Reference

Ernst M, Altenburg B, Bellmann M, Schmalz T.

Research Biomechanics, CR&S, Otto Bock HealthCare GmbH, Göttingen, Germany.

Standing on slopes – how current microprocessor-controlled prosthetic feet support transtibial and transfemoral amputees in an everyday task

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Products

(Meridium, Elan, Proprio, TSA, Raize) vs conventional prosthetic feet

Major Findings

→ Only Meridium

- ➔ Joint angles and joint torques are closest to non-amputees for
  - Standing on an upward slope of 10°
  - Standing on a downward slope of 10°
- ➔ Autoadaptive dorsiflexion stop and sufficient range of motion improve symmetric loading
  - Clear superiority for Meridium compared to other microprocessor-controlled feet (MPFs)

→ With microprocessor-controlled prosthetic feet (MPFs) compared to conventional prosthetic feet:

- ➔ Full adjustment of the ankle joint improves symmetry of vertical ground reaction forces
- ➔ Compensatory posture necessary for transtibial and transfemoral amputees, when prosthetic foot has no automatic ankle angle adaptation

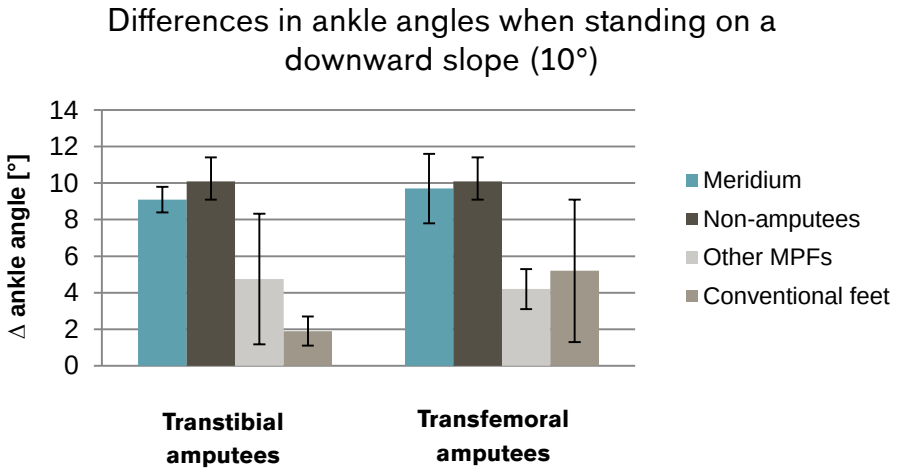


Figure 1: Differences in ankle angles when standing on a downward slope (10°) are illustrated for Meridium, other MPFs, conventional prosthetic feet and non-amputees.

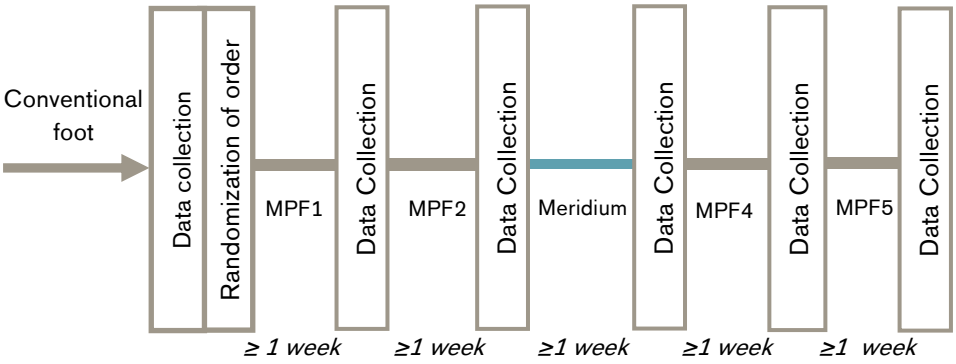
Population

Subjects:	4 unilateral transtibial amputees (TT) 4 unilateral transfemoral amputees (TF) 20 non-Amputees (control group)
Previous prosthesis foot:	Conventional prosthetic feet (Non-MPF)
Amputation causes:	not reported
Mean age:	4 TT: 56.2 yrs ± 12 yrs; 4 TF: 44.5 yrs ± 3 yrs 20 non-Amputees: 22.5 yrs ± 3 yrs
Mean time since amputation:	> 3 yrs
MFCL:	K3 and K4

Study Design

Interventional, crossover design:

Transtibial (N = 4) and transfemoral* (N = 4) amputees



The order of wearing the MPFs was randomized for each subject. The graph shows an example, where Meridium is selected as the third MPF.

* Transfemoral amputees were not equipped with the Raize foot, which reduced the number of data collection session from 6 to 5.

Results

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 prosthetic TT and TF vs. non-Amp	Sig.*	Results for sound TT and TF vs. non-Amp	Sig.*
Level walking	Ankle torque	*Positive values: Dorsiflexion; Negative values: Plantarflexion*			
		No sig. differences for all feet.	0	**TT:** **Elan:** +0.34 ±0.08	**++**
	Knee torque	*Positive values: Knee extension; Negative values: Knee flexion*			
		TT: **Elan:** -0.01 ± 0.06	**--**	No sig. differences for all feet.	0
	Hip torque	*Positive values: Hip flexion; Negative values: Hip extension*			
		TT: **Proprio:** +0.07 ± 0.06	**--**	No sig. differences for all feet.	0

Category	Outcomes	Results for prosthetic TT and TF vs. non-Amp	Sig.*	Results for sound TT and TF vs. non-Amp	Sig.*
Ramps, Hills	Ankle torque	*Positive values: Dorsiflexion; Negative values: Plantarflexion*			
	Down (10°)	**TT:**		**TT:**	
		Elan: -0.10 ± 0.08	--	**Everyday Feet:** +0.43 ± 0.13	++
		Proprio: -0.10 ± 0.15	--		
		TSA: +0.04 ± 0.02	++	**Elan:** +0.39 ± 0.08	++
		Raize: +0.06 ± 0.03	++	**Proprio:** +0.39 ± 0.03	++
		TF:		**TF:**	
		Elan: -0.05 ± 0.07	--	**Everyday Feet:** +0.42 ± 0.14	++
		TSA: +0.04 ± 0.04	++		
	Up (10°)	**TT:**			
		Everyday foot: +0.62 ± 0.15	++	No sig. differences for all feet.	0
		Elan: +0.23 ± 0.01	++		
		Proprio: +0.46 ± 0.02	++		
		Raize: +0.52 ± 0.15	++		
		TF:			
		Everyday foot: +0.66 ± 0.07	++		
		Elan: +0.48 ± 0.09	++		
		Proprio: +0.52 ± 0.04	++		
		TSA: +0.61 ± 0.08	++		
	Knee torque	*Positive values: Knee extension; Negative values: Knee flexion*			
	Down (10°)	**TT:**		**TF:**	
		Everyday feet: -0.16 ± 0.04	--	**Elan:** -0.07 ± 0.11	--
		Elan: -0.17 ± 0.04	--		
		Proprio: -0.16 ±0.06	--		
		Raize: -0.03 ± 0.07	--		
		TF:			
		Everyday feet: -0.21 ± 0.28	--		
		Elan: -0.21 ± 0.05	--		
		Proprio: -0.24 ± 0.03	--		
		TSA: -0.09 ± 0.09	--		
	Up (10°)	**TT:**			
		Elan: +0.26 ± 0.04	++	No sig. differences for all feet.	0
		Proprio: +0.38 ± 0.06	++		
		TF:			
		Everyday feet: +0.29 ± 0.07	++		
		Elan: +0.30 ± 0.06	++		
		Proprio: +0.31 ± 0.09	++		
		TSA: +0.31 ± 0.04	++		

Category	Outcomes	Results for prosthetic TT and TF vs. non-Amp	Sig.*	Results for sound TT and TF vs. non-Amp	Sig.*
	Hip torques	*Positive values: Hip flexion; Negative values: Hip extension*			
	Down (10°)	**TT:**			
		Proprio: +0.09 ± 0.04	++		
		TSA: +0.14 ± 0.10	++		
		Raize: +0.12 ± 0.05	++		
		TF:		No sig. differences for all feet.	0
		Everyday feet: +0.26 ± 0.12	++		
		Elan: +0.1 ± 0.12	++		
		Proprio: +0.24 ± 0.1	++		
		TSA: +0.13 ± 0.04			
	Up (10°)	**TT:**		**TF:**	
		Raize: +0.15 ± 0.14	++	**Everyday feet:** +0.05 ± 0.05	++

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

Author's Conclusion

"A prosthetic foot that combines both key features – an auto-adaptive dorsiflexion stop and sufficient ROM to completely adapt to inclinations - enables lower limb amputees to stand on slopes in an almost natural manner. The biomechanical parameters indicate that this concept is superior to conventional passive feet or feet which provide only one key design feature such as a sufficient ROM. Finally, the results indicate that both, TT and TF amputees, benefit from such a foot.." (Ernst et al, 2017)