Keywords Bed height/Falls/Mobilisation/Popliteal height

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In this article...

- Why bed height is important when considering early mobilisation
- How to assess the optimal bed height for a patient
- The role of bed height in falls prevention

Calculating bed height for hospital patients using popliteal measurement

Key points

Early mobilisation in hospital is important to prevent complications and starts with sitting on the side of the bed

The popliteal measurement is an industry standard used to determine the optimum seating position

Looking at a dataset of British adults, hospital beds may be too high for some patients to safely move from sit to stand

Popliteal height should be considered as a way of assessing appropriate bed height, especially in those at risk of falls

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Abstract Early mobilisation is promoted in many NHS campaigns and has benefits for patients; getting patients moving often starts with sitting on the edge of the bed. This article discusses the use of popliteal height to assess the appropriate bed height for patients. Used to measure the distance from the floor to behind the knee, popliteal height is a well-accepted industry standard in calculating the optimal seated position. Here we look at measurements of a dataset of the British population to look at the ideal height for patients to sit safely on the side of the bed with their feet firmly on the floor.

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Many campaigns have promoted the benefits of increased mobilisation for patients in hospital. NHS England's recent 'pyjama paralysis' campaign noted that length of hospital stay was reduced by doubling the amount of walking a patient did while in hospital (NHS England, 2018). In a blog post, then-national clinical director for innovation at NHS England Professor Tony Young outlined the idea that "rest equals rust", by speeding up muscle loss, especially in the leg, chest and heart muscles (Young, 2013).

In a study of immobility, Kortebein et al (2007) showed that older participants with a mean age of 67 years had a greater lean tissue loss after 10 days than young individuals did after 28 days. Yet, it is not just members of the frail or older population who may suffer from spending more time in bed – patients in intensive care can lose 2-3% muscle mass a day over the first 10 days (Puthucheary, 2015). It has also been found that patients weakened from periods of immobility have worse outcomes, use more healthcare resources, and have yet to fully recover two years after discharge (Hermans and Van den Berghe, 2015).

Although there may be many steps to full mobilisation after an injury or event, for most patients it will start by sitting on the edge of the bed. Morse et al (2015) looked at a standard hospital bed measuring 58cm from the floor to the top of the foam mattress and a low bed of 38cm to consider how the patient was able to get in and out of bed. At 58cm, all 15 of the patients studied, were unable to get into bed and some were not able to sit completely on the bed with their feet on the floor or were supporting themselves on their toes. Similar findings were reported for getting out of bed – some participants had to reach down to the floor with one leg. Morse et al (2015) concluded that, as patients are all different sizes, a bed must be able to be adjusted so it:

- Fits the patient;
- Provides a safe height to get in and out.

They suggested that further research was needed on the ergonomics.

Merryweather et al (2015) also took the approach of standing patients from a bed without altering the height, but focusing on the lower-extremity biomechanics, torque and ability of patients to move from sitting to standing. They concluded that a suboptimal bed height for the patient may

contribute to a bedside fall because the strength needed to stand may exceed the strength capability of the patient in the hospital bed. The study beds were the same height and the patient group was similar to that of Morse et al's (2015) study, but there was no mention of patients who could not reach the floor to do the tasks.

The aim of this discussion piece is to clarify what height a bed needs to be for a patient to:

- Sit safely on the side and achieve safe mobilisation with their feet on the floor;
- Move from a sitting position to standing.

With bed height taken into consideration, the bed may then be used to help the patient move from sitting to standing, depending on their strength, ability or individual needs.

Popliteal height

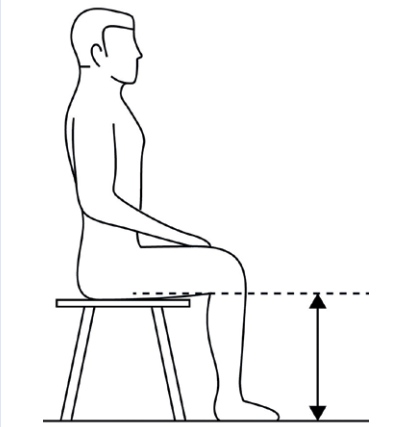
In industry, the maximum acceptable and safe height of a seat is assessed by measuring popliteal height. This is the measurement taken from the floor to the underside of the knee, where the tendon of the biceps femoris muscle inserts into the lower leg (Pheasant, 2003) (Fig 1).

Popliteal measurement is used as an indicator of best seated height because as it increases beyond the popliteal height of the user, pressure on the underside of the thigh will result in reduced circulation. If the height decreases below the popliteal measurement, the user will flex the spine, experience greater problems in standing, and require more leg room (Pheasant, 2003).

A literature search of "popliteal height" – removing papers that were more than 10 years old, had non-human subjects or did not discuss a seated position – resulted in 28 papers. Most looked at the suitability of the seated positions of students, or people in industry or work environments; only one study was on optimal heights of seating of older patients in chairs (Zhu et al, 2013).

All the papers assessed the best seated position in relation to popliteal height. One study – by Castellucci et al (2015) – concluded from a sample size of 3,046 individuals that popliteal height is the most accurate anthropometric measure for the optimal seated position, and Zhu et al (2013) ascertained that the best seat heights for an older population should be 100% of their popliteal height. Several papers – by Assiri et al (2019), Shahabi-Rabori et al (2018), Yusoff et al (2016), Baharampour et al (2013), Castellucci et al (2010) and Oyewole et al (2010) – agreed that mismatch in popliteal height and a seated position would cause pain and or musculoskeletal disorders.

Fig 1. **Popliteal height**



Although students would potentially be seated for a far greater time than a hospital patient getting out of a bed, patients do need to be able to achieve an optimal sitting position, with feet on the floor, as a starting point for safe mobilisation. Baharampour et al (2013), Bello and Sepenu (2013) and Castellucci et al (2010) suggested that the lack of adequate seating positions, or a mismatch between the user and the seated position, was caused by a lack of ergonomic concern about the equipment provided. Van Niekerk et al (2013) pointed out that there is no 'one-size-fits-all' solution.

Optimal seated position

The optimal seated position for patients at the edge of a hospital bed can be considered by identifying a relevant population and looking at popliteal measurements.

Several studies included popliteal measurements. Kothiyal and Tettey (2001) collated anthropometric data on 171 people aged >65 years in Australia to create a dataset of body dimensions for the purpose of allowing designers to improve or redesign living spaces for the older population. The researchers only measured body dimensions that were considered important and useful for the design of facilities and equipment. A second study – by Gordon et al (1989) – with a larger population looked at 3,982 US army personnel comprising 1,774 males and 2,208 females.

Pheasant (2003) published British population measurements, including the popliteal height for people aged 19-45 years, 45-65 years and 65-80 years. The measurements cover the fifth, 50th and 95th percentile of the male and female population, and are widely accepted and referenced in many papers. For this reason, it was decided to take these popliteal measurements as the best indicator of the British population; we focused on popliteal measurements of the 45-65-year-old and 65-80-year-old groups because, due to physical and cognitive deficits, older age groups are less likely to be able to compensate for an inappropriate bed height.

To calculate popliteal height for those people between the fifth, 50th and 95th percentile, normal distribution is approximated from Pheasant's (2003) dataset. This was done using the specified mean (50th percentile) and standard deviation given in Pheasant's popliteal measurements. To confirm this normal distribution, the fifth and 95th percentile values on the approximated distribution curve were calculated.

In the 45-65-year-old age group, the largest deviation was 0.16% on the fifth percentile value of 35cm and the largest deviation in the 65-80-year-old age group was 0.78% on the fifth percentile value of 39.5cm. Pheasant (2003) advised that, the optimal height to sit at is close to the popliteal height, and a seat should be based on the fifth percentile female popliteal height because the 95% of the population who are longer legged "will also be accommodated".

Hospital beds that are height adjustable can easily have the height increased to accommodate those with greater popliteal measurements. Kothiyal and Tettey (2001) agreed, pointing out that a higher percentile value (usually 95th) is considered when designing for clearance, such as when more legroom is needed.

Bed height

Using Pheasant's population data for the 45-65-year-old female population, bed height should be 35cm from the floor to the top of mattress (Table 1) and 35.5cm for the 65-80-year-old population (Table 2).

In Morse et al's (2015) study, the low bed with mattress was 38cm from the floor. Using the normal distribution curve and Z-score, this shows that in the 45-65-year age group, 29% of the female population would not be able to sit at the side of the bed with their feet on the floor. For the 65-85-year age group, this percentage would be 28%, due to the reference population. The higher bed in Morse et al's (2015) study, which was 58cm from floor to top of mattress, would be too high for nearly 100% of both male and female populations of all ages and explains why all patients were unable to safely get back onto the bed.

Discussion

The current medical surgical bed market provides many options ranging from 21-40cm for the lowest height. However,

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Table 1. **Anthropometric estimates for British adults aged 45-65 years**

	Male	Male	Male	Female	Female	Female
Dimension	**5th percentile**	**50th percentile**	**95th percentile**	**5th percentile**	**50th percentile**	**95th percentile**
Popliteal measurement, cm	39.0	43.5	48.0	35.0	39.5	44.0

Table 2. **Anthropometric estimates for British adults aged 65-80 years**

	Male	Male	Male	Female	Female	Female
Dimension	**5th percentile**	**50th percentile**	**95th percentile**	**5th percentile**	**50th percentile**	**95th percentile**
Popliteal measurement, cm	38.5	42.5	47.0	35.5	39.5	44.0

when combined with a 14cm foam mattress, many reach far above the 35-35.5cm popliteal measurement for fifth percentile of women aged 45-80 years.

Hospital admission statistics for 2019 show that the age group with the highest number of hospital admissions was 70-74 year olds; they had 1.9 million admissions accounting for 9.2% of the total. Female patients accounted for 11.3 million (54.6%) of admissions (NHS Digital, 2019). These figures suggest many patients who are most at risk of complications following immobility may need to be considered for a lower bed height.

Patients who are acutely unwell are at greater risk of falls, especially as they are out of their normal environment. These risks can be amplified by sensory impairment, delirium or dementia (Royal College of Physicians, 2015). The addition of reduction in muscle mass when immobile makes this at-risk group less likely to be able to compensate for a bed that is too high. To promote independence and safe mobilisation, a bed height that allows a patient to place their feet firmly on the floor would seem sensible. Lower beds may help with this issue but challenge providers in terms of how to manage a combination of different bed options, allocate them to the patients who need them and provide a safe working height for caregivers to ensure they need not bend over too far.

Conclusion

By using a widely accepted industry measurement of popliteal height and a sample representative of the British public for 45-80 year olds, this article has identified the necessary height of a hospital bed for the optimal seated position when the patient is seated on the side of the bed with their feet firmly on the floor.

Going by the popliteal measurement of the fifth percentile woman as the best accepted sitting height, a bed should reach 35cm from floor to the top of the mattress for 45-65 year olds and 35.5cm for 65-80 year olds. In both scenarios, the 95% of the population who are longer legged can also be accommodated.

The challenge for healthcare providers is to provide a bed that allows for safe mobilisation of at-risk patients, who make up a large proportion of hospital inpatient populations. Those with reduced lean muscle mass due to immobility or cognitive or sensory impairment will be less able to compensate for inappropriate bed height; this places them at risk of falls and means they have a lower chance of being rehabilitated safely and effectively. The popliteal measurement can be used to ensure an appropriate height is used for independence and safe mobilisation. Further studies should be used to verify these calculations and take into account the fact that the measurements of a population can change over time. **NT**

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