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WHITE PAPER

Making low bed height an educated solution

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Novis Healthcare is a specialist in the design, manufacture and supply of pressure care devices, assistive technology solutions and clinical training. A strong focus on clinical outcomes including pressure injury prevention and patient handling ensures Novis provide healthcare products that exceed clinical and therapeutic expectations.

Novis utilises best practice, gold standard procedures and clinical evidence to ensure our research, innovation and design facilitate clinical excellence. Novis maintains a strong focus on delivering successful patient outcomes in acute care, long term care, Rehabilitation and in the community

INTRODUCTION

As the human population continues to grow and modern medicine produces longer life spans, the numbers of those at risk for injurious falls due to age and disease increases [1].

While falls can occur at any age, those over 65 have greater rates and more severe consequences, including death, which is considered the sixth leading cause of mortality in this group [1].

Injuries sustained from falls in this age group predispose individuals to declines in motor abilities required for day-to-day life, including loss of function in independent living activities and further disease and co-morbidities [1].

While it is unlikely that all falls can be avoided, it is both possible and necessary to continue efforts at finding simple methods to reduce falls in the most vulnerable populations across a wide variety of settings [1].

The design and engineering of technologies in the bed and surrounds can impact on falls risk and outcomes, however utilisation of this equipment appropriately is key to realising positive outcomes.

BACKGROUND

The World Health Organisation defined a fall as “an event which results in a person coming to rest inadvertently on the ground or floor or other lower level”.

Risk factors for falls include older age, physical weakness, imbalance, gait disturbance, poor vision, limited mobility, cognitive impairment, impaired functional status and postural hypotension [2].

Patient falls are a high-risk, high-volume, and high-cost adverse event [3].

Falls comprise the largest single category of reported incidents in hospitals. Most falls occurred in the patient’s room (50-85%) on or near the bed while unassisted (79%), citing lost balance as the most common reason (12%) [1]. More than 70% of falls occur while patients are walking or being transferred [4].

In adults more than 65 years of age who fall, 90% of fractures involve falls from standing height or lower [5]. The level of height fallen is a good predictor of overall outcome and survival [6].

When assessing falls prevention strategies, no single definitive method exists for hospital falls prevention [7]. Equipment solutions form one part of a multifactorial prevention program.

Considering both the extrinsic and intrinsic risk factors related to falls, applying the concepts of ergonomics to optimise furnishings in the physical care environment might be one of the most effective individual components in the multifactorial solution [8].

FALL MECHANISM

Falls can be described in terms of three phases (Figure 1):

The first phase is an initiating event that displaces the body’s centre of mass beyond its base of support. Initiating events involve extrinsic factors such as environmental hazards, intrinsic factors (such as unstable joints, muscle weakness, and unreliable postural reflexes) and physical activities in progress at the time of the fall [9].

The second phase of a fall involves a failure of the systems for maintaining upright posture to detect and correct this displacement in time to avoid a fall. This failure is generally due to factors intrinsic to the individual, such as loss of sensory function, impaired central processing, and muscle weakness [9].

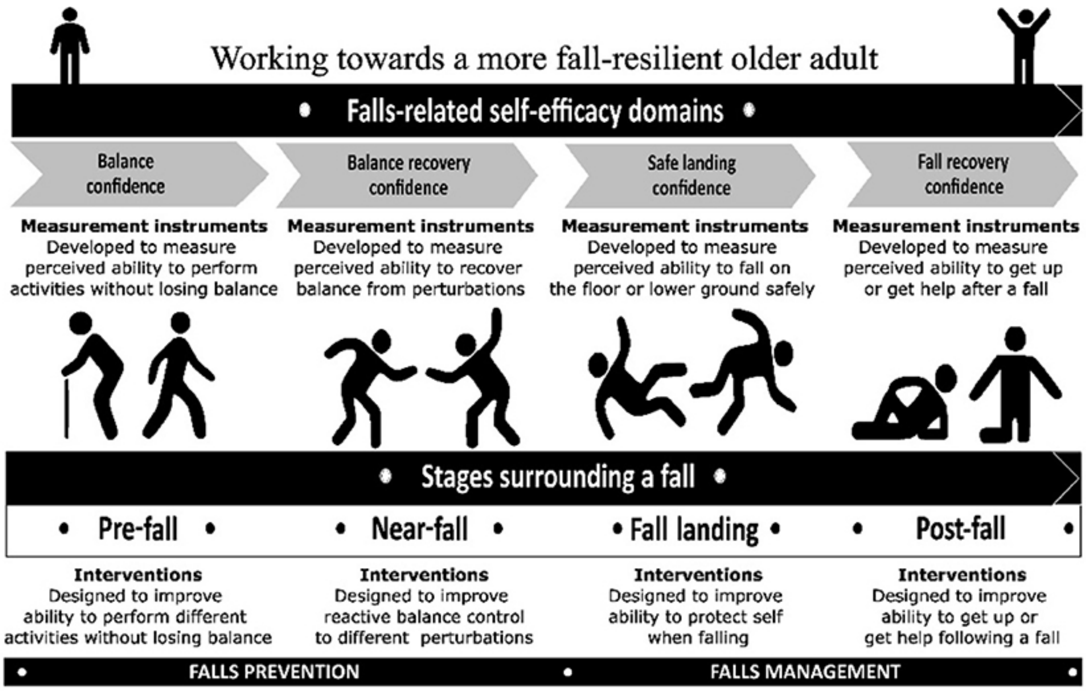

Figure 1: Phases of the Falls Mechanism [10]

The third phase is an impact of the body on environmental surfaces, usually the floor or ground, which results in the transmission of forces to body tissue and organs. The potential for injury is a function of the magnitude and direction of the forces and the susceptibility of tissues and organs to damage [9].

A fourth phase, although not part of a fall, concerns the medical, psychological, and health care sequelae of the fall and attendant injuries. These sequelae affect the degree of damage and disability resulting from the fall [9].

Approaches to preventing falls and their consequences should focus on factors related to each of these phases [9] (figure 1). Bed functionality needs to accommodate design features that contribute to reducing likelihood, risk and harm during phase one, two and three of the fall mechanism.

IMPACT FORCE

The risk of injury from a fall can be predicted by the relationship between bed height and injury risk through calculating gravitational potential energy (GPE). Physics determines that the further a person falls, the greater the impact, therefore potential injury will be.

GPE is one way of showing the increased risk of harm from falls from a bed with increasing height [11].

The relative increase in GPE based on bed and mattress height can be calculated as in Figure [2].

For every 5cm of additional height over 15cm bed height plus 15cm mattress height, the impact of potential energy in the fall increases 17% (Figure 2).

Bed Height m	Add Mattress m	Gravity m/s^2	Mass kg	GPE	Difference	% increase
0.15	0.15	9.807	70	205.95		
0.2	0.15	9.807	70	240.27	34.32	17
0.25	0.15	9.807	70	274.6	68.65	33
0.3	0.15	9.807	70	308.92	102.97	50
0.35	0.15	9.807	70	343.25	137.30	67

Figure 2: Gravitational Potential Energy as varied heights

Regardless of fall direction, the mean maximum values measured at the head, thorax, and pelvis were all determined to increase significantly with increasing height [15]. The risk of head and brain injury is directly proportional to increasing bed height and greater patient mass [12].

However, falls with equivalent impact energy may not affect people of different ages or comorbidities in the same way [5].

FALLS AT THE BED SIDE

Bedside falls are associated with significant physical and psychological complications, including hip injuries, fractures, immobility resulting in muscle weakness, functional disability, and psychological distress, such as depression and fear of falling. They are also associated with an increased risk of subsequent falls [8].

There are three types of falls that occur at the bedside.

The first is a fall from the bed when the body is in a in the horizontal, lying position or sitting up in bed. 'Rolling out of bed' involves someone moving outside the confines of the bed and falling either partially or wholly onto the floor. These are falls that occur when a person is attempting to reposition in the bed [13] or reaching from the bed [8].

The second occurs when a person attempts to leave the bed and mobilise, losing balance during the phases of the sit-to-stand or sit-to-walk motion. These are falls that occur during egress or ingress to the bed [13].

The third relates to a disturbance of sitting balance when sitting on the side of the bed. This will commonly be caused when the centre of mass moves outside of the base of support, such as reaching in sitting. Alternatively, it can be caused by slipping off the edge of the mattress, the base of support moving away from the centre of mass. (This topic is covered in a separate Novis White Paper.)

It is essential to differentiate these fall types as the subsequent preventative intervention will need to be determined by the specific causation. The likelihood of each will need to be evaluated in a risk assessment as part of an individualised falls prevention program.

FALLS OUT OF THE BED

Falling out of bed was a patient safety concern and perceived as preventable patient harm in institutional settings [14].

People often fall from bed while repositioning or reaching for an object placed on a side table 8. The bed width contributes to the risk of falling from bed, as the traditional facility based beds provide less surface area for movement and repositioning, than those found in a home [8].

Falling out of bed requires a person's centre of mass to pass beyond their base of support. In lying the centre of mass needs to pass beyond the confines of a bed, whilst sitting on a bed the centre of mass needs to go beyond the pelvic and lower limb base of support.

A significant risk of head injury exists due to patient falls from bed onto a hard floor surface, as determined by head impact acceleration and head injury criterion [12].

The bed height and potential for injury is highly individualised. A fall from bed base height of 410mm could cause significant head injury in a small female patient (1.52m, 56.7kg), whereas the same injury may be caused in an average size male patient (1.67m, 79.3kg) falling from a bed base height of 320mm [12]. This reinforces that bed height and patient mass are major determinants of injury potential [12].

It has been commonly recommended that to prevent the most injuries resulting from falling from bed, the bed should be positioned to the lowest height available while the patient is left unattended [14, 15].

BED WIDTH

Patient falls out of beds are often the result of a repositioning manoeuvre in the bed or occur when reaching for an object outside of the bed [8].

Reviewing bed width and assessing the person demonstrating repositioning in the bed is essential to ensure the bed is sufficient size to accommodate the natural movement patterns the person uses to independently perform these essential manoeuvres.

A patient has an approximately 51% chance of falling from an 890mm wide mattress (approx. single) during a repositioning event. A patient's risk of falling from their bed can be reduced to 33% (a 36% improvement in risk reduction) simply by replacing an 890mm wide mattress with those that have a width of 106cm. (approx. King Single) [8].

BED RAILS

Bed Rails have historically been used to create orientation of the bed edges, prevent someone rolling out of bed, prevent someone moving out of bed, used as an assistance for bed repositioning and for support during sit to stand.

However, bed rails are considered a restraint when they are used to intentionally prevent a person from getting in and out of bed.

Injuries and deaths have occurred internationally due to the use of bed rails. Injuries occur when people try to climb over or through gaps in the bed rails and additionally people have been suffocated between the mattress and bed rails. The risk of bed rails involves both falls and entrapment risk.

Bed rail entrapment is a serious adverse event, which includes patients being trapped, entangled, or strangled in beds [3]. This can result in fatal injury [2].

If the bed rail barrier is insufficient to prevent a patient from exiting their bed, the patient must then reach the ground from the top of the bed rail, which is higher than the mattress and may result in more severe injuries [2]. There will be an increase in mean maximum force and injury criteria for all body regions occurs [15].

The traditional use of bed rails in a fall prevention program not only fail to reduce the frequency of falls, but may also exacerbate the severity of injury [16].

Bed rails should not be standardly utilised, although in certain situations they can be used safely. This will only be in limited circumstances, where there is no other feasible solutions and where the benefits outweigh the risks. A formal risk assessment and consent process must be followed.

BEDSIDE SAFETY MATS

There is a significant risk of head injury when a person falls from bed onto a hard floor surface [12]. A person falling out of bed has approximately a 40 percent chance of sustaining a serious brain injury as a consequence of the fall out of the normal height bed onto unprotected flooring [15].

The use of a bedside safety mat significantly reduced this relatively high risk of injury and serious injury [15]. The risk of severe head injury is reduced to 1% when falling from a lower bed position onto a safety mat.

Falls onto safety mats demonstrate significant reduction in injury risk to the head and pelvis for all drop heights. Thoracic injury risk is significantly reduced for all but the highest of drop heights [17].

A limitation of the bedside safety mat can be:

- Restricted access for floor lifters: A person who falls from the bed onto the safety mat and is unable to be returned to the bed without using lifting equipment. The mobile floor lifters are not able to be utilised on or over a floor mat and the person will need to be taken from the mat to the floor using slide sheets prior to the lift

- Risk of pressure injury: A person who has fallen from the bed and left to remain on the safety mat for a duration of time will be without the preventative pressure care qualities of their mattress.

- Trip Risk: A person who attempts to independently perform a sit-to-stand or sit-to-walk motion may be negatively impacted by standing fully or partially on the mat leading to risk of trips, slips and falls [15, 18].

FALLS MOBILISING FROM BED

Falls at the bed side are common among people with lower extremity dysfunction, cognitive disorders, or on medications that impair their ability to rise up and move independently [8].

More than 70% of falls occur while patients are walking or being transferred [4] with 51% of falls occurring whilst getting into or out of bed [14].

Sit-to-walk is an everyday motor task and is fundamental for independence. It requires a complicated overlap of postural stability and locomotor sequences initiating a cascade of events which demand mobility [1].

It is a dynamic movement requiring an individual to transition from sitting to standing to walking while moving the centre of mass up and over a reduced base of support. Thus, sit-to-walk can be considered an even more complex motor task than sit-to-stand with greater demands on stability [1].

Elevated bed heights and soft mattresses can contribute to falls when a resident is trying to get out of bed. Bladder dysfunction can lead to more frequent attempts to leave the bed, increasing falls risk. When new residents are placed in unfamiliar surroundings and beds with casters that are set at a different height and width than what they are accustomed to, risk of falls increases [8].

Although it is a historic standard protocol to maintain occupied beds in the lowest position, it is recommended that staff assess the patient's ability to move in and out of bed at this height. For some patients, the low height may not be the safest position, and they may require assistance either to get into bed, or out of bed, or require the bed to be slightly higher than the low setting [13].

IDEAL BED HEIGHT

Ideal height of the surface for sit-to-stand and sit-to-walk will be individual. The height of the bed for a person who is attempting to leave the bed and mobilise is directly linked to falls risk during this task. Appropriate height can be determined utilising the popliteal height (Distance from floor to behind the knee Figure 3) of the individual, followed by functional assessment [19].

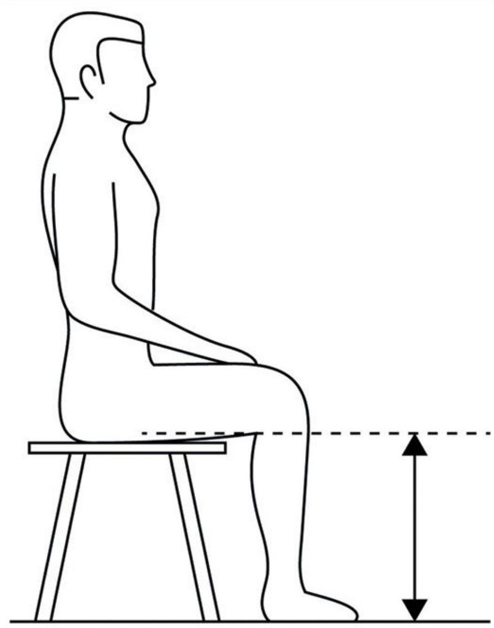

Figure 3: Measurement of Popliteal height [19]

Published popliteal height data has been analysed to determine the proportion of the population that would be able to achieve a safe position, feet flat on floor, with beds of varying low heights [19, 20].

A seat height between 100% and 120% of popliteal height is considered optimal to prevent falls when a mobile person is egressing the bed. This is because it requires less knee extension, less work by the quadriceps muscles, and less forward leaning during transfer [21] resulting in less likelihood of falls from bed heights higher or lower than this.

Popliteal Height	Female >65yo Australia	Male >65yo Australia
Range	310-465	372-468
Mean	379	416
5th Percentile	330	373
95th Percentile	430	460

Figure 4: Popliteal height over 65yo Australians [20]

Low bed height (height less than popliteal height) is the least safe position for elderly during bed egress, particularly during flexion and extension as one moves to achieve seat-off and stand. A greater risk than the bed being too high [22].

Utilising anthropometric data for people over 65 in Australia the popliteal height of a short woman and a tall man can be determined (Figure 4).

The anthropometric measurements in figure 4 demonstrate that if a bed can reach a low height of a bed plus mattress is 310mm it will in theory be low enough for potential ingress and egress of all females and males.

If a high height of a bed plus mattress can reach 468mm it will in theory be high enough for potential ingress and egress of all females and males.

To account for the optional addition of 20% popliteal height for a tall male, to increase standing safety, the upper height should reach 468 +20% = 562mm.
Ideally the bed plus mattress should aim to be able to be positioned from 310-562mm at a minimum range, which will potentially accommodate all older Australians.

With a 150mm mattress this means the bed deck transitioning between 160 – 412mm will be required to suit the majority of over 65yo bed users to safely ingress and egress via sitting (Figure 5).

A range lower than 160mm is advantageous for minimising risk of injury in falls out of bed, and a measurement higher than 412mm will be advantages for Carers working at the bedside.

ULTRA-LOW BED HEIGHT

The purpose of the ultra-low bed position is to reduce distance between the bed and the floor when a patient falls 'from the bed' (whilst sitting in bed, repositioning [8] or reaching [13]. If distance is reduced, severity of trauma is reduced [15] and injury minimises [14].

Commonly falls prevention strategies involve the use of ultra-low height beds. More frequently these are being implemented as the standard bed option as part of a broad falls prevention program. Thus, they are not being prescribed as an individual risk reduction solution.

More appropriately determining bed height suitable for night and day bed use will then require a specific individualised risk assessment based off the risk of either falling out of the bed, falling whilst ingressing or egressing the bed or both.

Evidence to support ultra-low bed use for falls minimisation remains unclear.
Overall, the evidence concluding on the effectiveness of ultra-low beds designed to prevent patient injuries from their beds remains inclusive [2, 23]. There is a lack of conclusive evidence for reduction of falls at the bedside or reduction of injury following the fall [23].

No significant increase or decrease in the injurious fall rates can be concluded following implementation of ultra-low beds [2].

One study, amongst very few, found rate of bed falls, falls resulting in injury, and falls resulting in fracture did not reduce following implementation of ultra-low beds [24]. In fact, the effect of ultra-low beds showed that they were correlated with an increased fall rate tendency [24].

Further sound intervention studies are necessary to strengthen the confidence in the evidence for ultra-low beds [25].

BIOMECHANICS OF LOW HEIGHT EGRESS

During bed egress, compared to a high bed, low beds pose a more posturally challenging transition and require more time to accommodate balance impairments while using the same momentum strategy as the other bed heights [1].

As bed height gets lower, momentum magnitudes tend to increase during rising, indicating individuals may need to use more speed during extension in order to develop the needed hip moment to rise. This is probably because individuals place their centre of mass further over their base of support as seat height drops [1].

At a low bed height, hip torque for bed entry is significantly higher, and hip, knee, and ankle flexion angles are significantly smaller. The absence of significant differences in knee and ankle torques were the result of a compensation strategy that shifts the centre of mass forward by flexing the torso during low bed ingress [26].

While ultra-low beds may reduce injury if the patient rolls out of bed, they may actually cause injury on ingress and egress [13].
The lower bed height created "a more posturally challenging transition and require more time to accommodate balance impairments which using the same momentum strategy as the other bed heights". Ultra-low beds "do not appear to reduce fall risks during bed exit, rather, they may exacerbate them" [1].

An increase in falls risk occurs when a person with strength, gait and mobility impairment attempts to stand or perform sit-to-walk from a low bed position [1].

Furthermore, on ingress, patients who lack hip flexibility will 'fall' onto the low bed in an uncontrolled descent, which may also result in an incident as they roll over the bed and out the other side [13].

The person's ability to ingress and egress the bed at the determined bed height must be assessed [13] individually and at regular intervals or when status changes.

Following assessment, fall risks may be reduced in high risk populations by setting a bed deck height that compliments the balance strategies commonly used to compensate for deficits in strength and mobility [1].

IMPACT OF LOW BED HEIGHT

In error, many organisations have included ultra-low bed position as a universal fall prevention intervention in care plans. This potentially is a follow through from standardised recommendations of keeping the bed in its lowest height [1, 14] prior to the introduction of ultra-low bed alternatives.

As such often bed height has not been individualised based on an assessment of patients' height, weight, muscle strength, pain, balance, gait and functional ability.

If the bed was in a low position, too low for the individual, then that bed position was a contributing factor to the patient's fall [23], Most falls occurring from bed or chair, are attributed to suboptimal height furniture, an environmental risk factor that is modifiable [23].

When not being used to reduce risk of falling out of the bed, ultra-low beds can be elevated electronically for transfer and activities of daily living which may mitigate fall risk [26].

Organisations have to also consider the inappropriate use of low beds when used to prevent a person to be able mobilise from the bed. Utilising the bed to reduce the need for other restraints and to "limit the ability of the cognitively confused impaired patient to stand from the bed, and therefore not place themselves at risk of falling" [24] is not an appropriate utilisation of the ultra-low bed height.

SUMMARY

The ideal bed height and width will be determined upon assessment. An individual risk assessment needs to determine whether the goal of the bed height is to minimise risk when falling out of a bed, or minimise risk when getting in and out of bed.

The lowest bed position will reduce the severity of the fall outcome when a person falls out of the bed whilst repositioning or reaching [12]. A low bed height in combination with a safety mat results in the risk of severe head injury being potentially reduced from 40% to 1% [15].

However, for a person who attempts to egress the bed in its lowest position may be put at greater risk of falls due to the biomechanics of the sit-to-stand and sit-to-walk from a position lower than popliteal height [1, 18, 27].

For a person who will attempt to mobilise, the ideal bed height may be the safest height to facilitate ingress and egress from the bed. This would be 100 - 120% of the popliteal height of that person [21].

This height is considered optimal to prevent falls when a mobile person is egressing the bed. This height results in less likelihood of falls than from bed heights higher or lower than this [21].

By utilising anthropometric data, it is possible to conclude that a bed with a 150mm mattress will require a bed deck to move between 160 – 412mm [20]. This will suit the majority and potentially all of over 65yo bed users to safely ingress and egress via sitting.

A range lower than 160mm is cautiously advantageous for minimising risk of injury in falls out of bed, and a measurement higher than 412mm will be advantages for Carer's working at the bedside (Figure 5).

CONCLUSION

Arguably the most important furnishing within the care environment is the bed system. Understanding the needs of the person through a proper assessment, and matching available bed system features to those needs might be the most important individual solution component when devising a multifactorial solution to address the risk of falls [8].

The increased use of ultra-low beds needs to come with an appreciation for the biomechanics of function in and around the bed. A blanket use of the lowest height position can no longer be standardly recommended given the low height of many of these beds falls lower than the average height required for a safe bed egress movement.

The importance of a comprehensive assessment can't be underestimated when determining the specific falls risks at the bed and the appropriate bed height to mitigate those risks.

Figure 5: Novis 'Invacare CS8 Bed' exceeding low and high height requirements

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