The effect of low bed height on a person's ability to egress a bed

Author: **Dr Mike Fray,** School of Design & Creative Arts, Loughborough University, Loughborough, Leics.UK.

Introduction

Bed provision in acute and long-term care has changed significantly over the last 50 years. From the addition of powered movement for height and position, beds now have a wide range of possible technologies to monitor and support the people in them. This supports the role of the bed as being part of the overall treatment package for someone in a care environment being key for positioning, pressure injury prevention, mobilisation etc

Recent patterns of use across a wide range of care delivery suggests that beds are being used to reduce the distance and injury risks from falls by the bed.[1] This has created a market for care beds with different lowest heights e.g., Standard height 25+ cm, low height bed 10–20 cm or ultra-low (floor) beds <10 cm. This leaves care staff in an interesting position where they might have to balance the choice of safety against falls harm against the requirement to promote mobility and rehabilitation for improved function and discharge from care. This paper reviews the use of low and ultra-low beds and a study completed to indicate the optimum height of beds to best facilitate the sit to stand activity required for mobilisation.

Background

Not facilitating mobilisation for people in acute or long-term care reduces their functionality. These changes can occur quickly and are one possible route to reduced patient outcomes[2]. Evidence reports many physiological benefits of early mobility.[3,4,5,6,7,8] Patients should be mobilised as soon as possible in any health intervention as there is clear evidence that early mobilisation reduces length of stay.[9]

The relationship between bed height, carers and the bed occupant has considered both staff wellbeing[10] and patient safety (e.g., bed rail design[11,12]). To support effective mobilisation a series of studies investigated biomechanical movements for sit-to-stand (STS) and sit-to-walk (STW). Merryweather et al[13], reported that a low bed is 'dangerous for patients with limited hip flexion, and increased effort is needed to rise out of the low bed'. Morse et al[14], added that impaired balance or reduced function makes this more challenging. These studies support Christman et al[15], that preferred bed height might be knee height or higher which agreed with the anthropometric analysis by Fajobi et al[16].

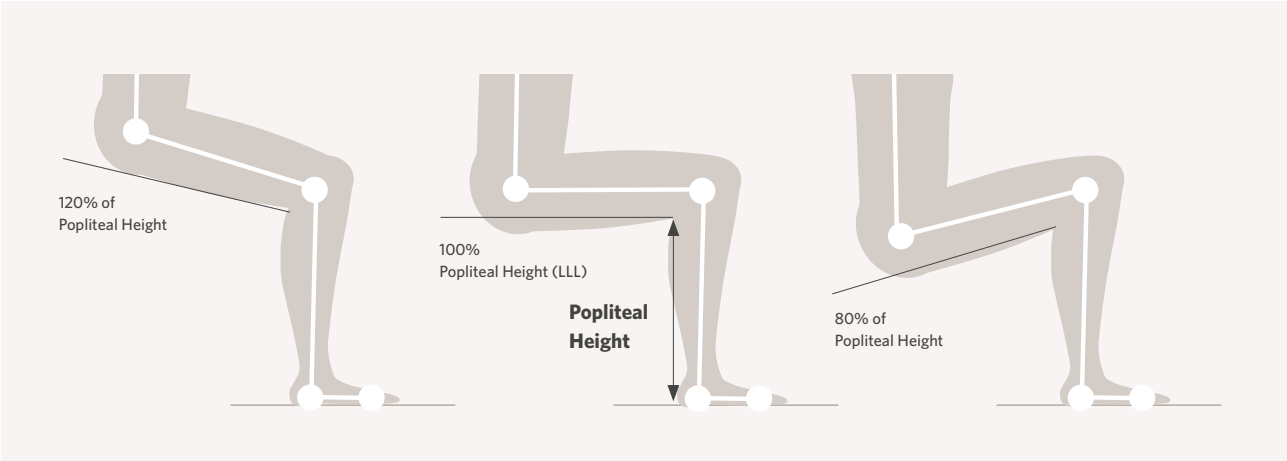


Figure 1. Popliteal Height sometimes reported as Lower Leg Length (LLL).

Two further studies reported guidance for the preferred bed height to support the STS activity relative to lower leg length (LLL) which is measured in this study as popliteal height. Lindeman et al[17] looked at forces applied during a STS movement with older users at different bed heights with, and without, the use of hand rails to assist. When comparing 80%, 100% and 120% of popliteal height, the higher bed height (120%) was the easiest. Similarly, Capezuti et al[18], in a review paper suggested a height between 100% and 120% of popliteal height (or LLL) is considered optimal as it requires less biomechanical effort.

The recent changes in bed designs with a shift to low and ultra-low beds have significantly changed the relationship to popliteal height (LLL) and independent STS/STW movements.

Beds can now be set to very low, almost floor height (ultra-low) which will totally impair a person's ability to get out of the bed. Overall, the recent review from Fray Hignett and Gyi[19] summarises that low height (<80% LLL) will limit mobility for STS/STW without using a grab rail (and pushing up from the bed) and optimal height would be above 100% of LLL as part of the wider room design considerations.

Low height (<80% LLL) will limit mobility for sit to stand and sit to walk; and optimal height would be above 100% of LLL.

Evenda® study

Introduction

The literature for ultra-low bed height acknowledged that very low beds will inhibit normal movement and will prevent independent egress. The research question for this study is to quantify the optimum bed height to support mobility for any user by exploring the relationships between the bed height, user's anthropometry (LLL) and their ability to stand from the bed (STS).

Specifically, to inform the design and use of the Evenda bed to best support mobility and safety for the bed users with the following deliverables:

a. Report the effects of bed height around popliteal heights for STS from a bed.
b. Report a critical disabling height (i.e., too low) for STS from a bed.
c. Report the effects of parallel and perpendicular positions of the egress handle.
d. Suggest a protocol for optimum bed height for the most effective mobility for patients with limited ability or lower limb function.

LLL: Lower Leg Length or Popliteal height
STS: Sit-to-stand
STW: Sit-to-walk

Methods

Participants were recruited by invitation (n=24, 8M, 16F), age >60 years (range 64–92). Their anthropometry matched normal spread (stature 1.53–1.85 m, mass 45.5–112.8 kg, BMI 19.6–44.8 kgm^{-2}). In line with the Covid requirements specific ethical permission was required through Loughborough University procedures etc. All participants had a level of mobility that allowed attendance at the laboratory for the trial.

Number of participants:	24	**Stature**	1.53 m – 1.85 m
Males:	8	**Mass:**	45.5 kg – 112.8 kg
Females:	16	**BMI:**	19.6 kgm^2 – 44.8 kgm^2
Age range:	64–92		

Bed heights included in trial
Popliteal height +10 cm to –20 cm

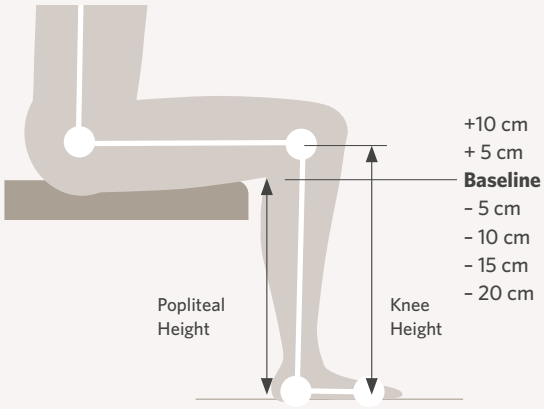


Figure 2. Popliteal Height and Knee Height and heights included in trial (+10 cm to –20 cm around popliteal height).

The procedure and data collection required basic anthropometry measures to be collected for stature, leg length, popliteal height, knee height and hand position in sitting (Fig 2). The 90° sitting height was measured and then replicated on the Evenda bed as a baseline position allowing for mattress compression. The participant was then required to stand from the bed from all the different heights (Baseline first, +10, +5, –5, –10, –15, –20cm) in an unbiassed order. At each height they were required to stand with the parallel handle, the perpendicular handle and with no handle (n=21 STS Fig 3).

The participant was required to stand from the bed from all the different heights (Baseline first, +10, +5, –5, –10, –15, –20cm) in an unbiassed order

After each STS participants reviewed the height of the bed and reported their subjective evaluation of the task of raising from the bed with 5 questions; muscle effort (Borg Effort Scale 0–10);

- preferred bed height (1–7 scale),
- handrail use (1–5 scale),
- handrail comfort (1–7 scale),
- handrail position (1–7 scale).

Measuring Popliteal Height during collection of anthropometric data

Top view of handle alignment

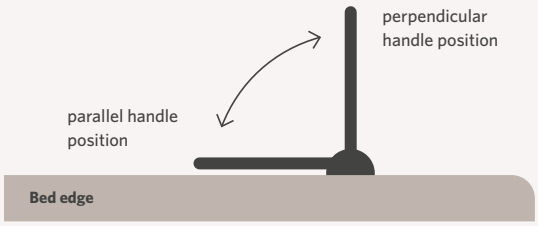


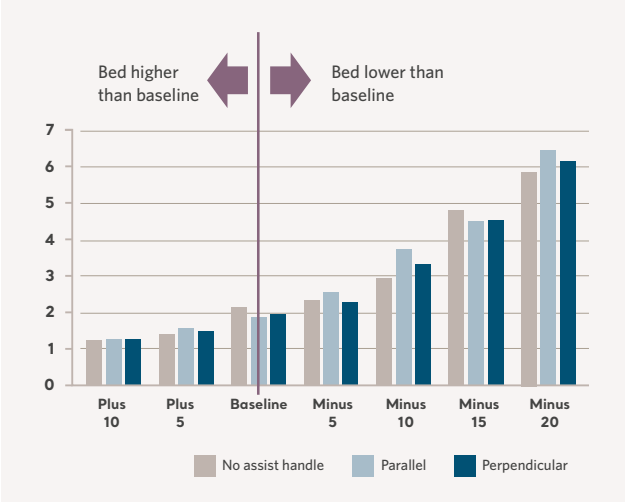
Figure 3. Handle alignment for Evenda trial i.e. parallel and perpendicular position of the mobility assist handle

After all conditions had been completed a comparison debrief was completed to support the selection of 2 specific bed heights:

a) the lowest acceptable height that they would be prepared to get up from,
b) the optimum height that they would like the bed to be set for regular egress.

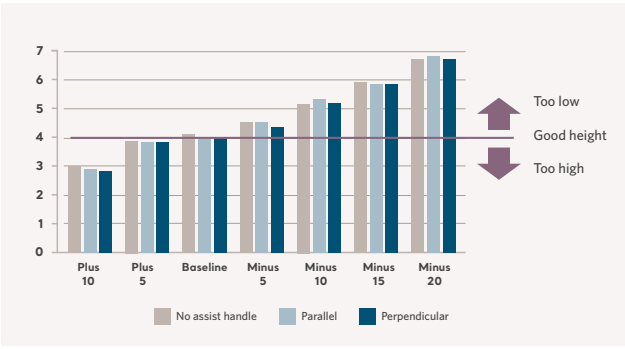
Results

a. Effect of bed height on sit to stand from a bed.
There was clear evidence that the height of the bed made a difference to the effort required for the sit to stand (STS) task. Statistical analysis (ANOVA) showed all the variation to be caused by the height and very little effect was seen between the different hand positions.



Graph 1. Biomechanical effort for STS from different bed heights with different egress hand positions (0=No effort 10=maximum effort).

Participants were required to make a subjective assessment of the actual height of the bed judging if it was too high or too low. Similar to the previous there was no clear difference between the assist handle positions (Graph 2).



Graph 2. Perception of bed height for different heights and hand positions. (1=too high 7=too low)

b. Critical disabling height for STS from a bed.
Evidence reported in this study showed 21% (5/24) of the group could not stand from a bed height of 20 cm below popliteal knee height. One of the participants could not stand from 15 cm below the baseline. Using an inclusive design philosophy this indicates that if a standard protocol was required to allow all people to be able to stand the bed height could never be 15 cm below popliteal height as some people would be prevented from standing. This agrees with the literature review[19] but suggested that 20% below knee height might be disabling, the figure in this study is closer to 5% below popliteal height.

> 21% of the group could not stand from a bed height of 20 cm below popliteal knee height.

c. Effects of positions of the egress handle.
75% of participants preferred the perpendicular position of the mobility assist handle to aid their sit to stand from the bed. The explanation for this was the preference of a chair arm format to push themselves up from the bed.

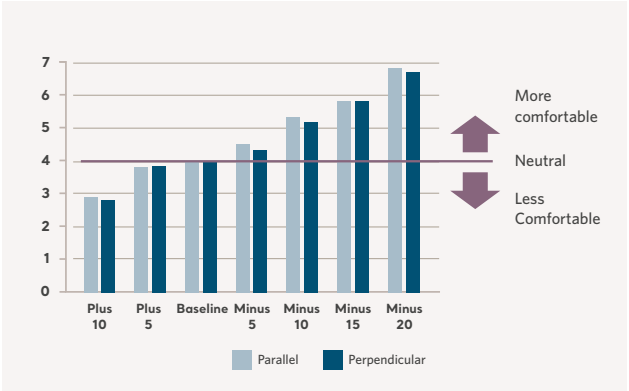
> 75% of participants preferred the perpendicular position of the mobility assist handle to aid their sit to stand from the bed.

The reported muscle effort needed to stand was consistently lower for the perpendicular handle when compared to the parallel handle across the range of heights (Graph 1).

The reported comfort was consistently better for the perpendicular handle across all heights above and below popliteal level (Graph 3).

Mobility assist handle in parallel position

Mobility assist handle in perpendicular position



Graph 3. Assist handle comfort perpendicular vs parallel positions

> The reported comfort was consistently better for the perpendicular handle across all heights above and below popliteal level.

d. Suggest a protocol for optimum bed height for the most effective STS from a bed

The creation of a specific protocol for preferred height to give an effective inclusive height to assist all bed users to stand from the bed lacked any statistically strong pattern to support the judgement. There were individuals within the group that had strong personal preferences which affected the overall correlation relationships across the cohort. However, there was correlation between the popliteal height and knee height and the lowest acceptable height for STS and the optimum height for STS (p=0.11 and 0.055). There was stronger correlation between the angle of inclination of the thigh and the preferred heights of the bed, and this showed that taller people did not need all the additional height that the shorter people required.

By continuing to use the inclusive design criterion 96% of the group reported optimum height for sit to stand from the bed to be greater than 90° knee angle.

> 96% of the group reported optimum height for sit to stand from the bed to be greater than 90° knee angle

References

1. Bowers, B., Lloyd, J., Lee, W., Powell-Cope, G., Baptiste, A. (2008). Biomechanical Evaluation of Injury Severity Associated with Patient Falls from Bed. Rehabilitation Nursing 33: 253–259
2. Ljungqvist O, Scott M, Fearon K, (2017). Enhanced Recovery After Surgery; A Review. JAMA Surg. 2017;152(3):292-298. doi:10.1001/jamasurg.2016.4952
3. Klein K, Mulkey M, Bena JF, Albert N, (2015) Clinical and Psychological Effects of Early Mobilization in Patients Treated in a Neurologic ICU: A Comparative Study. Crit Care Med. 2015 Apr;43(4):865-73
4. Titsworth, W, Hester, J, Correia, T, Reed, R, Guin, P, Archibald, L, Mocco, J., 2012. The effect of increased mobility on morbidity in the neurointensive care unit. J. Neurosurg. 116 (6), 1379–1388.
5. Balas MC, Vasilevskis EE, Olsen KM, et al. Effectiveness and safety of the awakening and breathing coordination, delirium monitoring/management, and early exercise/mobility bundle. Crit Care Med . 2014 May;42(5):1024-36.
6. Winkelman, C., Johnson, K.D., Hejal, R., Gordon, N.H., Rowbottom, J., Daly, J., Levine, A.D., 2012. Examining the positive effects of exercise in intubated adults in ICU: a prospective repeated measures clinical study. Intensive Crit. Care Nurs. 28 (6), 307–318.
7. Wainwright T, Gill M, McDonald D, Middleton R, Reed M, Sahota O, Yates P, Ljundqvist O (2020). Consensus statement for perioperative care in total hip replacement and total knee replacement surgery: Enhanced Recovery After Surgery (ERAS®) Society recommendations. Acta Orthopaedica Vol 91; 1, p3-19
8. Martinez-Velilla N, Cadore L, Casas-Herrero A, Idoate-Saralegui F, Izquierdo M. (2016) Physical activity and early rehabilitation in hospitalized elderly medical patients: systematic review of randomized clinical trials. J Nutri Health Aging. 2016; 20:738–751.
9. Guerra M, Singh P, Taylor N. (2015). Early mobilization of patients who have had a hip or knee joint replacement reduces length of stay in hospital: a systematic review. Clin Rehabil 2015; 29(9): 844–54
10. De Looze, M., Zinzen, E, Caboor, D, Heyblom, P, Van Bree, E, Van Roy, P, Toussaint, H, Clarijs, J, (1994) Effect of individually chosen bed-height adjustments on the low- back stress of nurses Scandinavian Journal of Work, Environment and Health, 20 (6), 427- 434
11. Hignett, S. Griffiths, P. (2005). Do split-side rails present an increased risk to patient safety? Quality and Safety in Healthcare. 14, 113-116
12. Hignett, S., Sands, G., Fray, M., Xanthopoulou, D., Healey, F., Griffiths, P. (2013). Which bed designs and patient characteristics increase bed rail use? Age & Ageing. 42, 531-535
13. Merryweather AS; Morse JM; Doig AK; Godfrey NW; Gervais P; Bloswick DS, Effects of bed height on the biomechanics of hospital bed entry and egress. Work 52 (3), 707-13;
14. Morse JM, Gervais P, Pooler C, Merryweather A, Doig AK, Bloswick D, (2015). The Safety of Hospital Beds: Ingress, Egress, and In-Bed Mobility. Global Qualitative Nursing Research
15. Christman, M., Morse, J., Wilson, C., Godfrey, N., Doig, A., Bloswick, D., Merryweather, A., (2015). Analysis of the influence of hospital bed height on kinematic parameters associated with patient falls during egress. Procedia Manufacturing 3, 280–287
16. Fajobi M, Awoyemi E, Onawumi A, (2016) Ergonomic Evaluation of Hospital Bed Design and Anthropometric Characterization of Adult Patients in Nigeria. International Journal of Scientific & Engineering Research, 7, 8, 640-651
17. Lindemann, U., van Oosten, L., Evers, J., Becker, C., van Dieen, J.H., van Lummel, R.C. (2014). Effect of bed height and use of hands on trunk angular velocity during the sit-to-stand transfer, Ergonomics, 57:10, 1536-1540
18. Capezuti, E., Wagner, L., Brush, B.L., Boltz, M., Renz, S., Secic, M. (2008) Bed and Toilet Height as Potential Environmental Risk Factors. Clinical Nursing Research 17(1): 50-66
19. Fray M, Hignett S, Gyi D, (2022 In review) Impact of ultra-low height healthcare beds on falls and mobility: a systematic review. IJSPHM

Arjo AB • Hans Michelsensgatan 10 • 211 20 Malmö • Sweden • +46 10 335 4500

www.arjo.com