Reference

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Sprinting with prosthetic versus biological legs: insight from experimental data

R Soc Open Sci. 1 January 2022;9 (1):211799.
https://doi.org/10.1098/rsos.211799. OpenAccess

Products

Ottobock 1E90 Sprinter, stiffness category 3

Major Findings

Fastest Bilateral amputee (BA) athlete, wearing Ottobock 1E90 Sprinter, stiffness category 3 compared to non-amputee athletes (NA):

→ Similar maximum running velocity for BA and to non-amputee athletes

- The fastest bilateral amputee (BA) reached a maximum treadmill velocity of 11.4 m/s, which is within the range of elite non-amputee (NA) sprinters (≈11.7 m/s).

→ Better running economy for BA

- Fastest bilateral amputated (BA) athlete had a better running economy than non-amputee athletes (NA) 400 m athletes and was comparable to NA distance runners.
- BA athletes exhibit a lower VO_2peak, and results in a vVO_2peak that is not faster than that of non-amputee 400-m sprinters or distance runners

→ Sprint endurance profile matches elite athletes

- The ability to sustain high velocities over time was nearly identical to NA athletes, indicating prosthetic legs do not limit endurance during sprinting.

→ Similar competitive race performance across 400 m

- Despite slower initial acceleration, BAs compensate in later segments (e.g., faster final 100 m split) and achieve overall race times similar to elite NA athletes.

→ Similar biomechanics within NA range

- With optimized prosthetic configuration, BA exhibits stance average vertical GRF, contact length, and step frequency values that are within 2 SD of NA athletes, supporting comparable sprint mechanics.

→ Clear measuabe disadvantage in the start phase for BA

- 40% slower time to sprint for 0-20m performance from starting block position for the BA compared to NA
- The difference in the 20m was related to the 31% lower mass-normalized horizontal force for the fastest BA, resulting in a 32% slower horizontal velocity getting out of the starting blocks

Overall, no clear performance advantage in 400m running for bilateral amputees using 1E90 Sprinter compared to non-amputee athletes.

However, it should be noted that the BA's data were collected using prostheses exceeding the regulated limb length defined by the MASH rule (2015) which influence biomechanical parameters. Therefore, comparisons with non-amputee athletes should be interpreted cautiously, especially given the limited information on the reference group in this publication.

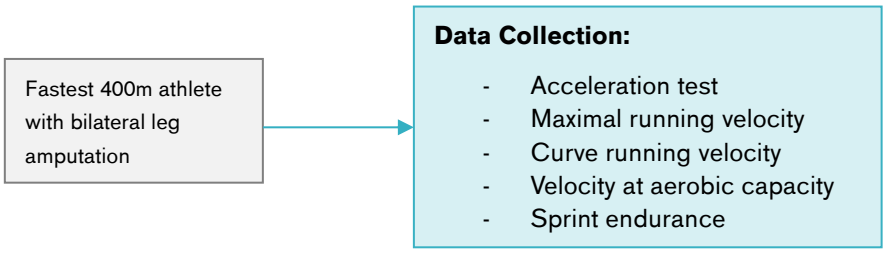
Abbreviations - NA non-amputee athlete, fastest BA = the fastest bilateral amputated athlete with prosthetic legs, UA = unilateral amputated athlete with a prosthetic leg

Population

Subjects:	1 (fastest 400m athlete using running prostheses)
Previous prosthesis:	Ottobock 1E90 Sprinter, stiffness category 3
Amputation level:	bilateral, transtibial
Amputation causes:	n.a.
Age:	29 years
Weight:	without prosthesis: 65.9kg (mass of both prostheses 2.5kg)
Standing height:	with prostheses: 1.89m (standing leg length: 1.07m)
Mean time since amputation:	n.a.
MFCL:	n.a.
Season-best 400m:	44.42s

Study Design

5-day experimental testing series:



A 5-day experimental testing series followed the subjects competition season, in which he ran a season-best 400 m in 44.42 s. Each test (acceleration test, max. running velocity, curve running, velocity at aerobic capacity and sprint endurance) was conducted on separate days, with the subjects' competitive passive-elastic carbon-fibre running prostheses (1E90 Sprinter). It is not further specified in which order the tests were performed.

Collected data was compared to other bilateral amputee athletes, unilateral athletes and non-amputee (NA) athletes data.

Results

Activities		Participation				Body function			Other
Sprinting, running, jumping	Other sports	Leisure / recreational sports	Competitive sports	Paralympic sports	Preference, satisfaction, QoL	**Biomechanics (kinematics / kinetics)**	**Clinical (metabolic / performance)**	Medical (pain, injuries)	Technical aspects / alignment

Category	Outcomes	Results for 1E90 Sprinter	Sig.[a]
Level Walking	Initial acceleration	40% slower time to sprint for 0-20m performance from starting block position for the BA than NA	--

Fastest BA	Elite NA	Sub-elite NA
4.13 ± 0.10s	2.94s	3.13s

→ The difference in the 20m was related to the 31% lower mass-normalized horizontal force for the fastest BA, resulting in a 32% slower horizontal velocity getting out of the starting blocks

Similar mechanistical force generation for the fastest BA and NA (BA: 0.372 ± 0.13s vs. NA 0.362s)	n.a.

Category	Outcomes	Results for 1E90 Sprinter	Sig.[a]
	Maximum running velocity	Similar max. velocity for the fastest BA compared to NA and UA Fastest BA: 11.4 m/s; Elite NA: 11.72 m/s; UA: 11.55 m/s	n.a.
		Faster max. treadmill running velocity of the fastest BA compared to other bilateral athlete with prosthetic legs	n.a.
	Ground reaction force (GRF) and step kinematics	Similar average vertical GRF, contact length and step frequency biomechanical parameters at t 10m/s for the fasted BA compared to NA – less than 8% difference	n.a.
		19-23% higher stance average vertical GRF relative to body weight and 14% longer but less frequent steps for fastest BA compared to 2nd fastest BA (who hast lower stiffness in the running prosthesis) -	n.a.
	Curve running	Similar curve running velocities – on a 36.5m curve fastest BA curve speed was approx. 6% slower than straightaways speed, for NAs it is 3 – 4.7% slower on a curve than straightway	n.a.
	Sprint endurance	Similar sprint endurance profiles for BAs and NAs – fastest and 2nd fastest BA show nearly identical model predictions to NAs (3% difference)	n.a.
	400m race splits	Fastest BA's 400 m time (44.42 s) was less than 1 s.d. from the average and within the range of elite NA athletes 400 m time from the 2017 IAAF World Championships	n.a.
		1st 400m split (0 – 100m): slower first 100m for BA than NAs→ fastest BA was 8.3% slower (greater than 7 s.d.) than the elite NA athlete	n.a.
		2nd 400m split (100-200m): Similar times midrace for BA and NAs → the fastest BA was 2.5% slower (less than 2 s.d.) compared to the elite NA athletes	n.a.
		3rd 400m split (200-300m): Similar times midrace for BA and NAs → 0.2% faster (less than 2 s.d.) compared to the elite NA athletes	n.a.
		4th 400m split ticket (300.-400m): faster last 100m for BA than Nas → fastest BA ran 9.9% faster (greater than 3 s.d.) than the elite NA athletes	n.a.
Metabolic Energy Consumption	Velocity at aerobic capacity (vVO_2 peak)	14% slower vVO_2peak for fastest BA than than that reported by the 2nd fastest BA, which is nearly identical to the average from NAs. Fastest BA: 4.3 m/s; 2nd fastest BA: 5.0 m/s; NA: 4.9 ± 0.04 m/s vVO_2peak of the 2nd fastest BA is 19% slower than that of NA distance runners	n.a.
	Running economy	Fastest BA's average running economy was better than any other athlete with prosthetic legs and 19% better (greater than 8 s.d.) than NA 400 m athletes (and non-different (less than 1 s.d.) from NA distance runners	n.a.
	VO2 Peak	22% lower Vó2peak for fastest BA compared to the 2nd fastest BA Fastest BA: 41.2 ml O2/kg/min; 2nd fastest BA: 52.7 ml O2/kg/min; NA 400m: 63.5 ml O2/kg/min	n.a.

Category	Outcomes	Results for 1E90 Sprinter	Sig.[a]
		V̇o2peak of the 2nd fastest BA is 17% (greater than 2 s.d.) and 33% (greater than 6 s.d.) lower than that of the same NA 400 m athletes and NA distance runners respectively	

[a]Significance criterion: values >2 SD (Standard deviation) outside NA mean were considered *meaningfully different* and was used as conservative statistical threshold
no difference (0), positive trend (+), negative trend (–), significant (++/––), not applicable (n.a.)

Author's Conclusion

"Currently, no athlete with bilateral leg amputations using passive-elastic carbon-fibre running-prostheses, including the fastest such athletes, has ever been reported to have a single 400 m performance metric that is better than that achieved by NA athletes. Therefore, based on experimentally derived 400 m performance metrics, athletes with bilateral leg amputations using passive running prostheses cannot be unequivocally considered to have an advantage over NA athletes during 400 m competitions." (Beck et al., 2022)

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