

Reference

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

Research Biomechanics, CR&S, Ottobock SE & Co. KGaA, Göttingen, Germany.

Benefits of a microprocessor-controlled prosthetic foot for ascending and descending slopes

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Products

Meridium

Major Findings

With Meridium compared to energy-storage-and-return (ESR) feet:

→ Increased toe clearance

The increase of toe clearance is due to fact that Meridium remains in a dorsiflexed position during swing

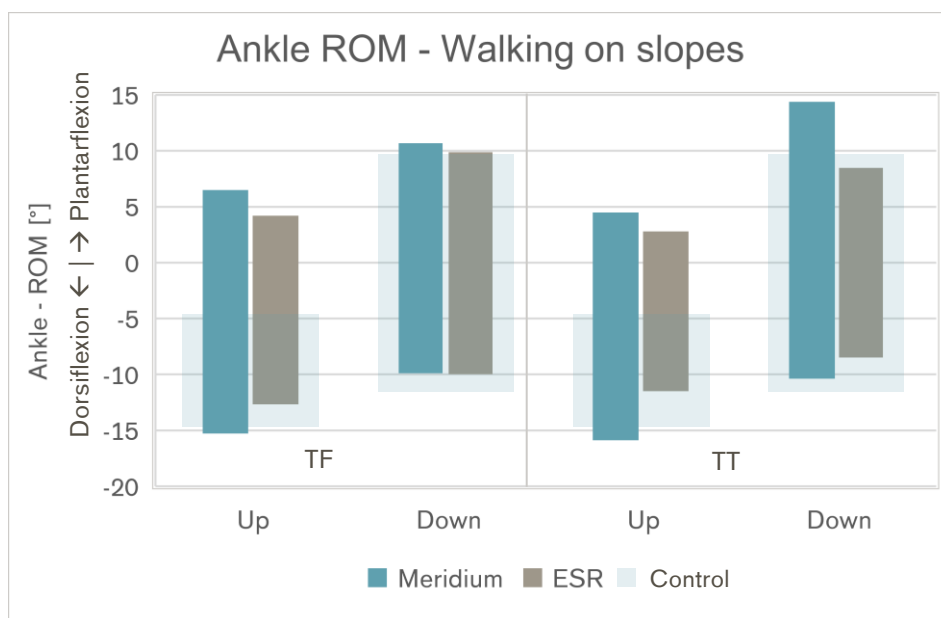
→ Larger range of motion during slope walking

Meridium offers a larger and situation-dependent ankle range of motion (ROM) than ESR feet.

→ Reduced moments while ascending slopes with Meridium

- Reduced dorsiflexion moment by 29% for transfemoral amputees (TF) and 49% for transtibial amputees (TT)
- Reduced knee extension moment by 26% (TF) and 49% (TT)

→ For TF, the prosthetic knee joint is likely the more important component with regard to safety and walking modes on slopes than the foot.



Population

Subjects:

TT: 7 unilateral TT

TF: 7 unilateral TF

Control: 10 able-bodied subjects

Previous prostheses:

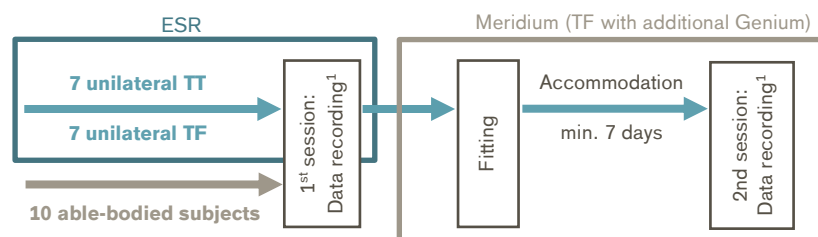
TT: Triton 1C60 (2x), C-Walk 1C40 (2x), Trias 1C30 (1x), Triton Harmony (1C62) (1x), Triton LP 1C63 (1x)

TF: Prosthetic feet: Triton 1C60 (6x), C-Walk 1C40 (1x); Prosthetic knee: X3 (3x), Genium (2x), C-Leg (2x)

Amputation causes: **TT:** Trauma (4x), Infection (1x), Arterial occlusion (1x), Cancer (1x)
TF: Trauma (7x)
Mean age: **TT:** 52 ± 10 years
TF: 46 ± 7 years
Controls: 23 ± 3 years
Mean time since amputation: **TT:** 20 ± 13 years
TF: 28 ± 8 years
MFCL: K3 and K4

Study Design

Interventional, pre-post design:



¹Slope ascent (“Up”) and descent (“Down”) were measured on a ramp (3m) with a handrail and a 10° inclination. Kinetic data was measured with a force plate installed on the ramp. Additionally, kinematic data of the subjects and prostheses was recorded.

Prior to each measurement session, participants accommodated to the lab environment and test setup. At least seven valid trials with one gait cycle each were recorded for each situation (ramp up/down, Meridium/ESR).

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

Results

Category	Outcomes	Results			Sig.*	
Ramps, Hills	Sagittal joint angles [°] <i>Positive: Plantar flexion</i> <i>Negative: Dorsiflexion</i>	TF				
		Sagittal joint angle	Meridium	ESR		
		UP	Ankle – most plantar-flexed angle (early stance)	6.5	4.2	++
			Ankle – most dorsiflexed angle (mid stance)	-15.3	-12.7	++
			Ankle – angle in swing	-6.5	0.1	++
		DOWN	Ankle – most plantar-flexed angle (early stance)	10.7	9.9	–
Ankle – most dorsiflexed angle (mid stance)	-9.9		-10	0		
Ankle – angle in swing	-5.6		-0.2	++		

Category	Outcomes	Results			Sig.*
II					
	Sagittal joint angle	Meridium	ESR		
UP	Ankle – most plantar-flexed angle (early stance)	4.5	2.8	+	
	Ankle – most dorsiflexed angle (mid stance)	-15.9	-11.5	++	
	Ankle – angle in swing	-6.4	-0.1	++	
DOWN	Ankle – most plantar-flexed angle (early stance)	14.4	8.5	++	
	Ankle – most dorsiflexed angle (mid stance)	-10.4	-8.5	+	
	Ankle – angle in swing	-3.9	0.1	++	
Sagittal joint moments for the prosthetic side [Nm/kg]					
IF					
	Sagittal joint angle	Meridium	ESR		
UP	Ankle - Sagittal ankle moment (Vert. shank orientation)	0.65	0.92	++	
	Ankle - Peak sagittal ankle dorsiflexion moment	1.59	1.45	++	
	Knee - Sagittal knee moment (Vert. shank orientation)	0.53	0.72	++	
	Knee - Peak sagittal knee moment	0.68	0.74	0	
DOWN	Ankle - Sagittal ankle moment (Vert. shank orientation)	-0.18	-0.11	0	
	Ankle - Peak sagittal ankle dorsiflexion moment	1.18	1.27	--	
	Knee - Sagittal knee moment (Vert. shank orientation)	-0.34	-0.28	0	
	Knee - Peak sagittal knee moment	-0.78	-0.85	0	
II					
	Sagittal joint angle	Meridium	ESR		
UP	Ankle - Sagittal ankle moment (Vert. shank orientation)	0.42	0.83	++	
	Ankle - Peak sagittal ankle dorsiflexion moment	1.45	1.26	+	
	Knee - Sagittal knee moment (Vert. shank orientation)	0.28	0.55	++	

Sagittal joint moments for the prosthetic side [Nm/kg]

Ankle:
Positive = Dorsiflexing moment
Negative = Plantar flexing moment

Knee:
Positive = Extension moment
Negative = Flexion moment

Category	Outcomes	Results			Sig.*
DOWN	Knee - Peak sagittal knee moment	0.45	0.70	++	
	Ankle - Sagittal ankle moment (Vert. shank orientation)	0.02	-0.2	++	
	Ankle - Peak sagittal ankle dorsiflexion moment	1.17	1.08	0	
	Knee - Sagittal knee moment (Vert. shank orientation)	-0.13	-0.22	0	
	Knee - Peak sagittal knee moment	-0.35	-0.53	--	

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

Author's Conclusion

“The Meridium facilitated walking on slopes by adapting instantaneously to terrain inclinations and, thus, easing the forward rotation of the leg over the prosthetic foot compared to ESR feet with a fixed ankle attachment, possibly making it easier to walk up a slope and to control the gait speed when descending. It assumed a dorsiflexed position during swing and enabled a larger ankle ROM and reduced the moments acting on the residual knee, which might help reduce knee overuse long-term. For individuals with TFA, the prosthetic knee joint seems to play a more important role than the foot for walking on ramps.” (Ernst et al, 2022)

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