| 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 | | | | | | |
| | Journal of NeuroEngineering and Rehabilitation (2017) 14:117. | | | | | | |
| 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° | | | | | | |
| | Standing on a downward slope of 10° Autoadaptive dorsiflexion stop and sufficient range of motion improve sym- | | | | | | |
| | metric loading | | | | | | |
| | Clear superiority for Meridium compared to other microprocessor- controlled feet (MPFs) | | | | | | |
| | → With microprocessor-controlled prosthetic feet (MPFs) compared to con- ventional prosthetic feet: | | | | | | |
| | Full adjustment of the ankle joint improves symmetry of vertical ground re- | | | | | | |
| | action forces Compensatory posture necessary for transtibial and transfemoral ampu- | | | | | | |
| | tees, when prosthetic foot has no automatic ankle angle adaptation | | | | | | |
| | Differences in ankle angles when standing on a | | | | | | |
| | downward slope (10°) | | | | | | |
| | Meridium Non-amputees Other MPFs Conventional feet | | | | | | |
| | Transtibial Transfemoral | | | | | | |
| | amputees amputees | | | | | | |

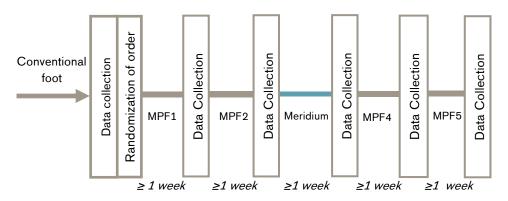
Figure 1: Differences in ankle angles when standing on a downward slope (10°) are illustrated for Meridium, other MPFs, conventional prosthetic feet and non-amputees.

| 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 |
| MECL | K3 and K4 |
| | Previous prosthesis foot: Amputation causes: Mean age: |

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.

| Activities | | | | | | | | Participation | Environmen | | |
|------------------|------------|-----------------|---|--|---|-------------|--------------------------------|---------------------------------------|---------------------|--|--|
| Level walking | Stairs | Ramps, Hills | Uneven ground, Obstacles | Cognitive demand | Metabolic energy consump- tion | Safety | Activity, Mobility, ADLs | Preference, Satisfac- tion, QoL | Health economics | | |
| Category | | Outcomes | | ults for pro TF vs. non | | Sig.* | Results for and TF vs. | | Sig.* | | |
| Level walking | | Ankle torqu | Ankle torque Positive values: Dorsiflexion; Negative values: Plantarflexion | | | | | | | | |
| | | | No sig. differences for all | | 0 | TT: | | | | | |
| | | | feet. | | | Elan: +0.34 | 1 ±0.08 | ++ | | | |
| | | Knee torqu | Knee torque Positive values: Knee extension; Negative values: Knee flexion | | | | | | | | |
| | | | TT: | | | | | No sig. differences for | | | |
| | | | Elaı | Elan: -0.01 ± 0.06 | | | all feet. | | 0 | | |
| | Hip torque | | | Positive values: Hip flexion; Negative values: Hip extension | | | | | | | |
| | | | TT: | | | | | | | | |
| | | | Pro | prio: +0.07 | ′ ± 0.06 | | No sig. dit all feet. | ferences for | 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: Plantarflexi | | | | | |
| | Down (10°) | TT: | | TT: | | | |
| | | Elan: -0.10 ± 0.08 | | Everyday Feet: +0.43 | ++ | | |
| | | Proprio: -0.10 ± 0.15 | | ± 0.13 | | | |
| | | 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: | | | |
| | | TSA: +0.04 ± 0.04 | ++ | $+0.42 \pm 0.14$ | ++ | | |
| | Up (10°) | TT: | | | | | |
| | | Everyday foot: | | | | | |
| | | $+0.62 \pm 0.15$ | ++ | | | | |
| | | Elan: +0.23 ± 0.01 | ++ | | | | |
| | | Proprio: +0.46 ± 0.02 | ++ | | | | |
| | | Raize: +0.52 ± 0.15 | ++ | No sig. differences for | 0 | | |
| | | TF: | | all feet. | | | |
| | | Everyday foot: +0.66 ± | ++ | | | | |
| | | 0.07 | ++ | | | | |
| | | Elan: +0.48 ± 0.09 | ++ | | | | |
| | | Lian. $\pm 0.40 \pm 0.03$ | TT | | | | |
| | | Proprio: $+0.52 \pm 0.04$ | ++ | | | | |
| | | | | | | | |
| | Knee torque | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ | ++ | ; Negative values: Knee fle | kion | | |
| | Knee torque Down (10°) | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ | ++ | ; Negative values: Knee flex TF: | kion | | |
| | | Proprio: +0.52 ± 0.04 TSA: +0.61 ± 0.08 Positive values: Knee TT: Everyday feet: -0.16 ± | ++ | | kion | | |
| | | Proprio: +0.52 ± 0.04 TSA: +0.61 ± 0.08 <i>Positive values: Knee</i> TT: Everyday feet: -0.16 ± 0.04 | ++ extension | TF: | kion | | |
| | | Proprio: +0.52 ± 0.04 TSA: +0.61 ± 0.08 <i>Positive values: Knee</i> TT: Everyday feet: -0.16 ± 0.04 Elan: -0.17 ± 0.04 | ++ extension | TF: | cion | | |
| | | Proprio: +0.52 ± 0.04 TSA: +0.61 ± 0.08 <i>Positive values: Knee</i> TT: Everyday feet: -0.16 ± 0.04 | ++ extension | TF: | cion | | |
| | | Proprio: +0.52 ± 0.04 TSA: +0.61 ± 0.08 <i>Positive values: Knee</i> TT: Everyday feet: -0.16 ± 0.04 Elan: -0.17 ± 0.04 Proprio: -0.16 ±0.06 | ++ extension | TF: | cion | | |
| | | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Elan: -0.17 ± 0.04 Proprio: -0.16 ± 0.06 Raize: -0.03 ± 0.07 | ++ extension | TF: | cion | | |
| | | Proprio: +0.52 ± 0.04 TSA: +0.61 ± 0.08 <i>Positive values: Knee</i> TT: Everyday feet: -0.16 ± 0.04 Elan: -0.17 ± 0.04 Proprio: -0.16 ±0.06 Raize: -0.03 ± 0.07 TF: | ++ extension | TF: | cion | | |
| | | Proprio: +0.52 ± 0.04 TSA: +0.61 ± 0.08 Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Elan: -0.17 ± 0.04 Proprio: -0.16 ±0.06 Raize: -0.03 ± 0.07 TF: Everyday feet: -0.21 ± | ++ extension | TF: | cion | | |
| | | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Proprio: -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 | ++ extension | TF: | cion | | |
| | | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Proprio: -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 | ++ extension | TF: | cion | | |
| | | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Proprio: -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 | ++ extension | TF: | <i>cion</i> | | |
| | Down (10°) | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Proprio: -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 | ++ extension | TF: | cion | | |
| | Down (10°) | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Proprio: -0.16 ± 0.06 Raize: -0.03 ± 0.07 TF: Everyday feet: -0.21 ± 0.028 Elan: -0.21 ± 0.05 Proprio: -0.24 ± 0.03 TSA: -0.09 ± 0.09 | ++ extension | TF: | <i>cion</i> | | |
| | Down (10°) | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Proprio: -0.17 ± 0.04 Proprio: -0.16 ± 0.06 Raize: -0.03 ± 0.07 TF: Everyday feet: -0.21 ± 0.028 Elan: -0.21 ± 0.05 Proprio: -0.24 ± 0.03 TSA: -0.09 ± 0.09 TT: Elan: $+0.26 \pm 0.04$ | ++ extension ++ | TF: Elan: -0.07 ± 0.11 No sig. differences for | <i>cion</i> 0 | | |
| | Down (10°) | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Proprio: -0.16 ± 0.04 Proprio: -0.16 ± 0.06 Raize: -0.03 ± 0.07 TF: Everyday feet: -0.21 ± 0.03 TGR Elan: -0.21 ± 0.05 Proprio: -0.24 ± 0.03 TSA: -0.09 ± 0.09 TT: Elan: $+0.26 \pm 0.04$ Proprio: $+0.38 \pm 0.06$ TF: | ++ extension ++ | TF: Elan: -0.07 ± 0.11 | | | |
| | Down (10°) | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Proprio: -0.17 ± 0.04 Proprio: -0.16 ± 0.06 Raize: -0.03 ± 0.07 TF: Everyday feet: -0.21 ± 0.028 Elan: -0.21 ± 0.05 Proprio: -0.24 ± 0.03 TSA: -0.09 ± 0.09 TT: Elan: $+0.26 \pm 0.04$ Proprio: $+0.38 \pm 0.06$ | ++ extension ++ ++ | TF: Elan: -0.07 ± 0.11 No sig. differences for | | | |
| | Down (10°) | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Proprio: -0.16 ± 0.06 Raize: -0.03 ± 0.07 TF: Everyday feet: -0.21 ± 0.03 TF: Everyday feet: -0.21 ± 0.03 Proprio: -0.24 ± 0.03 TSA: -0.09 ± 0.09 TT: Elan: $+0.26 \pm 0.04$ Proprio: $+0.38 \pm 0.06$ TF: Everyday feet: $+0.29 \pm$ | +++ extension ++ ++ ++ | TF: Elan: -0.07 ± 0.11 No sig. differences for | | | |
| | Down (10°) | Proprio: $+0.52 \pm 0.04$ TSA: $+0.61 \pm 0.08$ Positive values: Knee TT: Everyday feet: -0.16 ± 0.04 Proprio: -0.16 ± 0.06 Raize: -0.03 ± 0.07 TF: Everyday feet: -0.21 ± 0.03 Proprio: -0.24 ± 0.03 TSA: -0.09 ± 0.09 TT: Elan: $+0.26 \pm 0.04$ Proprio: $+0.38 \pm 0.06$ TF: Everyday feet: $+0.29 \pm 0.07$ | +++ extension ++ ++ ++ | TF: Elan: -0.07 ± 0.11 No sig. differences for | | | |

| 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 | | | | | |
| U | Up (10°) | TT: | | TF: | | | |
| | | Raize: +0.15 ± 0.14 | ++ | Everyday feet: +0.05 ± 0.05 | ++ | | |
| * no di | fference (0), positive | trend (+), negative trend (-), s | ignificant | (++/), 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)

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