
Reference

King, Shane T. ¹; Eveld, Maura E. ¹; Zelik, Karl E. ^{1,2,3}; Goldfarb, Michael ^{1,3,4}

Factors leading to falls in transfemoral prosthesis users: a case series of prosthesis-side stumble recovery responses

Journal of NeuroEngineering and Rehabilitation (2024) 21:117; DOI: 10.1186/s12984-024-01402-0 [Open Access](#).

Products

Transfemoral Prostheses; C-Leg (MPK) and nMPKs

Major Findings

Transfemoral prosthesis users:

→ **53% of trials (perturbations) resulted in a fall.**

→ **83% of participants fall at least once, 33% fall every time.**

→ **Successful recovery strategies in mid swing performed were entirely from C-Leg users.**

Transfemoral prosthesis users compared to control subjects:

→ **Four potential prosthesis deficits leading to falls identified:**

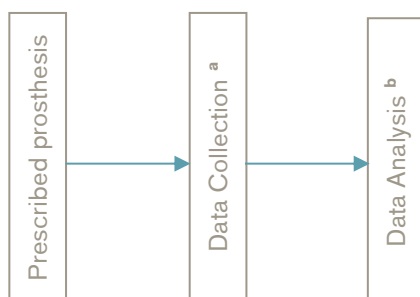
- (1) insufficient resistance to stance knee flexion upon ground contact → affected both C-Leg and nMPK users but appeared to be more sustainable for nMPK users.
 - (2) insufficient swing extension to ensure knee extension after a perturbation → difficult for both groups.
 - (3) difficulty initiating swing flexion following a perturbation.
 - (4) excessive swing flexion impedance in early swing preventing the utilization of the elevating strategy. – in C-Leg users unable to perform elevating recovery strategy.
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Population

Subjects:	N = 6 (1 female)
Current Prosthesis:	4x C-Leg (MPK); 1x 3R80 (nMPK); 1x Blatchford KX06 (nMPK)
Amputation causes:	4x Trauma; 1x Congenital; 1x Infection
Mean age:	41 ± 13 years
Mean time since amputation:	19 ± 17 years
MFCL:	5x K4 and 1x K3

Study Design

Case Series:



^a Instrumented Gait Analysis at 0.8 m/s with stumble perturbation during swing phase (24 trials over 6 participants)

^b comparison within the group (C-Leg vs. mechanic knee joints) and to data from instrumented gait analysis at 1.1 m/s with stumble perturbation during swing phase of healthy controls (190 trials over 7 participants) (King et al. 2019)

Results

Functions and Activities								Participation	Environment
Level walking	Stairs	Ramps, Hills	Uneven ground, Obstacles	Cognitive demand	Metabolic Energy Consumption	Safety	Activity, Mobility, ADLs	Preference, Satisfaction, QoL	Health Economics

Category	Outcomes	Results for transfemoral prosthesis users	Sig.*
Uneven Ground, Obstacles	Falls across swing phase	53% (13 out of 24) of all trials resulted in a fall.	n.a.
		83% of the participants fell at least once and 33% fell every time.	n.a.
	Falling rate in swing phase	<u>Early swing:</u> 64% (7 out of 11 perturbations)	n.a.
		<u>Mid Swing:</u> 57% (4 out of 7 perturbations)	n.a.
		<u>Late swing:</u> 33% (2 out of 6 perturbations)	n.a.
	Number of Falls during swing phase	<u>Early swing:</u> 83% (5 out of 6) of participants fell at least once.	n.a.
		<u>Mid swing:</u> 50% (3 out of 6) of participants fell at least once.	n.a.
		<u>Late swing:</u> 33% (2 out of 6) participants fell during late swing perturbation.	n.a.
	Recovery strategy in swing phase	<u>Early swing:</u> Elevating (2x) and delayed lowering (9x) strategies were used. Hopping was observed in 89% (8 out of 9) delayed lowering strategies.	n.a.
		<u>Mid swing:</u> Either delayed lowering (3 out of 7) or lowering (4 out of 7) were used. Hopping was observed in all 3 delayed lowering strategies and 50% lowering strategies.	n.a.
<u>Late swing:</u> 100% (6 out of 6) lowering were used. Hopping was observed in 33% (2 out of 6) of lowering strategies.		n.a.	
Recovery strategies resulted in falls	<u>Early swing:</u> 50% (1 out of 2) elevating attempts resulted in a fall, while 67% (6 out of 9) of delayed lowering attempts resulted in falls.	n.a.	
	<u>Mid swing:</u> 66% (2 out of 3) of delayed lowering attempts resulted in a fall and 50% (2 out of 4) of lowering attempts.	n.a.	
	<u>Late swing:</u> 50% (1 out of 2) of hopping attempts resulted in a fall.	n.a.	
Successful recovery strategy		<u>Early swing:</u> Utilized thigh abduction (avg = 36.0°) across all strategies. Elevating strategy resulted in lower abduction (24.9°) than the delayed lowering strategy (62.0°), when used by the same subject	n.a.
			n.a.

Category	Outcomes	Results for transfemoral prosthesis users	Sig.*
		In non-fallers, knee extension was increased before fully loading the prosthesis via hip extension during elevating strategy, or hip extension coupled with ground friction during delayed lowering strategy.	
		<u>Mid swing:</u> Successful recovery strategies were entirely from C-Leg users – all utilized thigh abduction in the subsequent recovery step (avg. 34.2°).	n.a.
		<u>Late swing:</u> Knee extension was less than 30° at ground contact and thigh abduction to the obstacle (avg. 32.4°) were used.	n.a.
	Recovery metrics	<u>Early swing:</u> Trunk angle and angular velocity were higher in transfemoral prosthesis users relative to controls, demonstrating a large disparity in trunk controls ($p < 0.001$)	++
		<u>Mid swing and late swing:</u> Similar trunk metrics apart from trunk angle in mid swing ($p=0.029$)	0/++
	Forward reach (body CoM to foot CoM)	Disparity of the forward reach remained high for transfemoral prosthetic users compared to controls across all three regions ($p < 0.001$)	++
		Low forward reach in early swing (average: $0.09m \pm 0.19m$), mid swing ($-0.03m \pm 0.17m$) and late swing ($-0.05m \pm 0.08m$)	n.a.
	Knee angle at ground contact	<u>Early swing:</u> Variable knee angle at ground contact with most trials above 30° and 3 three trials greater than 60° (average: $39.8^\circ \pm 25.8^\circ$)	n.a.
		<u>Mid swing:</u> Knee flexion at ground contact was high for most trials ($40.8^\circ \pm 13.1^\circ$)	n.a.
		<u>Late swing:</u> Low knee flexion angle (average: 23.1 ± 12.6)	n.a.

^a no difference (0), positive trend (+), negative trend (–), significant (++/--), not applicable (n.a.)

^b p value after post hoc Bonferroni correction did not significance set at $p < 0.05$; trends set at $0.1 > p > 0.05$ effect sizes classified by authors as small (< 0.3), moderate (> 0.3 and < 0.5) or large (> 0.5)

Author's Conclusion

“While this preliminary case series was not constructed to directly compare the functionality of MPKs relative to non-MPKs, as such a study would employ both devices on the same set of participants, some interesting initial trends have emerged with regard to prosthesis type which generally align with previous reports of the inferior performance of non-MPKs during stumbles.”

“[...] transfemoral prosthesis users are in general much more susceptible to stumble perturbations than controls, particularly for early and mid-swing perturbations. Specifically, five of six transfemoral prosthesis users experienced a fall [...], (with two participants falling every time. [...] Using the same [...] protocol (albeit at higher walking speed), seven [healthy] control participants collectively exposed to 190 perturbations experienced no falls[...] the authors identify four potential prosthesis deficits leading to falls: (1) insufficient resistance to stance knee flexion; (2) insufficient swing extension; (3) difficulty initiating swing flexion following a perturbation; and (4) excessive swing flexion impedance in early swing preventing the utilization of the elevating strategy. Addressing these deficiencies through revisions to prosthetic design and tuning or the implementation of strength or perturbation and balance training

could potentially improve quality of recovery and reduce the likelihood that a stumble perturbation will result in a fall for transfemoral prosthesis users.” (King et al., 2024)

Author's Affiliation

¹ Department of Mechanical Engineering, Vanderbilt University, Nashville, USA.

² Department of Biomedical Engineering, Vanderbilt University, Nashville, USA.

³ Department of Physical Medicine and Rehabilitation, Vanderbilt University, Nashville, USA.

⁴ Department of Electrical Engineering, Vanderbilt University, Nashville, USA.

Author's References

King, S. T., Eveld, M. E., Martínez, A., Zelik, K. E. & Goldfarb, M. (2019). A novel system for introducing precisely-controlled, unanticipated gait perturbations for the study of stumble recovery. *Journal Of NeuroEngineering and Rehabilitation*, 16(1). <https://doi.org/10.1186/s12984-019-0527-7>

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