Reference

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Crawling Kinematics in an Early Knee Protocol for Pediatric Prosthetic Prescription

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Products

3R38

Major Findings

With 3R38 (free posterior-offset single-axis knee hinge with manual lock and adjustable knee extension assist) in unlocked and locked state:

→ **Children under 3 years, with locked knee prostheses as first fitting, showed variable and frequently greater compensatory movements during crawling compared to having an unlocked knee**

→ **When the knee was unlocked, all subjects achieved knee flexion with an average peak knee flexion of 97.76°**

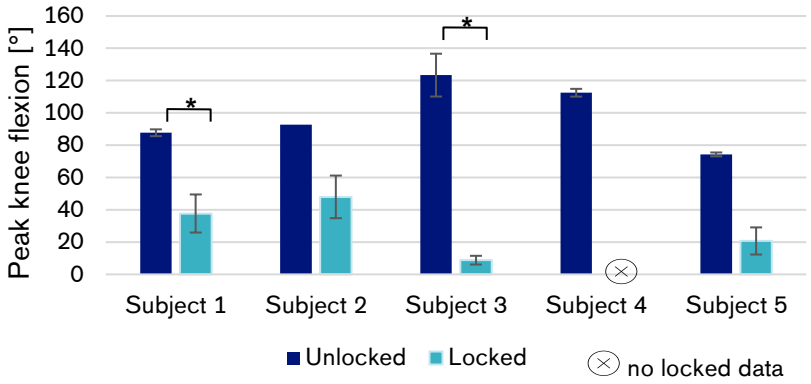


Figure 1. Prosthetic limb, peak knee flexion for all subjects in the locked and unlocked prosthetic knee condition (mean and standard deviation (SD); no SD for subject 2 in unlocked state available; * indicates a statistically significant difference).

→ **Bilateral asymmetry of movements in the unlocked condition is reduced compared to locked state but still significantly apparent,**

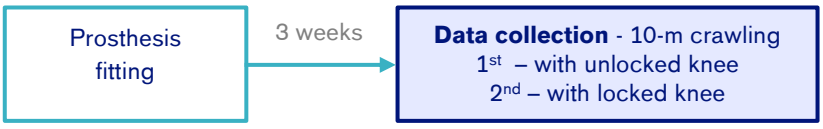
- Less knee flexion on prosthetic side in the unlocked state (Δ 25.2°±7.2°, p=0.0005) compared to the locked state (Δ 91.0°±7.5°, p<0.0001)

Population

Subjects:	5 children (2 male, 3 female)
Amputation level:	unilateral: knee-disarticulation (2), transfemoral (3)
Current prosthesis:	Ottobock 3R38, TRS infant foot, TES belt (3) Ottobock 3R38, Seattle child´s play foot, TES belt (2)
Amputation causes:	congenital and acquired, tibia deficiency (2), congenital, amniotic banding (2), congenital, amniotic banding very short residual limb (1)
Age:	16.8 months (range: 13-23 months)
Time since amputation:	5 and 2 months (2 subjects with acquired limb loss, 3 congenital)

Study Design

Before-and-after experimental design:



Within three weeks before enrollment in the study, children were fitted with a prosthesis according to the Early Knee protocol. For data collection during the study, the children crawled on extended arms in quadruped crawling along a 10m-trial with their prosthesis set to two different conditions (1st: prosthetic knee unlocked and 2nd: prosthetic knee locked). For familiarization, the children crawled and played within the laboratory setup, then at least 5 trials for each condition were performed in the same single session. A trial was successful if a child crawled the 10m-pathway three times without stopping. Cadence and crawling velocity were measured using a motion tracking system.

Results

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**

Category	Outcomes	Results for 3R38	Sig.[a]
Level Walking	**Peak knee flexion [°]**	Mean peak knee flexion was significantly greater ($p < 0.0001$) in the prosthetic knee unlocked condition (97.76° ± 17.75°) compared to the locked condition (25.32° ± 17.20°). In the unlocked condition, knee flexion was exhibited by all subjects.	

	Unlocked (Mean ± SD)	**Locked** (Mean ± SD)	
Subject 1	87.7° ± 2.1°	37.7° ± 11.8°	++
Subject 2	92.7° ± 0°	48.0° ± 13.2°	0
Subject 3	123.4° ± 13.25°	8.8° ± 3.7°	++
Subject 4	112.5° ± 2.4°	--	n.a.
Subject 5	74.3° ± 1.2°	20.7° ± 8.4°	+
Difference |left – right|	25.2° ± 7.2°	91.0° ± 7.5°	++

In the locked condition flexion was nonzero as well → prosthetic knee created a long lever arm that caused relative motion between the markers on the prosthesis and the marker on the greater trochanter, which was interpreted by the system as knee flexion.

Bilateral symmetry of knee flexion	**Non-symmetric bilateral knee flexion in both conditions, showing less flexion on prosthetic side, with a greater difference when using a locked knee:** • unlocked state: Δ 25.2° ± 7.2° • locked state: Δ 91.0° ± 7.5° Bilateral asymmetry associated with the locked condition was consistent for all subjects when comparing bilateral knee flexion differences across conditions.	 ++ ++

Category	Outcomes	Results for 3R38	Sig.[a]
	Frontal plane hip angles	Generally, more abduction in the prosthetic limb than the contralateral limb.	
		Inconsistent between subjects and sometimes across an individual's trials. • *Subject 2: substantially altered crawling pattern (prosthetic limb was shifted completely under the trunk, in hip adduction; adaptation was exacerbated in the locked condition)*	
	Peak hip abduction	Greater peak hip abduction in prosthetic limbs during locked condition compared to the contralateral limb by an average of: • Locked condition: 25.4° • Unlocked condition: -- n.a.	 + n.a.
	Peak hip adduction	Greater peak hip adduction in prosthetic limbs during unlocked condition than contralateral limb by an average of: • Locked condition: -- n.a. • Unlocked condition: 17.3° (suggests either a more variable pattern or a generally larger range of motion on the prosthetic side)	 n.a. +

	Bilateral hip asymmetry	No statistical significance was found (p=0.0957 for locked condition, p=0.1505 for unlocked condition):
		• high variability in the compensatory motion of the trunk
		  ○ *Subject 5: high variability in the locked condition*
		  ○ *Subject 3: inconsistent trial in the unlocked condition*
		• Range of motion varied across subjects	

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

Author's Conclusion

"This study demonstrates that toddlers as young as 13 months with knee disarticulation and transfemoral amputation levels can incorporate prosthetic knee function during crawling when offered an articulating knee prostheses and that symmetry is improved in several different crawling patterns. Combined with previous research indicating advantages in temporal and spatial parameters with the Early Knee protocol, the approach seems to have advantages in several kinematic outcomes. Therefore, a prosthesis with a free bending prosthetic knee should be considered as soon as an infant with knee disarticulation or transfemoral level amputation begins to crawl and pull to stand." (Geil et al., 2013)

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