Reference

Morgenroth[1,2], Roland[1], Pruziner[3,4,5], Czernieki[1,2]

Transfemoral amputee intact limb loading and compensatory gait mechanics during down slope ambulation and the effect of prosthetic knee mechanisms

Clinical biomechanics (Bristol, Avon), *55*, 65–72 (2018).
DOI: 10.1016/j.clinbiomech.2018.04.007

Products

C-Leg

Major Findings

<u>With C-Leg compared to Power Knee (PK) (Össur) (all using Vari-Flex foot, Össur):</u>

→ **No significant differences in intact limb loading between amputees and controls or between prosthetic knee types.**

→ **Compensatory strategies were used to normalize limb loading for both prosthetic knee joints:**

- Amputees walked slower with prosthetic knee joints compared to controls (C-Leg vs. Control: Δ -0.29 m/s (-24%), p = 0.008 and PK vs. control: Δ - 0.38 m/s (-31%), p < 0.001), but no sig. difference between knee joints.
- Amputees walked with shorter intact limb step length with prosthetic knee joints compared to controls (C-Leg vs. Control: Δ -0.12 m (-19%), p < 0.001 and PK vs. control: Δ -0.16 m (-25%), p < 0.001), and with longer intact limb step length with C-leg compared to Power Knee (Δ +0.05 m (+10.4%), p < 0.001)

→ **Prosthetic trailing limb ankle absorbed less energy than controls (with C-Leg knee -22%, with PK -24%)**
(difference between knees not statistically significant)

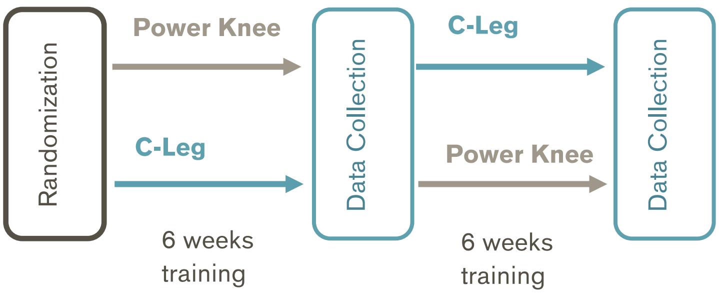
→ **Amputees showed continuous progressive knee energy absorption pattern instead of the biphasic curves of the healthy controls**

Population

Subjects:	5 male amputees (+ 5 healthy male controls)
Previous prosthetic knee:	n.a.
Amputation level:	unilateral transfemoral
Amputation causes	trauma
Mean age:	27 ± 5.8 yrs (control: 23.8 ± 2.6 yrs)
Mean time since amputation:	1.65 ± 0.45 yrs
MFCL:	K3 or above (community ambulator without any assistive device)

Study Design

Interventional, randomized crossover design with control group:



All amputees wore a Low Profile Vari-Flex prosthetic foot. Resting was allowed at any point during data collection. A healthy control group did the same tests as the patient group. 3D gait analysis with Cleveland marker set; walking surface including force plates: 12° slope, 5.75m rigid ramp (gait analysis during descent).

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 C-leg and Power Knee (PK)	Sig.[a,b]
Ramps, Hills	**Intact limb loading**	**No difference between transfemoral amputees vs. control (with and without adjusting for walking speed)**	
		Peak ground reaction force (GRF)	
		C-Leg – control: Δ -0.19 N/kg	0
		PK – control: Δ -0.21 N/kg	0
		C-Leg – PK: Δ -0.02 N/kg	0
		Rate of rise (RoR)	
		C-Leg – control: Δ -2.1 N/kg/s	0
		PK – control: Δ -1.3 N/kg/s	0
		C-Leg – PK: Δ +0.8 N/kg/s	0
	Average walking speed	**Higher velocities in controls than in amputees, and no difference between C-Leg and PK**	
		Average velocity (Center of Pelvis Velocity) (CPVel)	
		C-Leg – control: **Δ -0.29 m/s**	**++**
		PK – control: **Δ -0.38 m/s**	**++**
		C-Leg – PK: Δ -0.09 m/s	0
		Velocity at heel strike (leading/healthy limb) (CPVelHS)	
		C-Leg – control: **Δ -0.33 m/s**	**++**
		PK – control: **Δ -0.39 m/s**	**++**
		C-Leg – PK: Δ -0.06 m/s	0
	Step length (Leading limb)	**Longer step length in controls than in amputees, and longer with C-Leg than PK (intact limb)**	
		C-Leg – control: **Δ -0.12 m**	**++**
		PK – control: **Δ -0.16 m**	**++**
		C-Leg – PK: **Δ +0.05 m**	**++**
	Energy absorption	**Prosthetic (trailing) limb ankle absorbed less energy throughout stance phase than in controls, no difference between knee energy absorption**	
		Ankle energy absorption	
		C-Leg – control: **Δ +0.22 J/kg**	**++**
		PK – control: **Δ +0.22 J/kg**	**++**
		C-Leg – PK: Δ 0.00 J/kg	0
		Knee energy absorption	
		C-Leg – control: Δ +0.22 J/kg	0
		PK – control: Δ +0.24 J/kg	0
		C-Leg – PK: Δ +0.02 J/kg	0
		Leading (intact) limb knee in PK had less absorption of energy during weight acceptance than control, no differences for ankle energy absorption	
		Knee energy absorption	
		C-Leg – control: Δ +0.14 J/kg	0

Category	Outcomes	Results for C-leg and Power Knee (PK)	Sig.[a,b]
		PK – control: Δ +0.17 J/kg (not sig. after velocity adjustment)	++ (0)
		C-Leg – PK: Δ +0.03 J/kg	0
		Ankle energy absorption	
		C-Leg – control: Δ -0.04 J/kg	0
		PK – control: Δ -0.05 J/kg	0
		C-Leg – PK: Δ -0.01 J/kg	0

[a] no difference (0), positive trend (+), negative trend (–), significant (++/––), not applicable (n.a.)
[b] significance set at p<0.05 (differences highlighted in **bold**); trends set at 0.1>p>0.05

Author's Conclusion

"There is an increased prevalence of intact limb knee OA in the transfemoral amputee population thought to be associated with increased mechanical loading. This is the first study to compare intact limb loading and compensatory joint kinetics in transfemoral amputees relative to the able-bodied controls walking down a slope. There were no differences observed in transfemoral amputee intact limb peak loading or rate of loading compared with controls during ramp descent, and prosthetic knee type (PK versus C-leg) had no significant effect on these loading variables. Transfemoral amputees employ different strategies than non-amputee controls to modulate intact limb loading during ramp descent. To compensate for reduced prosthetic (trailing) limb energy absorption compared with controls, transfemoral amputees take a shorter intact step length thus reducing the center of mass velocity at intact limb heel contact.[…] " (Morgenroth et al., 2018)

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