Evaluation of a Powered Ankle-Foot Prosthesis during Slope Ascent Gait

PLoS ONE 11(12): e0166815.

Products

BiOM (Bionic powered ankle-foot prosthesis)

Major Findings

With BiOM compared to passive, energy-storing-returning prosthetic ankle foot (ESR) and matched able-bodied subjects (AB):

- **Increased ankle range of motion with BiOM on inclines**
  
  by 29% compared to ESR

- **Improved push-off with BiOM compared to ESR**
  
  Plantarflexion improved by 283.5%
  
  Ankle power generation increased by 102.7%

- **Less demand on the intact limb knee with BiOM**
  
  44.7% lower knee power generation compared to ESR

Population

Subjects: 10 unilateral, transtibial amputees (TTA)
10 matched able-bodied subjects (AB)

Previous prosthetic foot: Re-Flex VSP (5), Renegade (3), Flexfoot (1) and Pathfinder (1)

Mean age:

TTA: 30.2 ± 5.3 years
AB: 23.3 ± 4.1 years

Mean height:

TTA: 1.83 ± 0.1 m
AB: 1.8 ± 0.09 m

Mean weight:

TTA: 96.1 ± 6.8 kg
AB: 94.9 ± 8.8 kg
Participants with TTA attended two separate gait analysis sessions using their ESR as well as the BiOM. Participants with TTA were given three weeks to acclimate to the BiOM. The AB subjects attended a single gait analysis session. During data collections, participants walked up a 5m long, 5° sloped ramp.

### Results

| Functions and Activities | Participation | Environment |
|--------------------------|---------------|-------------|
| Level walking            | Self-selected velocity [m/s] | Faster with BiOM (+17.8%) and ESR (+11.9%) compared to AB. |
|                         |                | No difference with BiOM compared to ESR (+5.3%). |
| Stairs                  | Step length [m] | Longer step length for prosthetic limb with BiOM compared to ESR (+3.7%) and AB (+15.1%). |
| Ramps, Hills            | Ankle range of motion [°] | Increased for prosthetic limb with BiOM compared to ESR by +29%. |
| Uneven ground, Obstacles|                | Decreased with BiOM (-27.6%) and ESR (-43.8%) compared to AB. |
| Cognitive demand        |                | ++ |
| Metabolic energy        |                | ---- |
| Sensation               |                | |
| Safety                  |                | |
| Activity, Mobility, ADLs|                | |
| Preference, Satisfaction, QoL|   | |
| Health Economics        |                | |

#### Category: Ramps, Hills

**Outcomes**

- **Prosthetic limb:**
  - **Dorsiflexion [°]:**
    - Decreased by 23.9% with BiOM compared to ESR.  
    - No difference for BiOM (-14.3%) and ESR (12.5%) compared to AB.
  - **Ankle power absorption [W/kg]:**
    - Lower with BiOM compared to AB by 200%  
    - Decreased by 60% with BiOM compared to ESR.
  - **Hip power generation [W/kg]:**
    - Higher with BiOM (+76.8%) and ESR (72.3%) compared to AB.
    - No difference with BiOM compared to ESR (+2.6%).

- **Intact limb:**
  - **Ankle power generation [W/kg]:**
    - Increased by 47% with BiOM compared to AB.
    - No difference with BiOM compared to ESR (+5.5%).

---

Ottobock | Evaluation of a Powered Ankle-Foot Prosthesis during Slope Ascent Gait

BiOM (Bionic powered ankle-foot prosthesis)
Evaluation of a Powered Ankle-Foot Prosthesis during Slope Ascent Gait

**BiOM (Bionic powered ankle-foot prosthesis)**

| Category                                                                 | Outcomes                                                                                           | Results for BiOM vs ESR vs AB                                                                 | Sig. * |
|--------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|--------|
| Transiting OFF the prosthetic limb (Push-off)                            | **Prosthetic limb:**                                                                                 |                                                                                                |        |
|                                                                         | *Plantarflexion [*]:**                                                                                | Improved with BiOM compared to ESR by 283.5%.                                                 | ++     |
|                                                                         | Decreased for BiOM (-44.3%) and ESR (-130.4%) compared to AB.                                        | **−−**                                                                                         |        |
|                                                                         | **Ankle power generation [W/kg]:**                                                                   | Increased with BiOM compared to ESR by 102.7%.                                                 | **++** |
|                                                                         | No difference with BiOM compared to AB (+27.2%).                                                    | **0**                                                                                          |        |
|                                                                         | **Intact limb:**                                                                                    | Lower by 44.7% with BiOM compared to ESR.                                                      | **++** |
|                                                                         | **Knee power generation [W/kg]:**                                                                    | No difference with BiOM compared to AB (-1.7%).                                                | **0**  |

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

**Author’s Conclusion**

“While the PWR (Note: BiOM) provided active ankle plantarflexion and push-off power when transitioning off the prosthetic limb, it was not capable of active dorsiflexion. Thus, the PWR functioned similar to a passive ESR device during the transition onto the prosthetic limb resulting in similar prosthetic limb hip and intact limb ankle compensations. In contrast, when transitioning off the prosthetic limb, the increased ankle plantarflexion and push-off power provided by the PWR contributed to decreased intact limb knee extensor power production, lessening demand on the intact limb knee. Further work is needed to determine whether the provided active ankle plantarflexion and push-off power would improve slope descent gait mechanics.” (Rábago et al., 2016)