso.

STABILITY

We emphasise the importance of stability, but what do we mean? Stability is an interesting term when it is applied to the seated person, and around what that person can do. If we take a matchbox, and place it on its end, it could be considered to be stable. However, it could be knocked over to a more stable position on its side (Fig 9). When one has a so-called stable item that can be transferred to a more stable position, the former is known as being metastable.

***Figure 9**. Metastable and stable match boxes*

For a seated person 'metastability' is potentially more functional than full stability, in that it allows the person to move their centre of gravity further towards the edge of their seating area – but, this only works for the individual if the person is able to fight against gravity to get back into the original

metastable position. So, in seating, the degree to which the cushion both supports and aids the occupant as they reach sideways or forwards is critical – an area now catered for and measurable in the recent ISO 16840-13 standard[10].

In this and the next chapter, we explore elements which can be designed into a cushion in order to help keep the pelvis in a central or 'neutral' position, to counteract the effects of gravity trying to pull the individual away from this metastable position, and to allow maximal functionality.

NEUTRAL PELVIS

What do we mean by a neutral pelvis? A neutral pelvis is where the Posterior Superior Iliac Spines (PSIS) (Fig 10:K) and Anterior Superior Iliac Spines (ASIS) (Fig 10: L) are level with each other in the horizontal plane (approximated visually by the line of your belt): this equates to the hip joint (Fig 10:M) and the iliac crest (Fig 10: J) being aligned vertically.
Consequently, the spine will be at its straightest at this point, and the torso and head at a maximum height. This stretched shape of the spine offers the most benefit to the torso, allowing optimum breathing, digestive, cardiovascular, and bladder function, and allows the head to be positioned best for communication and other functions. However, staying in this position can be tiring, and most people 'relax' back into a pelvic posterior tilt where the PSISs

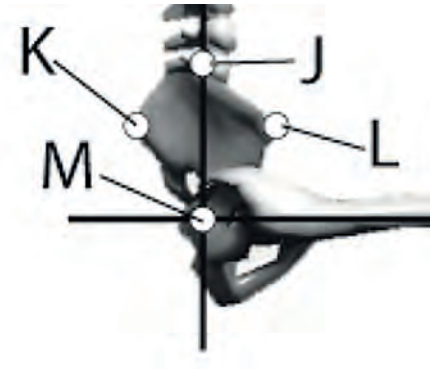


Figure 10. *Alignment of the pelvis in a neutral position[11]*

become lower than the ASISs. In setting up the seat it is not unusual to allow a couple of degrees of posterior pelvic tilt, for comfort.
However, too much tilt leads to kyphotic curvature of the spine, compression of the internal organs of the torso, and misalignment of the head. On top of this, gravity will 'grab hold' of any distortion and make it worse.

PLAYING BALL WITH THE PELVIS

So what can we do within the seating and cushion design to combat this 'posterior tendency'? The pelvis behaves a bit like a basketball, in that it can rotate in three planes, and with posterior tilt it rotates in the anterior-posterior plane.
Therefore the first thing we need to do is place the pelvis on a horizontal plane if we want the pelvis to be neutral. Many wheelchairs are provided with

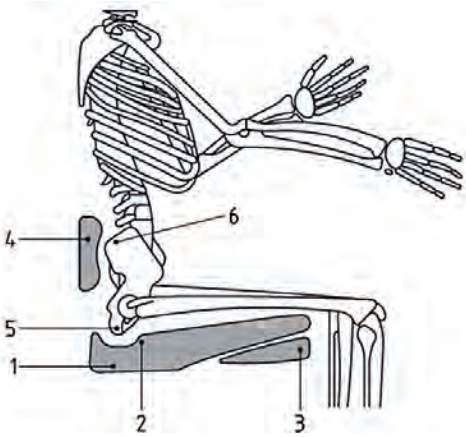


Figure 11. *Protecting against posterior tilt[12]*

Key
1. Flat seat base under ischials
2. Pre-ischial ridge
3. Ramping wedge under thighs
4. PSIS block
5. Ischial tuberosity
6. PSIS

a 'dump' with the seat plate angled upwards (which is often employed to make the occupant feel more secure and stable, on the one hand, and to bring the knees higher and the feet off the ground, on the other). This 'dumping' does not provide a horizontal base, and tips the pelvis back into a posterior tilt.

The solution is to have the seat plate horizontal, and therefore the pelvis neutral, but place a wedge under the cushion at the anterior part of the plate, thereby both elevating the knees, and also allowing pressure redistribution away from under the pelvis to below the thighs – to tissues more suited to carrying the pressures (Fig 11: 3). This wedge is best if placed inside the cushion cover. Using a pressure mapping system is the ideal means to visualise where pressures are being most evenly redistributed away from the pelvis and under the thighs (see Fig 12 and chapter 8).

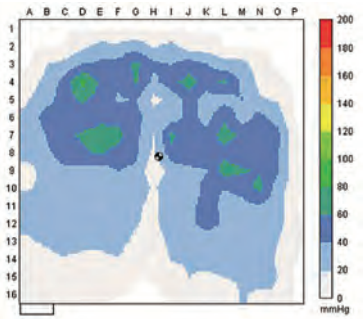
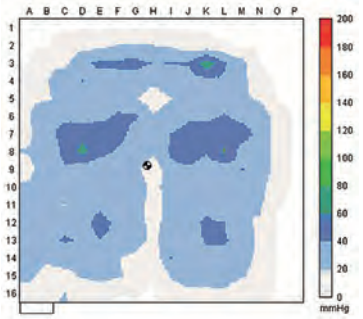


Figure 12. *The benefits of a wedge under the thighs for pressure redistribution. BodiTrak pressure map without wedge (left) and BodiTrak pressure map with wedge (right)*



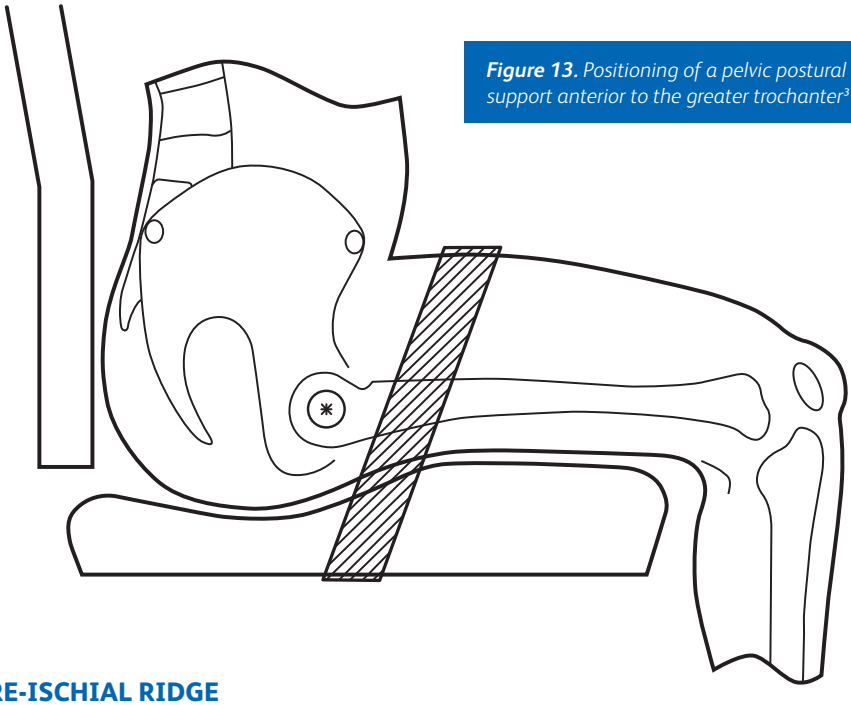


Figure 13. *Positioning of a pelvic postural support anterior to the greater trochanter*[3]

PRE-ISCHIAL RIDGE

We now have the pelvic 'ball' on a flat surface. How do we keep it from rolling backwards or forwards? The answer is, first, to place a PSIS block behind the pelvis, to stop the pelvis from rolling backwards (Fig 11: 4). This can be achieved by the base of a solid back support, or with tension adjustable straps in a flexible back support.

Next, to stop the pelvis from slipping forward, a small ridge anterior to the ischial tuberosities can be very effective (Fig 11: 2). Try folding a tea towel three times and place across your dining room chair, half way back from the front edge, and see how much difference that makes in controlling your ability to slide your backside forward on the chair.

A similar effect can be obtained by creating a buttocks recess in the cushion – the buttocks recess can also create greater immersion into the cushion, and therefore better pressure redistribution (Fig 11: 1). The critical element is that this depth should not be more than a maximum of 1 cm, otherwise you risk increasing pressures on the anterior side of the ischial tuberosities, and also you impair the user's metastability i.e. their opportunities to change position in a self-controlled manner.

At this point, if not enough control is being achieved, then a third point of

control, a positioning belt, should be applied. Remember: this should be mounted to the chair anterior to where the greater trochanter of the thigh bone is situated (Fig 13) as described in BS 8625[12].

IN CONCLUSION

There are many elements that should be taken into account when selecting what might be the most suitable cushion for an individual, and these go well beyond the immediate clinical needs of tissue integrity and the occupant's needs for functionality. This chapter has provided a number of relevant solutions around stabilising and positioning the pelvis, under the posture and positioning heading. Other elements relating to posture and positioning are covered in the next chapter.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Posture and positioning

In the previous chapter we addressed the benefits of a neutral pelvis and stability for posture management. This chapter unpicks further aspects around posture and positioning that can be enhanced by selective contouring.

For the clinician, as well as for the occupant, tissue integrity around the buttocks may well come first when selecting the attributes of a cushion. As discussed in the previous chapter, the construction and resultant stability of the elements of the cushion's design will have major effects - on the occupant's ability to carry out their normal activities while on the cushion, on the one hand, and, on the other, effects on the control of deformities or preventing development of deformities elsewhere in the body.

In this chapter we consider further elements that can be incorporated into the design of a cushion through contouring to provide further postural support to the benefit of the occupant. Some of these elements, as well as helping the occupant to obtain the benefits of a better posture, will have a positive influence on pressure distribution.

CONTOURING

Contouring or shaping in cushions can be achieved by fixed components built into the cushion (e.g. different density or thickness of materials), by adjustability within the cushion (e.g. by selective removal of air), or by external additions (e.g. with shaped wedges under the cushion). This contouring or shaping can be placed selectively and to different degrees to meet the specific needs of the occupant.

AN ALTERNATIVE MEANS OF CONTROLLING POSTURE AND POSITION.

When the contouring in or around the cushion is not enough, an alternative means of controlling posture and position may also be needed, such as the application of positioning belts and harnesses, or additional appropriately placed pads.

Thus contouring can be designed to achieve specific aims to manage the occupant's posture and positioning, which may lead to improved functionality and/or better controlled skeletal management, especially during growth phases.

The downside is that contouring, by restricting some movement, may also have a negative outcome on functionality. In addition, the contours might physically impair transfers.

THIGH ABDUCTION

Anatomically, the ideal angle of the thighs is 5° of abduction from the midline, to ensure you have the head of the femur best located in the hip joint (the acetabulum) in the pelvis (Fig 14). This can be achieved by a thigh recess (trough) in the cushion, and or extra or more dense material at the front of the cushion, creating an abduction pad between the thighs. These elements can also be used to help manage rotation of the pelvis. In more complex cases involving pelvic rotation and/or 'windsweeping', then the thigh recesses may need appropriate customisation.

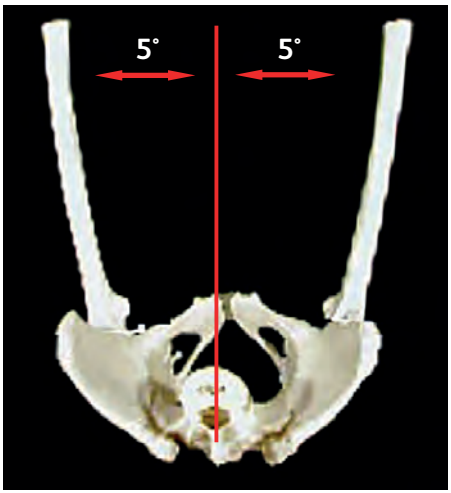


Figure 14. *Optimal thigh angles for femur-hip joint positioning*

LATERAL SUPPORT

In contrast with the needs to adduct the thighs by a small amount, there will be times where there is a need to restrict the amount that the thighs abduct. This can be achieved by increased support built into the sides of the cushion – again by using more dense or additional material.
Increased lateral support further back in the cushion can be used to reduce the amount of rotation experienced at the pelvis, and this can be used in combination with a buttocks recess in the cushion.

SUB-TROCHANTERAL SUPPORT

A more specialist piece of posterior lateral support can be to create a 'sub-trochanteral' ledge. The greater trochanter is the bony prominence sticking out of the side of the femur near where it is located in the acetabulum. If the cushion has sufficient thickness (>10cm), and allows for sufficient immersion in the buttocks area, then some of the pressure from the ischial tuberosities can be 'offloaded' onto the greater trochanters, by the use of a subtrochanteral ledge at the side of the cushion. By taking some of the body mass load onto this area, this also provides greater stability for the occupant, since the support base is at its widest at this point (Fig 15).

Figure 15. *Greater trochanter offloading options*

Please do be careful though: too much 'offloading' can have an adverse effect on the hip joint.

OBLIQUITY MANAGEMENT

In the previous chapter, we referred to the pelvis as being like a basketball, which can rotate in all three planes. There we covered managing the ball's tendency to roll backwards. Earlier in this chapter we've referenced any tendencies to rotate in the horizontal axis, as seen from above from the transverse view. The third direction of possible rotation is seen when viewed from in front - a rotation we refer to as pelvic obliquity, where one side of the pelvis ends up higher than the other.

The degree of obliquity is measured by taking a line through the two ASISs at the front of the pelvis, and measuring by how many degrees this line deviates from the horizontal. If the person's right side is lower than the left this is a positive angle, but if higher then this is a negative angle[13].

A pelvic obliquity is usually accompanied by a scoliosis of the spine, as the body tries to keep the head straight and the eyes horizontal (Fig. 16). The pelvic obliquity may be the cause of the scoliosis, or vice versa. Depending on the degree of flexibility of the spine, the shaping of the cushion may be used to accommodate the deformity, or assist in correcting it. To achieve this, sometimes it works better to decrease the thickness of the cushion on one side, and in other cases to increase the thickness on the other.

Figure 16. *The association of pelvic obliquity with scoliosis of the spine*

Using a pressure mapping device gives objective feedback as to the effectiveness of the respective interventions. The application of an appropriately placed positioning belt (often a rear pull one) can help in correcting a flexible obliquity[12].

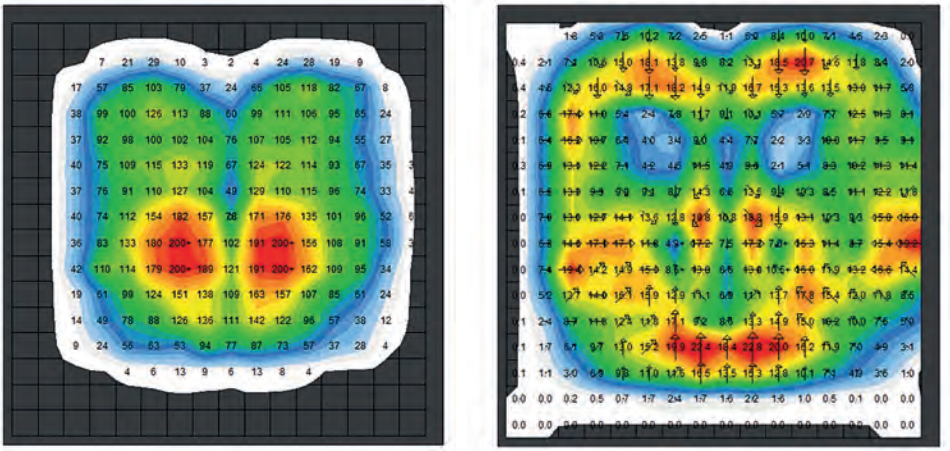


Figure 17. *Pressure map showing left: pressures with highest pressures under the ITs and right: the gradients from the same map, showing greatest gradients are occurring around the sacral/coccyx area*

GLUTEAL (POSTERIOR) SUPPORT

Apart from the ischial tuberosities under the pelvis, a major bony area at risk of pressure and shear injuries, is the sacral/coccyx area at the base of the spine – an area that has little skin protection, and an area that has forces from the back support as positions are changed. Many of us have more tissue than we feel we need around our buttocks. If we can spread the support of the body more widely over this area, we are taking the forces into tissues well away from inadequately covered bony prominences, as described in the paragraph above. Using a pressure mapping system which shows gradients as well as pressures can show clearly the potentially damaging forces around areas which are normally out of sight to the naked eye (Fig. 17).

Where the maximum pressures occur are not where the largest rates of change occur, and the greater the rate of pressure change, the greater likelihood of damaging shear strain. To what extent does your cushion provide contouring around this area (one area of contouring that, incidentally, will not have an adverse effect on transfers)?

IN CONCLUSION

There are many elements that should be taken into account when selecting what might be the most suitable cushion for an individual that go well beyond the immediate clinical needs of tissue integrity and the occupant's needs for functionality. This chapter provided a number of the relevant related aspects that can be achieved through contouring of the cushion that can lead to a better posture, better function, and have tissue integrity benefits.

Functionality

In the first chapter we identified the three key elements around which a cushion can be assessed – functionality, tissue integrity, and posture management. This chapter unpicks aspects around functionality.

For the clinician, tissue integrity and positioning elements of a cushion come at the top of the list, while for the user, once these aspects have been covered, functionality comes top of their list, and can make the difference as to whether the cushion will be used, or just left on the shelf.

COMFORT

Comfort is subjective. Barbara Crane, in the US, interviewing wheelchair users as the background for her PhD thesis, established that Comfort was the most important element to users[14]. The subjectivity behind comfort is why in Switzerland a clinician will prescribe a choice of three cushions, each of which would be suitable for the user's clinical needs, and the user then tries and selects which cushion they prefer.

CUSHION WEIGHT

The weight of the cushion should be a crucial part of the decision process. If the user will be moving the cushion from one site to another, how easy is it for that person to lift and move it? If the user is acquiring a manual wheelchair, then every extra gram that the cushion weighs, will equate to the extra effort that will be needed by the user or carer to move the chair.

MINIMISING FATIGUE

Vibrations coming up through the wheels and the seat add to the levels of a user's fatigue when propelling a manual wheelchair. A study from the University of Pittsburgh compared four different cushion materials, and reported that air-foam cushions dampened vibrations better than foam, air, or gel cushions[15], so the materials that the cushion is made from make a difference to the user's rate of fatiguing.

MAINTENANCE AND DURABILITY

Although we expect elements such as moisture, temperature, and sunlight

to be the fastest source of aging cushions, it is not these elements, but instead the faecal bacteria that are released with flatulence that have been found to be the biggest aging element for cushions. Thus it is ideal that the cushion and its cover can be readily cleaned and disinfected.
Under UKCA and CE marking regulations for Instructions for Use, cushions are required to be supplied with instructions for approved methods of cleaning and disinfection.
Just as we might have more socks than shoes, mainly because it is what's closer to the skin that needs washing most frequently, it is recommended that we have at least two covers for each cushion, so that while one cover is in the wash, the cushion can still be used with the other cover.

ENABLEMENT OF DAY-TO-DAY ACTIVITIES

The needs of the user to carry out their normal daily activities should be taken into consideration when selecting a suitable cushion. If the user needs to reach away from their wheelchair to carry out their daily activities, then the stability of the cushion to permit this is important. There is now an International Standard (ISO 16840-13)[10] to assess the lateral stability of one cushion as compared with another.
Another area for consideration relates to transfers. The smoother the cover, the easier it is to transfer. Likewise, the less precontoured shape there is to the cushion, the easier it is to slide off it. This has to be balanced with the value of the contouring for posture management needs.
If the one cushion is to be used in different applications, how easy is it to be taken from one device to another – is there a handle? How strong are the hook-and-loop attachments?
Appropriate labelling is also valuable, particularly to aid inexperienced carers. Simple indications of top and front are often needed to ensure the correct part of the cushion is interfacing with the relevant parts of the user's body. Simple washing instructions should be supplied. UK furnishing flammability regulations require certain warning and related labelling for cushions (Fig. 18).

FAIL-SAFE

A final, but possibly the most important aspect: how important is it and how likely is it for the user that the cushion, if it fails, fails safely?
Different materials each have their own level of risk. Foam over time will tend to develop a 'set', or the cells break down, and thus the development of a failure to give optimal immersion to redistribute pressure forces is a slow (indiscernible) process. At the other end of the scale, whereas an air cushion provides excellent immersion, a puncture immediately leaves the user at risk of tissue injury. If a gel cushion leaks, or the gel gets displaced, then what is in place under the gel becomes critical for continued protection of the skin.

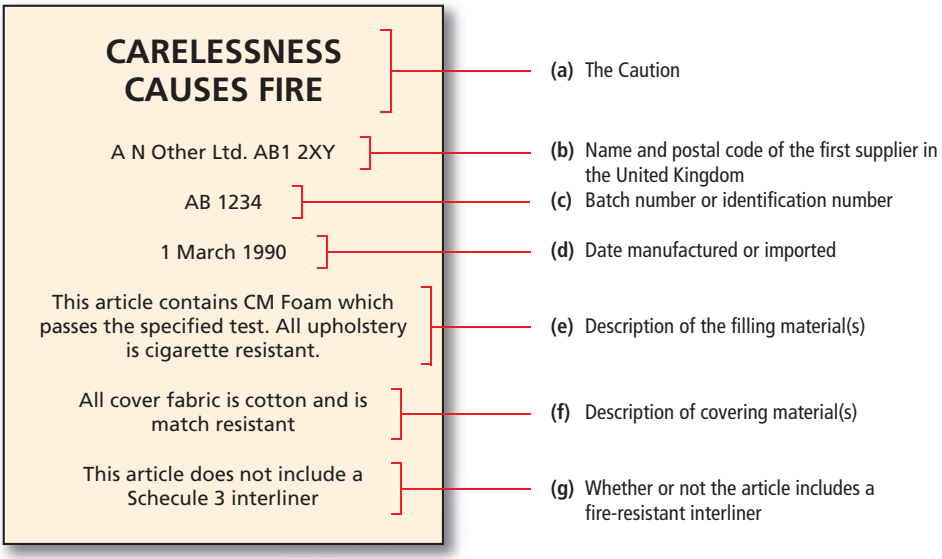


Figure 18. *Flammability label in the UK*

IN CONCLUSION

There are many elements that should be taken into account when selecting what might be the most suitable cushion for an individual that go well beyond the immediate clinical needs of tissue integrity and posture management. This chapter provided a number of the relevant items under the functionality heading.

Standard of evidence

In previous chapters, we have looked at elements of cushion design that influence a cushion's properties for managing skin health and tissue integrity, for providing postural support, and for aspects of functionality. This chapter looks at some of the specific data that have been generated for a wide range of cushions, all of which establishes that no two cushions are the same, and that a cushion selected for a client needs to be selected around the specific characteristics which suit that individual client's needs.

Are there any differences between one cushion and the next and, if so, how much difference is there? What do the values from cushion characteristic tests mean for the end user? These are valid questions, and are important when explaining to procurement departments that all cushions are not the same – even within the 'same' category (see below).

There's a number of cushion characteristics which we can measure, and that are important for the well-being of the client. These include aspects such as pressure distribution, immersion, envelopment, stability, temperature regulation, moisture regulation, changes with aging, amongst others. This builds a complex picture of each cushion, and to help actually quantify these aspects there are a number of tests covered by the range of international standards within the ISO 16840 series for wheelchair cushions.

WHEELCHAIR AND CUSHION INFORMATION

The University of Pittsburgh's Wheelchair & Cushion Standards Group is using an NIDILRR[16] grant to translate these ISO performance standards into a way that is understandable and gives practical and applicable advice which can be used by healthcare professionals, manufacturers, wheelchair users, etc, to implement and call upon in daily practice. The results of their work to date can be found on their website https://www.wheelchairstandards.pitt.edu

This site is an excellent resource, with useful fact sheets on a variety of topics, for example, aspects of wheelchair performance, as well as on Cushion Performance Overview and a Cushion

Performance Interpretation Guide. The latter covers seven of the available tests, explaining the reason why each is used, a summary of the test (with pictures of the test set-up), the range of values found across a range of cushions, and an indication of the significance of being at one end or the other of a range of values for that test.
If you turn to the Explore Our Data Tab, here you will find data for around 50 different cushions, measuring:

- *Loaded Contour Depth and Overload Deflection (ISO 16840-2[17] Clause 11): a test to evaluate a cushion's ability to immerse the buttocks*

- *Envelopment (ISO 16840-12[19]): a test that characterizes a cushion's ability to envelop and immerse the buttocks (data to be added shortly)*

- *Hysteresis (ISO 16840-2[17] Clause 14): a test to evaluate a cushion's ability to provide support consistently during a cycle of loading and unloading*

- *Impact Damping (ISO 16840-2[17] Clause 9): a test to evaluate a cushion's ability to reduce impact loading on tissues and help maintain postural stability when performing tasks such as going off a kerb*

- *Horizontal Stiffness (ISO 16840-2[17] Annex C): a test to evaluate a cushion's response to slight horizontal movements in the forward direction*

This report also shows the effects of accelerated aging (using methodology from ISO 16840-6[18]) involving laundering, disinfection, accelerated aging, and cyclic loading protocols on some of the cushions for various of the previous measures, as well as

- *Pressure Mapping (ISO 16840-6[18] Clause 14): a test that utilizes interface pressure measurements to assess the magnitude and distribution of pressure on a loaded cushion*

- *10% Force Deflection (ISO 16840-6[18] Clause 20): a test to evaluate a cushion's ability to 'cushion' or elastically deform by measuring the force necessary to produce a deflection of 10% of the cushion thickness*

The accelerated aging protocols were then repeated a second time from which one can see which of the tested cushions saw their characteristics change the first time round, and which ones changed again after the repeated aging process.

TEST DATA

For all the tests, the values are provided for comparison purposes with those for a reference foam cushion made up of a 3" thick, high density polyurethane foam with a 25% IFD of 170 N and 65% IFD of 320 N. The reference foam cushion had a cover with a 2-way stretch nylon/spandex top and non-slip polyester bottom.
On this report, you can select tabs for the different tests which colour code the cushions by their 'CMS code'. What is a CMS code I hear you ask – well, unlike the UK or Australia where we do not have codes, in the US, the Centers for Medicare and Medicaid Services (CMS) have created codes which cover certain

Figure 19. *The stability report from 'Explore our data'*

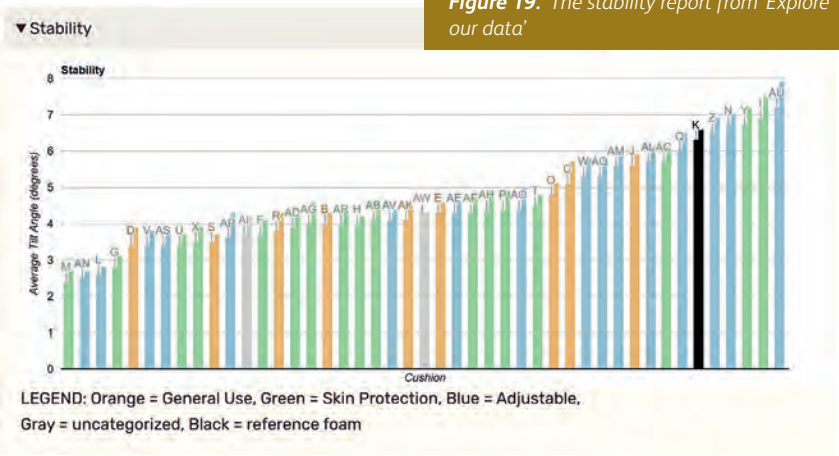
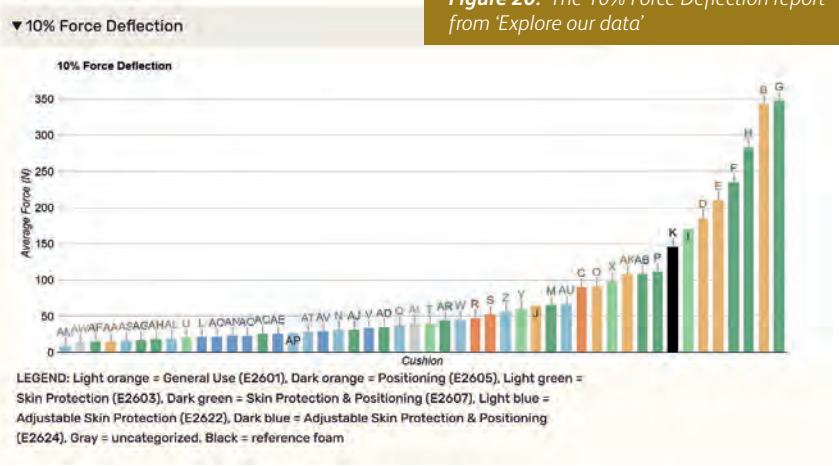


Figure 20. *The 10% Force Deflection report from 'Explore our data'*



criteria which a cushion has to meet for that code, and from that the reimbursement level it receives. The separate codes cover cushions for: General Use; Positioning; Skin Protection; Skin Protection and Positioning; Adjustable Skin Protection; and Adjustable Skin Protection and Positioning (See Fig 20).

A couple of the graphs are reproduced here as Figures 19 and 20 showing the different performances of the cushions tested against the parameters of stability and force deflection. Note that cushions M and AU, for example, are at opposite extremes in Figure 19, whereas they have similar values in Figure 20.

To apply the data in a helpful manner, one needs to choose a measure or measures that is/are appropriate for your client's needs. It is also interesting to note that generally the cushions do not group together by their CMS code: this raises the question as to whether the bases for these codes have been set alongside the most appropriate criteria. (The coding is based upon the Loaded Contour Depth test with added immersion and overload deflection requirements per code.) At least these criteria are somewhat better than defining a cushion by what it is made from, or what it looks like, which has occurred in some tendering processes in the UK.
At this stage, all the cushions have been 'blinded' while permission is sought from the manufacturers to identify their cushions, but why not ask your supplier which cushion letter represents their tested cushion? The important thing to note is that the data are not pass/fail criteria, and do not point to one cushion necessarily being 'better' than another. For some clients it is important for them to have a cushion performing at one end of a scale, while for others it might be the opposite end.
Eventually, the Pitt team aims to bring all the data together, to populate, in the Cushion Concierge page, cushion performance data resource, based on these ISO standard tests. This resource can then be used to help healthcare professionals transform the wheelchair cushion selection process, and advance evidence-based clinical practice.

Myth: Pressure mapping is only used to compare cushions

In earlier chapters we have referred to pressure mapping as a tool for assessing the interaction between the cushion and the person. In this chapter we review the benefits of modern pressure mapping systems, and what additional information they can provide the clinician as part of their assessment and prescription process.

Interface pressure mapping (IPM) is a technology that has been in use for more than 30 years, and over that time the technology has evolved so that now it is as easy to use routinely as measuring blood pressure. And, like the latter, the technology provides clinical information that cannot normally be accessed without the technology.
The term IPM refers to the pressures at the **interface** between the person's skin (or more usually the clothing under their buttocks) and the support surface or cushion underneath. Note: these are unlikely to equate to the pressures experienced deeper into the skin and around capillary blood vessels, but they do give a qualitative guide to the pressures likely to be occurring deeper in the skin tissues.

As the technology has advanced, mats have become more flexible (more easily following the contours of the body), able to provide data in real time (reflecting that sitting is a dynamic activity), able to transmit data wirelessly (allowing remote monitoring – even across the internet), and costs have come down (what cost USD16000 ten years ago, can cost less than USD3000 now).

ESTABLISHED CLINICAL BENEFITS

There are published reports that show that using pressure mapping (IPM) alongside clinical judgement provides better outcomes than clinical judgement on its own. Data from a cushion study[19] showed that on **clinical judgement on its own,** 21% of the clients developed pressure ulcers, while with **clinical judgement plus IPM,** only 9% developed ulcers. In another study[20], in an ICU, with no use of IPM, 16 out of 320 patients developed Stage 2+ pressure ulcers, while with the use of an IPM, only 1 out of 307 patients developed a Stage 2+ pressure ulcer.

WHAT CAN WE USE PRESSURE MAPPING FOR?

One can indeed use pressure mapping to view how one cushion compares with another in dispersing the forces applied by the seated person – but please do so with the user carrying out the activities they would normally do, and not in an artificial 90-90-90 position (in which no-one normally sits). Also bear in mind that the picture will change with time as the cushions adapts to the user, and the user's tissues adapt to the cushion. However, pressure mapping has wider applications.

A valuable use of pressure mapping is to visualise whither the pressure has been redistributed as a consequence of seat and positioning adjustments. Back in the '90s, Professor Ian Swain reported that the simplest way to get better pressure redistribution of pressures away from the bony parts of the pelvis (the ischial tuberosities), was to adjust the foot position (through the height of the foot supports) to have more pressure distributed under the thighs. Pressure mapping allows you to see the optimum set up of the different parts of the chair – foot supports, arm supports, back support, etc – for optimal pressure redistribution. (Note: The iShear product (Fig. 22), in combination with pressure mapping, can be used to provide further information as to the distribution of forces arising from different positions of the individual.)

Figure 21. *A modern pressure mapping mat that is designed for USB cabled or wireless recordings*

AN EDUCATIONAL TOOL

Pressure mapping is a great educational tool for use with carers and users. It's a great way of showing in colour what the effects are of good vs poor positioning. A great use of the tool is to show a user how far forward the user needs to lean to offload their ischial tuberosities (see Fig. 23).

As discussed in Chapter 2, in recent years, the greater impact of shear strain, rather than pressure alone, on skin tissue integrity has become appreciated. Using the 'gradient' view that pressure mapping systems offer, allows one to visualise where the greatest rate of change of pressure is occurring: the greater the pressure gradient, the greater is likely to be the distortion of the skin tissues.

Figure 22. *The iShear seating assessment and wheelchair set-up tool*

AND HOW DOES A PRESSURE MAPPING SYSTEM PAY FOR ITSELF?

Apart from the benefits around clinical outcomes, pressure mapping has financial benefits. Often a lower cost solution, such as a cushion, can be shown to be as effective as a requested higher cost item. Documentation of the effects of different solutions assessed in clinic, and the justification based on these assessments, cover the clinician and their employer where the user later prosecutes for clinical malpractice based on the solutions provided.

AND HOW DOES A PRESSURE MAPPING SYSTEM PAY FOR ITSELF?

In the US, medical insurance companies will not pay for treatment of pressure ulcers that develop while a person is in hospital, and thus individuals are inspected more closely when they arrive in hospital: pressure mapping is used as part of the assessment of the person's risk of developing pressure ulcers while in hospital. Ideally, we should be taking this approach in our country!

For further advice around pressure mapping, visit the Posture and Mobility Group's Best Practice Guidelines BPG2[21]: This BPG is the core of the international standard ISO/TR 16840-9[22].

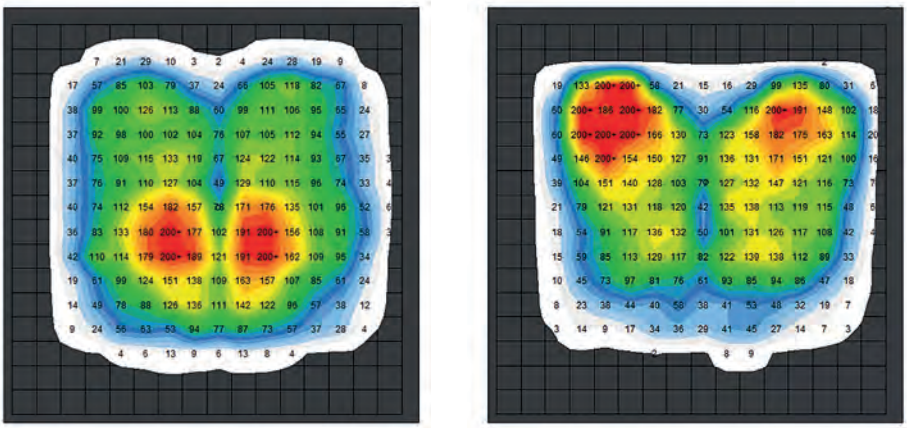


Figure 23. *Demonstration of offloading pressure from under the pelvis by leaning forward*

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Checklists

To compare a choice between two cushions for a single client score your alternative choices for each of the criteria descibed in chapters 2 - 6 as relevant to that client, and calculate which gives the higher score for that individual.

CUSHION PRESSURE MANAGEMENT

1. Immersion ☐ ☐
2. Envelopment ☐ ☐
3. Trochanteral off-loading ☐ ☐
4. Thigh off-loading ☐ ☐
5. Gluteal (posterior) support ☐ ☐

CUSHION COVER TISSUE INTEGRITY

1. Immersion ☐ ☐
2. Envelopment ☐ ☐
3. Friction optimisation ☐ ☐
4. Shear reduction under ITs ☐ ☐
5. Breathable cover ☐ ☐
6. Microclimate management ☐ ☐
7. Washability ☐ ☐
8. Ignition resistance ☐ ☐
9. Biocompatible components ☐ ☐

CUSHION POSTURAL MANAGEMENT

1. Stability ☐ ☐
2. Neutral pelvis ☐ ☐
3. Pre-ischial ridge ☐ ☐
4. Thigh abduction ☐ ☐
5. Lateral support ☐ ☐
6. Sub-trochanteral support ☐ ☐
7. Obliquity management ☐ ☐
8. Gluteal (posterior) support ☐ ☐

CUSHION FUNCTIONALITY

1. Comfort ☐ ☐
2. Cushion weight ☐ ☐
3. Vibration dampening ☐ ☐
4. Low maintenance ☐ ☐
5. Cleanability ☐ ☐
6. Stability ☐ ☐
7. Ease of transfers ☐ ☐
8. Transferability ☐ ☐
9. Appropriate labelling ☐ ☐
10. Fail safe ☐ ☐

This guide is brought to you by Healthcare Innovations Australia, manufacturer and distributor of pressure care, pressure mapping, seating, and children's mobility products.

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