A pressure ulcer (PU) is defined as ‘localized injury to the skin and/or underlying tissue usually over a bony prominence, as a result of pressure, or pressure in combination with shear. A number of contributing or confounding factors are also associated with pressure ulcers; the significance of these factors is yet to be elucidated[1]. Pressure is the amount of force acting on a unit of area[2], whereas shear forces occur in soft tissue when these tissues are stretched, as happens when the bony structures move, but the skin does not move correspondingly[3].

PUs are a significant healthcare problem, affecting individuals of all ages, cared for across a variety of clinical care settings synonymous with healthcare delivery today[4]. For example, a recent iterative review noted mean prevalence rates of 8.9% in Iceland, 17% in Norway, 16% in Ireland, 15% in Denmark and 25% in Sweden[5]. Incidence figures also vary across countries, for example, the single incidence study from Norway noted a figure of 16.4%, whereas mean incidence in Denmark is 1.8%, 11% in Ireland and 20% in Sweden[6].

Among individuals who have difficulty or an inability to stand or walk, use of a wheelchair is the means by which they can move from place to place. Indeed, the World Health Organization (WHO)[7] suggests that the wheelchair is one of the most commonly used assistive devices for enhancing personal mobility. Furthermore, 10% of the global population — almost 650 million people — have disabilities and of these individuals, 10% require the use of a wheelchair[8]. Among wheelchair users, the risk of PUs is higher than among the general population due to the protracted periods of time spent seated without pressure relief[9]. Indeed, in a study of community dwelling wheelchair users the most frequently reported continuous sitting time in a wheelchair was 12 hours. In addition, within this population the prevalence of PUs was 58%[10].

This article sets out to provide guidance on seating and pressure ulcer prevention. As pressure and shear are the key causative factors in PU development[11]. However, the nature of exactly how these two forces contribute to tissue damage is not as clearly understood[12]. It is postulated there are four mechanisms within three functional units that lead to pressure ulcer development[13]. The functional units are the capillaries, the interstitial spaces and the cells[14]. The mechanisms are local ischaemia, reperfusion injury, impaired interstitial fluid flow and lymphatic drainage, and sustained deformity of cells[15,16].

More recently, greater focus has been placed on the role of cell deformation in PU development, in that this mechanism has the potential to cause damage much quicker than is seen in the presence of ischaemia alone[17]. When muscle cells are under pressure, their metabolism changes immediately to an anaerobic state[18]. Cells under pressure are destroyed by two main mechanisms; waste products suffocate the cells and cell deformation changes the osmotic process, with death occurring as quickly as between 2 and 4 hours[17]. Cell deformation can also be extreme; when the muscle cells are stretched around the bony tuberocities (shear strain) changes in the cell membrane and nucleus membrane occur leading to permanent destruction of the muscle cell, resulting in deep tissue injury[19].

In the seated individual, body weight is loaded onto a relatively small surface area, namely the ischial tuberocities and buttocks, the coccyx and upper thighs[20]. Thus, in these individuals PUs occur most commonly around the bony prominences in these weight-bearing areas [Figure 1][21].

2 Understand the significance of pressure ulcers in the seated individual

PUs impact negatively on health related quality of life, with all the activities of daily living being adversely affected[22]. Worryingly, pain is one of the most common complaints with individuals suggesting this pain is intractable and often compounded by interventions offered to combat risk of further PU development[23]. For example, some patients report that pain was exacerbated by their pressure-relieving equipment and also that pain was a significant issue during dressing changes[24].

As pressure and shear impede normal osmosis and diffusion, tissue perfusion and also contribute to cell deformation, when an individual actually...
develops a PU they should not weight bear on the affected area, as perfusion is central to cell repair. Thus, PUs can be devastating in the seated individual as they will have to offload pressure and shear from the PU and thus will be unable to spend time seated as they normally do. Usually, this means the individual will be prescribed bed rest, however, Norton and Sibbald highlighted the negative effects this treatment modality can have on the individual. This includes cognitive and psychosocial complications with depression more common in these individuals compared to their matched counterparts. Thus, having an awareness of the significant negative impact of PUs should serve to act as a trigger to place particular emphasis on PU prevention in the seated individual. Indeed, a useful alternative to bed rest to consider for those with PU in the seating area can be to use a device on wheels for prone positioning where the person lies on their abdomen with an appropriate pressure redistribution device; this device will still give the patient mobility.

3 Know who is at risk
As mentioned previously, pressure and shear are the key causes of PU development. Therefore, in attempting to identify those at risk of PU development, it is logical to focus on those who may be exposed to prolonged unrelieved pressure and shear forces.

Given that pressure is equal to force divided by area, with most of the body weight resting in the seated area, it becomes evident that prolonged seating increases risk of PU development. Usually, following periods of prolonged immobility, a painful stimulus motivates the individual to move. Failure to reposition may be due to the individual’s inability to feel pain or to their actual physical ability to move or reposition themselves. This can also arise due to the excessive use of psychotropic medication, which is a common problem in the care of older people. Thus, these key factors need to be taken into consideration in determining which seated individuals are at risk of PU development.

In the late 1990s, Anthony et al. argued that risk assessment tools used for general patients were not well suited for use among wheelchair users. In their study of 150 wheelchair users, they found that risk factors for PU development were sex (males are more likely to develop a PU), and whether the individual uses a wheelchair all or part of the time. Further, consideration of these risk factors predicted almost as well as the Waterlow scale.

Other researchers have suggested that risk assessment in wheelchair users needs to take place outside of the clinic setting, focussing on where the person usually spends their time. These researchers highlighted the importance of understanding the individual’s sitting habits, whereupon an individual may inadvertently be placing more pressure on one buttock than the other.

Furthermore, active repositioning may be erratic, thus remote pressure logging may be useful in determining these disparities. Changes in usual habits may also be identified, for example, a reduction in usual activities arising due to illness or depression. The acquisition of this information will allow for a more focussed risk assessment and the subsequent development of a bespoke prevention care planning focussed not only on pressure redistribution, but also on enhancing health literacy.

4 Understand what you can do to combat pressure ulcer risk
Keeping focussed on the definition of PUs, helps in clarifying what needs to be done to combat the risks of PU developing in the first place. If PUs are caused by prolonged exposure to unrelieved pressure and shearing forces, then it is logical that the first step is to reduce this overexposure of the individual to these adverse forces. Whereas this may seem simple at first glance, in reality, this is a complex process and one which needs careful consideration of the impact of any strategies on the individual themselves. More recently, use of care bundles for PU prevention have become popular as they focus on the consistent application of key aspects of PU prevention. The SSKIN bundle is one such example and evidence suggests that when used within a collaborative team working model, significant reductions in pressure ulcer prevalence can be achieved.

A recent ‘Pressure Ulcers to Zero’ initiative, using the SSKIN bundle within the Health Service Executive in Ireland included advice and guidance for healthcare workers and patients alike regarding the importance of repositioning for the seated individual. Information posters were made available reminding care staff that the patient needed help with moving. Furthermore, information leaflets were devised for patients and carers, outlining the important aspects of PU prevention for them. The outcome from this campaign were a 75% reduction in PU prevalence over the first 6 months.

5 Choose the right seat
The type of seat a person sits on influences the potential for PU development. The chair should be the right width so the person fits comfortably into the chair. If the chair is too narrow, the person...
will be squashed into the chair, which may create a pelvic obliquity and rotates the spine, thus creates seating instability. Pelvic obliquity will also increase the weight bearing on one of the buttocks, which again, may lead to increased risk of the individual getting a PU. Conversely, if the seat is too wide, the user will lose seating stability, since wheelchair side supports help to stabilise the pelvis and thus create stability of the person. The general rule for wheelchair users is that the seat should be as small as possible, with just a finger width space on each side between the body and the side supports.\(^{[16]}\)

The seat depth should be such that when the buttocks are in contact with the backrest, there should be just a few fingers space between the front of the seat and the individual’s calf. If the seat is too long, the contact between the person’s calves and the seat will make the user slide forward in the seat. This increases shear forces in the buttocks and creates a slouched position, putting pressure on the coccyx. Conversely, a seat depth that is too short will reduce the area on which the pressure is distributed, thus increasing the pressure on the vulnerable areas.\(^{[1]}\)

The height of the chair is also of importance. The feet should always be supported, either by the chair’s footplates or by the floor. For a seated person, the correct height between the top of the seat cushion and the footplate/floor is identical to the distance of the heel to the back of the knee. If the feet are not supported, the person will lose stability and slide down in the chair, also creating a slouched position and increased pressure on the coccyx.\(^{[6]}\) The position of the seat should allow the knees to be placed at approximately 90°. It is good if the feet can be positioned in different angles on the footplates, but in general they should not be positioned too far forward. A common misunderstanding is to put the feet on angle adjustable leg rests and have the users knees nearly stretched, to ‘reduce’ oedema in the ankles. This position does not have an impact on the oedema and only causes the hamstrings to stretch which, in turn, will tilt the pelvis backwards, sliding the user out of the chair, once again causing a slouched position and increasing pressure on the coccyx.\(^{[29]}\)

A backrest designed to follow the shape of the back increases the contact area and reduces pressure on the seated area and also reduces the risk of sliding forces.\(^{[20]}\) This can be done in several ways, one is by the use of tension adjustable straps in the backrest upholstery; this enables the backrest to be shaped according to the user’s back. Also, in many modern chairs, the seat to back angle can be adjusted a few degrees forward and backwards to make the fit even better.\(^{[20]}\) Some chairs have a backrest recline, but this mechanism is not advised since many carers open the backrest angle and leave it in this position, which causes the user to slide down in the chair with the same consequences as described above.

Chairs with a seat tilt mechanism where the seat to floor angle can be actively and frequently changed, is advised for most wheelchair users with a reduced mobility. This mechanism enhances offloading of the pressure areas. American chairs have a seat tilt from around 0° (flat seat) to 40–60°, while the European chairs are tilted between 0° and up to 30°. The advantage of the American-style chairs is that the pressure can be completely offloaded from the seat area, but the disadvantage is that the pressure on the back is increased and also that the user is only able to see the ceiling as they will be looking upwards. The advantage of the European model chairs is the user still can engage with their surroundings, but the disadvantage is that pressure is not completely off loaded from the buttocks.\(^{[20]}\)

6 Consider the stability of the seated person

Being in a stable position in the wheelchair reduces shear forces and uneven pressures while seated. Stability is obtained by using as small a seat width as possible, employing a backrest shape that follows that of the individual’s back, using armrests that support the upper body and by choosing the optimal seat angle for the user. Physical changes due to the ageing process is often seen in the shape of the back, where the lumbar spine is flattening out, leading to a more rounded thoracic spine with the head in front of, rather than on top of, the body.\(^{[30]}\) This hunched up/slouched position reduces the fit between the back rest and the back, thus leading to reduced balance and, when seated, to find balance one will slide down in the chair increasing the shear forces in the seated area.\(^{[30]}\) Many modern wheelchair backs can be adapted effectively to these changes in the individual.

Instability while seated may cause the individual to slide within the seat. The resulting shear forces will enhance shear strains around the bony prominences increasing the risk of PU development.\(^{[31]}\) The value of armrests is often underestimated for the stability of the seated individual. The individual’s arms and the position of the arms support and stabilise the upper body. Unsupported arms will create a more rounded back position and can even create pelvic obliquity; both may result in increased and uneven pressures and increased shear forces. Armrest pads should be positioned so the elbows and underarms can rest in a relaxed manner on the pads. If the chair is too wide compared to the actual person’s
width, most users will lean over to get support from the armrests, which again will lead to an oblique seated position and all the adverse consequences of that position. In order to avoid this, it is important to ensure that the type of chair in use is adapted properly for the individual and that the chair fits correctly for the seated situations employed\(^{[11]}\).

### Choose the right pressure redistributing cushion

Some patients are positioned in a chair without a pressure redistributing cushion. This is not a viable alternative for any patients. Furthermore, the 2014 international guidelines on PU prevention recommend limiting the time an individual spends seated in a chair without pressure relief\(^{[10]}\). Selecting an appropriate pressure-distributing device for use in the chair can enhance the comfort of the individual, in addition to increasing the amount of time they can remain seated. The principles of pressure redistribution are based on the concept of distributing as much of the pressure (body weight) over as large a surface as possible\(^{[11]}\).

Furthermore, cushion materials may reduce tissue deformation by concepts known as immersion and envelopment\(^{[12]}\). Immersion enables the individual to sink into the material, if the material is too soft, the cushion will bottom out, if the cushion is too hard, there will be no immersion, resulting in the person balancing on the top of the cushion thereby increasing tissue deformation\(^{[12]}\). A cushion that is too thin will also mean there is insufficient material for the person to immerse into. Thus, the higher the cushion the greater is the potential for immersion into the cushion\(^{[12]}\).

On the other hand, envelopment is the ability of the material to encompass the contours of the human body. This envelopment equalises pressure and the greater the capacity for envelopment, the greater the reduction in deformation\(^{[13]}\).

More split in a material improves the envelopment potential, whereas a thicker material enhances the immersion potential\(^{[13]}\) [Figure 3]. There are two main types of materials used in pressure-redistributing cushions: those reacting with a reaction force (the body weight) and those reacting with a hydrostatic force. Foam materials generally react on a load with a reaction force. When the body weight compresses foam, foam cells are stretched (compression stretch), this stretch force creates a tension which has a negative impact on muscle cell deformation\(^{[14]}\). Repeated compression stretch may cause fatigue in foams reducing the lifespan in these materials\(^{[15]}\).

Air and fluids such as, water and oils normally react with a hydrostatic force when being loaded. Air and fluids, need to be placed into a storage container within the pressure redistributing cushion and the surface size of this container should be larger compared to the amount of fluid/air within it. In this situation, the fluid within the cushion can be displaced when loaded, the user can immerse into the cushion and the fluid will enable the cushion to envelop the body shapes\(^{[14]}\). Within a pressure redistributing cushion, fluids in a container with a large surface area are better suited to preventing PUs when compared with fluids in a container with a small surface area.

Furthermore, split foams have a better possibility for immersion and envelopment compared to non-split foam. Tests show that fluids deform muscle tissues much less than foam does, therefore, it is suggested that being seated on an appropriate fluid-filled redistributing cushion might increase seating time and reduce the risk of PU formation\(^{[14]}\). However, no materials are currently available that render the need to reposition regularly obsolete.

### Consider the duration of seating

There is much debate surrounding the length of time a person should remain seated at any one given time. In considering this problem, it is wise to remain focussed on the contributory factors pertaining to PU development, within the context of consideration of the health-related quality of life of the individual. Recent guidelines suggest that seating duration should not exceed 2 hours, particularly in acutely ill individuals\(^{[15,16]}\). However, some patients may only be able to tolerate sitting for shorter durations and a careful assessment of the patient and their response to sitting should influence care planning\(^{[15]}\).

Deep tissue injury, arising from cell deformation, is a particular risk in those who experience prolonged seating\(^{[16]}\). This occurs when the threshold for deformation damage exceeds the normal physiological values, these values have been shown to be high among this population\(^{[16]}\). Particular caution should be taken among those who do not have pain sensation, as they will be unaware of the discomfort of initial cell damage giving rise to the potential for worsening PU damage to occur\(^{[16]}\). The skin should, therefore, be assessed for changes in integrity, including localised heat, oedema or hardness. Other changes to skin condition,
not caused by pressure and shear, should be noted, such as incontinence associated dermatitis (IAD). IAD is defined as inflammation and erosion of the skin caused by prolonged exposure to various sources of moisture, including faeces, urine and perspiration. IAD affects the condition of the skin, thereby impacting on the ability to withstand the adverse effects of external mechanical loading. Frequency of skin assessment should be determined by the general skin condition of the individual, however, ideally should occur at each repositioning episode. If this is not possible, then skin should be checked before getting up in the morning and on retiring to bed in the evening or more frequently if possible.

The comfort of the patient should also be noted. Allowing the patient to rest in bed for periods throughout the day will relieve pressure and also reduce fatigue, thereby enhancing wellbeing. Furthermore, individuals should be encouraged to perform pressure relief activities regularly. Pressure may be redistributed through the use of chair tilting and self-positioning programmes. If the patient can stand, pressure may be relieved at regular intervals in this way. However, it is important to allow sufficient time during each standing episode.

In seating, offloading is frequently used. The most common offload technique of pushing up, holding the armrests or wheels, is a challenging exercise for many people and also demands a lot of coordination. Furthermore, individuals usually do not offload using this technique for long enough and tests show that the intermittent push up pressure relief for very short intervals actually has the same outcome on tissue deformation as being seated static for 2 hours. An easier technique is to let the individual lean forward, resting with their elbows on their knees, thus relieving the ischial tuberocities from pressure and decreasing a build-up of temperature and humidity. The individual can be seated quite securely in this position. A specific positioning cushion on the lap will also further increase security.

Consider the security of the seated person
A wheelchair user sliding down the chair due to an improperly assessed seated position or due to fatigue will feel insecure, and will also be afraid of sliding out of the chair altogether. As a result, the patient will strive to stay in place, however, due to lack of strength and coordination, the reverse more often occurs where the individual decreases stability and often ends up in a rotated position with an oblique pelvis. This attempted repositioning will increase pressure and the risk of shear. Wheelchair users need to be repositioned regularly, however, inadequate transfer techniques often include a dragging of the individual over the seat surface into a new position. Both sliding down in a chair and repositioning, may cause tissue stretch (shear strain) with a resulting discomfort and even a lack of security. In the seated individual, to maximise security, it is important to ensure the following factors are taken into consideration: choose a chair that fits the individual correctly, choose arm rests that are of the correct height, thickness and position relative to the chair and choose a seated position that maximises the individual’s ability to undertake usual activities. Once the individual feels secure in the seated position, they are at less risk of the adverse effects of shear forces; this in itself reduces the risk of PU development.

Consider the comfort of the seated person
Patient comfort is central to all activities aimed at PU prevention. Avoidance of pressure ulcers in the seated individual will ensure that they are able to participate in their usual activities of daily living. PUs are known to cause social isolation in seated individuals as they are often prescribed bed rest which takes place in a room separate from their usual family/social activities. Indeed a qualitative study of the impact of pressure ulcers captures this concept very well where ‘subjects reported that being alone in their rooms much of the time had significant negative impact on their lives’. Ensuring a correct seating posture will enhance comfort, thereby contributing to increased stability and reduced shearing forces, all of which reduce the risk of PU development.

Conclusion
PUs are a major challenge for individuals with activity and mobility problems who, as a result, spend an extended period in a seated position. However, PUs are not inevitable for these individuals, providing risk assessment and planning of preventative strategies is undertaken methodically.

A number of key points have been addressed in this article, which can
contribute to PU prevention in the seated individual. This begins with understanding the pathology of PU development; to appreciating the significant impact PUs can have on the person followed by enhancing the understanding of what can be done to combat PU risk. Choosing the correct chair and pressure-distributing device to suit the needs of the individual is the next step as this influences the duration the person can remain seated at any one time. This is followed by giving careful consideration to the key concepts of stability, security and comfort in the individual so that the seated position does not contribute to increasing shear forces which, in turn, increase the risk of PU development. Ensuring that appropriate seating is an integral part of daily living is important and if used carefully can significantly enhance quality of life.

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