Reference

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Ground Reaction Forces During Sprinting in Unilateral Transfemoral Amputees

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Products

3S80, 1E90

Major Findings

With *3S80* knee with *1E90* runner foot comparing prosthetic and intact limb:

→ Asymmetrical loading of the limbs due to significantly smaller forces and impulses in the prosthetic limb than the intact limb during sprinting.

- Bilateral differences in peak ground reaction forces for the vertical (26%), braking (54%), propulsive (27%) and medial components (50%) ($p<0.01$, large effect size).

→ Altered braking propulsion strategy in the prosthetic limb compared to the intact side.

- The prosthetic limb exhibits significantly reduced braking impulses (-52%, $p<0.01$) but comparable forward propulsive impulse relative to the intact limbs.
- 25% earlier transition during stance from braking to propulsion in the prosthetic limb (zero fore-aft shear[d], $p<0.01$) – indicating a shortened braking phase relative to the intact limb.

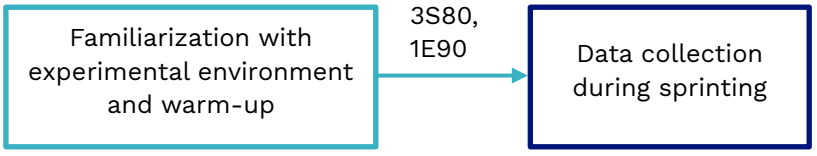
→ The study supports the development of limb-specific rehabilitation and training strategies.

Population

Subjects:	9 sprinters (5 male, 4 female)
Amputation level:	unilateral transfemoral
Prosthetic components:	Knee: 3S80 (9), Foot: 1E90 (9)
Amputation causes:	Trauma (5), Cancer (2), Infection (1), Sarcoma (1)
Mean time since amputation:	12.8 ± 8.3 years (range 3.5-29 years)
Mean age:	32.9 ± 11.7 years
Height:	1.61 ± 0.09 m
Mean body mass:	55.9 ± 9.2 kg without prosthesis
Personal sprinting record:	17.3 ± 2.3 s for 100 m
Running experience:	range: 0.9-3.2 years
MFCL:	not reported

Study Design

Prospective study design:



The participants all used the same knee units and running-specific prosthesis. They were asked to perform maximal sprinting on a 40m runway while kinetic and kinematic data were acquired using force plates and an optical motion capture system. Between trials, the participants rested for an adequate period. Four successful steps of each limb were analysed for each participant.

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 3S80, 1E90 [a]	Sig. [b]
Biomechanics (kinematics / kinetics)	Stance Time (s)	Significantly longer stance duration on the prosthetic limb.	

Prosthetic limb	Intact limb	Difference	
0.140 (±0.013)	0.127 (±0.015)	-12.6% [c]	++

Ground Reaction Force (GRF) (N/BW)

Significantly lower peak forces in the prosthetic leg during sprinting in all measured directions compared to the intact limb ($p<0.01$, large effect size), except for the peak lateral force.

Force component	Prosthetic limb	Intact limb	Difference	
Peak vertical	2.86 (±0.67)	3.86 (±0.58)	25.9%	−−
Peak braking	-0.44 (±0.14)	-0.95 (±0.20)	53.9%	−−
Peak propulsive	0.40 (±0.10)	0.55 (±0.07)	27.2%	−−
Peak medial	0.23 (±0.07)	0.46 (±0.12)	50.0%	−−
Peak lateral	-0.08 (±0.05)	-0.15 (±0.17)	48.3%	0

Zero fore-aft shear [d] (%)

The transition from braking to propulsion during stance happens 25.4 % earlier ($p<0.01$) in the prosthetic limb compared to the intact limb.

Prosthetic limb	Intact limb	Difference	
37.10 (±2.09)	49.73 (±2.88)	25.4%	−−

Impulses (Ns/BW)

Significantly lower braking impulse in the prosthetic limbs than in intact limbs.

Component	Prosthetic limb	Intact limb	Difference	
Braking impulse	-0.01 (±0.00)	-0.02 (±0.01)	52.2%	−−
No significant differences in vertical, propulsive, medial or lateral impulses between limbs.				0

[a] results shown as Mean (± Standard Deviation); relative difference expressed in percentage of intact limb (%INT)

[b] no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.) significance set at $p<0.05$; trends set at $0.1>p>0.05$

[c] stance time difference: value stated in paper, calculation error possible

Category	Outcomes	Results for 3S80, 1E90 [a]	Sig. [b]

[d] Zero fore-aft shear: The time point during stance at which the anterior–posterior ground reaction force crosses zero, indicating the transition from braking to propulsion.

Author's Conclusion

"Peak forces in vertical, braking, propulsive, and medial directions were significantly greater in intact limbs than those in prosthetic limbs, whereas there were no significant differences in peak lateral force between limbs. Further, significantly less braking impulses were observed in prosthetic limbs than in intact limbs; however, the other measured impulses were not different between limbs. Therefore, the results of the present study suggest that limb-specific rehabilitation and training strategies should be developed for transfemoral amputees wearing running-specific prostheses." (Makimoto et al., 2017)

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