Kinematic analysis of sit-to-walk movement in a fall-prone population

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Introduction

Despite the fact that falls comprise a large percentage of hospital injuries, little is known quantitatively about what induces patient falls[1,3], particularly with regard to hospital bed ingress and egress, and bedside transitions. This is concerning since many studies suggest that over 50% of falls occur during activities related to leaving the bed and during in-room patient ambulation.

Since most fall studies to date have focused on qualitative measurements and assessments, the focus of our study was to quantify key temporal/spatial gait parameters in a fall-prone population during hospital bed egress.

We hypothesized that bed height as well as the absence of a bed rail might alter fall-prone patients' kinematics during bed egress, thereby potentially increasing fall risks associated with stability challenges. We suspect that these two variables might affect the transition point and gait parameters of the sit-to-walk task.

Materials and methods

Fourteen older adults with ambulatory impairments (Table 1) were sampled from a larger recruited population with a history of falls (Morse Fall Scale score > 50). An 18-camera motion tracking system (NaturalPoint, Corvallis, OR) was used to track full-body biomechanics at 100 Hz. Participants exited an adjustable, instrumented hospital bed without side rails at three bed heights (Figure 3) calculated as a percentage of their lower leg length (LLL) and labeled as follows:

- High bed (HB): 125% LLL
- Medium bed (MB): 110% LLL
- Low bed (LB): 95% LLL

Movements consisted of sit-to-walk from the bedside to a chair, which required a sequence of functionally challenging ambulatory motions. As a control, the same events were captured from the chair (fixed height with arm rests) to the bed. Overall capture calibration volume error was <0.6 mm.

Table 1 – Study sample participant demographics

n	Age (y)	Ht (m)	Wt (kg)	MFS
14	72.5 *(10.1)*	1.7 *(0.1)*	80.1 *(18.1)*	70.7 *(13.0)*

Results

Time to first step initiation (TFSI), defined as first toe-off following seat-off, and time to first step (TFS), defined as first heel strike, showed significant differences in HB and LB conditions compared to the chair ($p < .001$). Participants took an average of one second longer to establish their first step during low bed conditions as compared to the control, and were about 1.5 s faster during high bed exits compared to the control (Figure 1).

Pairwise comparisons for both variables also revealed:

- Significant mean differences between HB and LB ($p < .000$)
- Significant mean differences between MB and LB ($p < .032$)
- Trending mean differences between HB and MB ($p < .101$)

Stride length means were also trending towards significance between the experimental conditions and the control ($p < .132$).

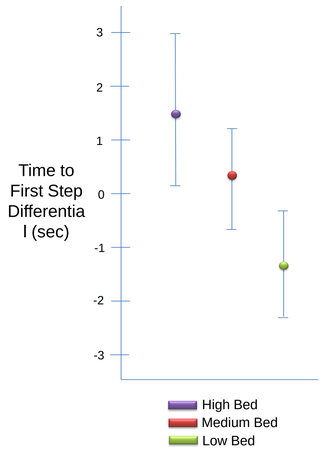

Figure 1 – 95% CI for mean difference in time to first step between chair control and three bed heights

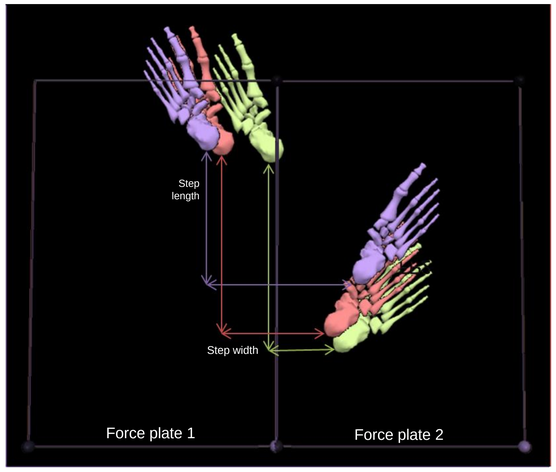

Figure 2 – Illustration of variation in first step between bed heights

Table 2 – Resulting means, (SD), and significance of kinematic gait parameters

Kinematic Variable	Control		High Bed		Medium Bed		Low Bed		p-value
Time to First Step (s)	4.1	*(3.0)*	3.0	*(1.8)*	3.3	*(2.1)*	5.0	*(3.4)*	0.001
Time to First Step Initiation (s)	3.7	*(3.0)*	2.6	*(1.9)*	3.0	*(2.1)*	4.7	*(3.4)*	0.001
Double Limb Support Time (s)	0.6	*(0.3)*	0.5	*(0.2)*	0.6	*(0.3)*	0.6	*(0.2)*	0.413
Left Stance Time (s)	1.0	*(0.4)*	0.9	*(0.1)*	1.0	*(0.2)*	1.0	*(0.3)*	0.882
Right Stance Time (s)	1.0	*(0.2)*	1.0	*(0.2)*	1.0	*(0.2)*	1.0	*(0.2)*	0.611
Stride Length Mean (cm)	43.2	*(15.9)*	48.0	*(18.2)*	40.1	*(20.4)*	41.5	*(19.1)*	0.132
Stride Width Mean (cm)	18.3	*(5.4)*	19.1	*(5.0)*	18.1	*(5.7)*	19.1	*(7.3)*	0.387
Speed (m/s)	0.30	*(0.12)*	0.30	*(0.18)*	0.21	*(0.18)*	0.24	*(0.17)*	0.937

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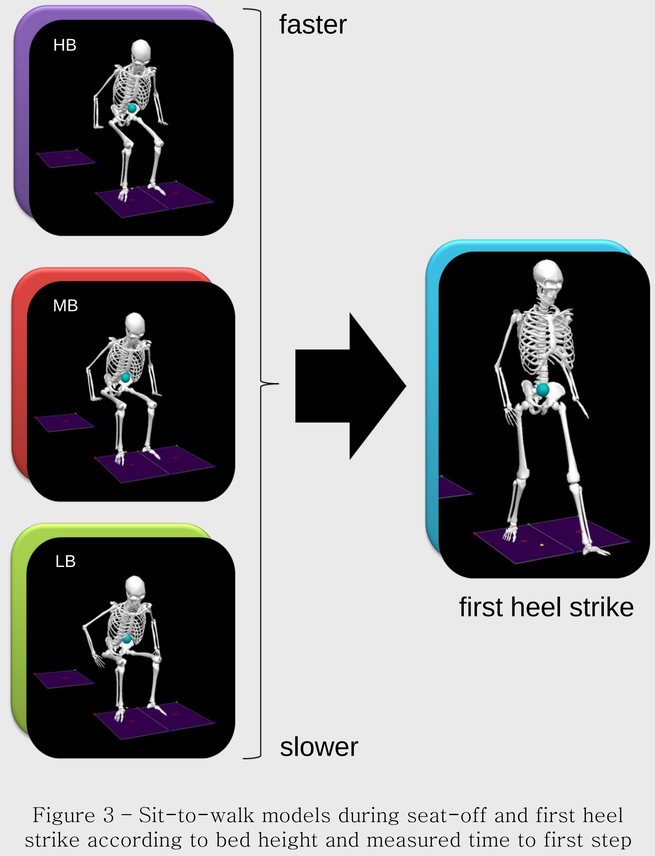

Figure 3 – Sit-to-walk models during seat-off and first heel strike according to bed height and measured time to first step

Conclusions

Sit-to-walk is a challenging task for those at risk of falling since it requires a fluid sequence of dynamic postural and locomotor control. Our results suggest that bed height may play a significant role in lengthening or shortening TFS/I during sit-to-walk motion and could influence stability. Emerging evidence indicates that slower sit-to-walk times are indicative of "fallers"[2].

Key Points

1. Patient-specific bed heights for egress affect patient kinematics.
2. Stability metrics are affected by bed height.
3. Selecting a patient-specific bed height could reduce fall probability resulting from instability during sit-to-walk transitions.

References

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