Wetenschappelijke exploraties van enkele biomechanische hypothesen

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Motion of the Calcaneus, Navicular, and First Metatarsal During the Stance Phase of Walking

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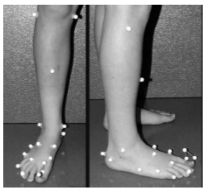
One hundred fifty-three subjects between the ages of 18 and 41 years (mean age, 26.2 years) with no history of congenital or traumatic deformity or foot problems walked along a 6-m walkway while the angular and linear displacement of the tibia, calcaneus, navicular, and first metatarsal was measured by means of an electromagnetic motion analysis system. Three-dimensional movement of the calcaneus relative to the tibia, of the navicular relative to the calcaneus, and of the first metatarsal relative to the navicular during the stance phase of gait was calculated. The results of this study provide information on, and an understanding of, how the calcaneus, navicular, and first metatarsal function during the stance phase of normal human walking. (J Am Podiatr Med Assoc 92(2): 67-76, 2002)

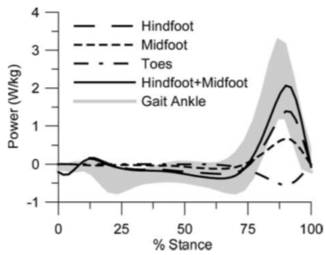
Further research needs to be done to better understand the action of the first ray relative to proximal segments, such as the rearfoot or lower leg. Despite the need for further research, the results of this study clearly show that **some of the current ideas about the kinematics of the foot during normal walking should be reexamined**.

Cornwall et al 2002

This study provides normative foot joint angles, moments and powers during adolescent gait. Eighteen subjects were evaluated using 19 retroreflective markers, six cameras, a pressure platform and a force plate. **A nine-segment model** determined 3D angles, 3D moments, and powers in eight joints or joint complexes. **Results also indicate that single link models of the foot significantly overestimate ankle joint powers during gait.**

Mac William et al 2002





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www.elsevier.com/locate/gaitpost

Functional units of the human foot

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It was further concluded that a marker setup for gait analysis should consist of the following four segments: **calcaneus, navicular–cuboid, medial cuneiform–first metatarsal, fifth metatarsal.**

A Clinically Applicable Six-Segmented Foot Model

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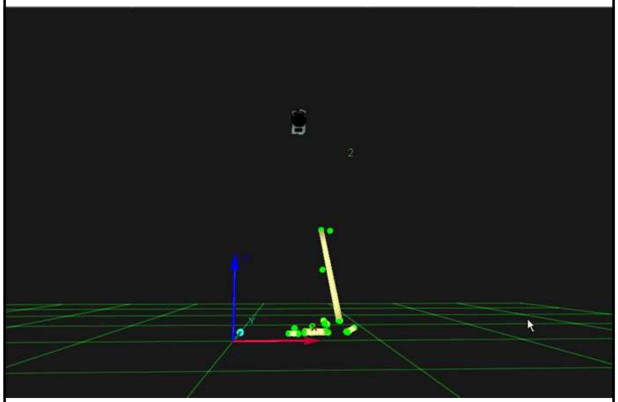
Ghent Foot Model

- **het onderbeen (tibia + fibula)**
- **de achtervoet (os talus + os calcaneus)**
- **de middenvoet (os naviculare + os cuboideum + ossae cuneiforme)**
- **de mediale voorvoet (MT I)**
- **de laterale voorvoet (MT II - V)**
- **de hallux**

Repeated measurements of each subject revealed **low intra-subject variability**, varying between 0.58 and 2.38 for the minimum values, between 0.58 and 2.18 for the maximum values, and between 0.88 and 5.88 for the ROM. **The described movement patterns were repeatable and consistent with biomechanical and clinical knowledge**. As such, the Ghent Foot model permits intersegment, in vivo motion measurement of the foot, which is crucial for both clinical and research applications.



Med Sci Sports Exerc. 2013 Nov;45(11):2129-36

Gait kinematics of subjects with ankle instability using a multisegmented foot model.

De Ridder R1, Willems T, Vanrenterghem J, Robinson M, Pataky T, Roosen P.

Gezonden n=20
CAI n=21

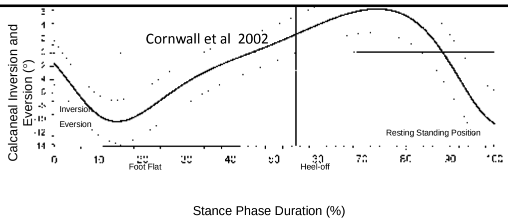
↓

Geen verschil
N = 42

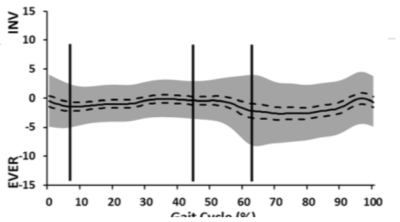
	Gezonde populatie	Chronische enkelinstabiliteit (CAI)
Leeftijd	25,8 (1.9) *	21.9 (3,3) *
Grootte	173,0 (8,9)	175,8 (9,8)
Gewicht	65,9 (9,2)	71.0 (13,4)
BMI	21.9 (1.8)	22,9 (3,6)
FADI	100,0 (0,0) **	86,3 (9,9) **
FADI-S	100,0 (0,0) ***	70,5 (11.5) ***

Onderzoeksvragen

- Fenomeen van counter-rotation
- Stabilisatie van de eerste straal
- Windlessfenomeen



Leardini 2014



	A	B	C
1	datapunt	RF	dRF
2	0	-4,33	0,42
3	1	-3,91	0,46
4	2	-3,45	0,46
5	3	-2,99	0,43
6	4	-2,56	0,38
7	5	-2,18	0,34
8	6	-1,84	0,32
9	...	...	...

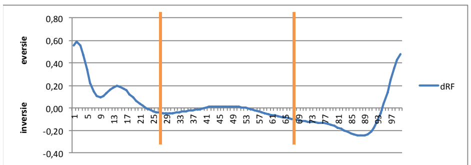
De d of delta slaat op de onderlinge verschillen van de datapunten (0-100%) binnen 1 meting van 1 segment.

Deze grafieken geven dus niet aan in welke positie het segment zich bevindt op een bepaald moment, maar wel in welke richting en in welke mate het beweegt.

Uit de helling van de curve kan afgeleid worden of het segment relatief snel of trager beweegt .

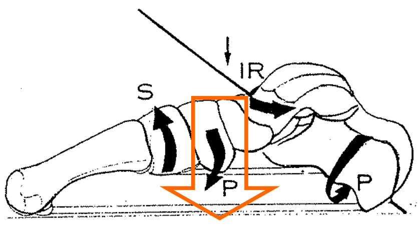
Wanneer een grafiek de horizontale as kruist, wil dit concreet zeggen dat het segment verandert van richting, het zij van in- naar eversie, plantair- naar dorsiflexie, en vice versa.

- Hielcontact 0-27 %
- Midstandsfase 27-67 %
- Propulsiefase 67-100 %



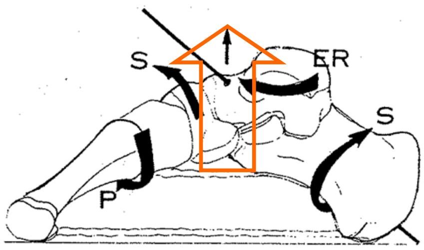
Counterrotation :

Pro calcaneus -> Sup voorvoet

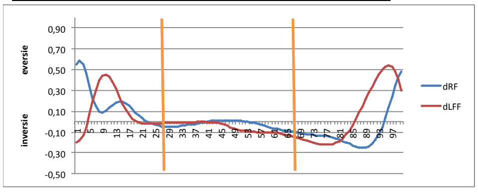


Counterrotation :

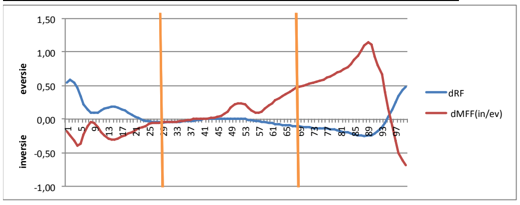
Sup calcaneus -> Pro voorvoet



Koppeling van beweging achtervoet (RF) en laterale voorvoet (LFF) (counter-rotation)



Koppeling beweging achtervoet (RF) en mediale voorvoet (MFFf) in het frontale vlak (eerste straal)

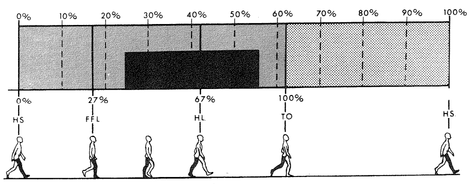


De koppeling tussen de achtervoet en de laterale voorvoet zoals beschreven in de literatuur en de hypothese van het fenomeen counter-rotation, kan dus niet bevestigd worden op basis van deze kwalitatieve interpretaties.

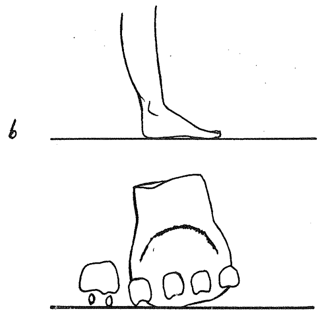
Toch is het opvallend dat het tegengestelde gedrag sterk tot uiting komt tussen de achtervoet en de mediale voorvoet of eerste straal. Bovendien kan duidelijk gesteld worden dat het bestaan van de eerste straal als aparte entiteit bevestigd is.

De laterale kolom volgt de achtervoet maar de mediale kolom leidt een eigen leven.

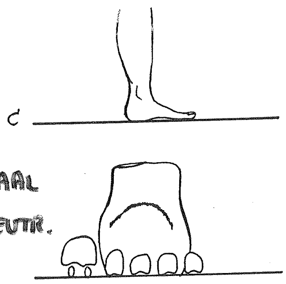
Werking van de m. peroneus longus tijdens het stappen



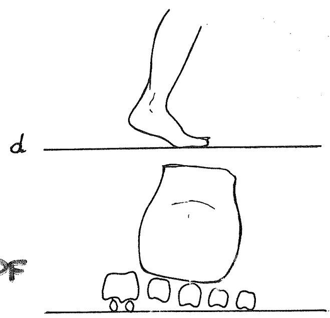
BEGIN MIDSTANDS
↓
CALC EV
1e STRAAL DF



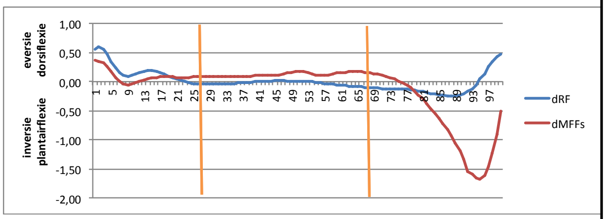
EINDE MIDSTANDS
↓
CALC NEUTRAAL
1e STRAAL NEUTR.



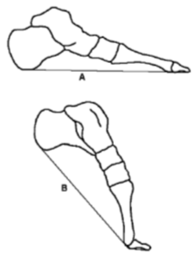
PROPULSIE
↓
CALC INV
1e STRAAL PF



Koppeling tussen beweging achtervoet (RF) en de mediale voorvoet in het sagittale vlak (MFFs) (stabilisatie van de eerste straal)

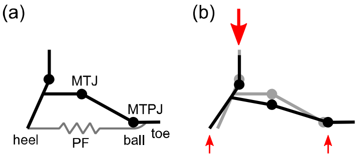


Deze synchrone koppeling tussen achtervoet inversie en mediale voorvoet plantairflexie tijdens de propulsiefase van de gangcyclus kan mogelijks wijzen op het feit dat de plantairflexie van de eerste straal als trigger kan dienen om een inversie van de achtervoet mogelijk te maken.

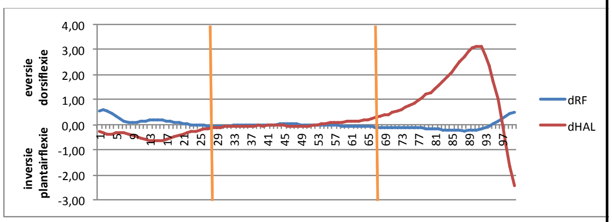


Studies show that walking with compliant feet incurs more energetic costs than walking with stiff feet. A possible explanation for this observation is that the power transfer of the leg tot the ground is more effective with stiff feet.

Song et al 2013



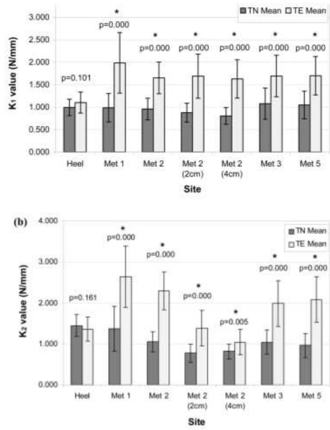
Koppeling van beweging achtervoet (RF) en hallux (HAL) (windlassmechanisme)



De relatie zoals vooropgesteld in de literatuur wat betreft het windlass mechanisme, kan op basis van deze gegevens bevestigd worden.

Plantar soft tissue stiffness

Garcia et al 2008



Foot (Edinb). 2008 June ; 18(2): 61–67. doi:10.1016/j.foot.2007.12.002.

Effect of metatarsal phalangeal joint extension on plantar soft tissue stiffness and thickness

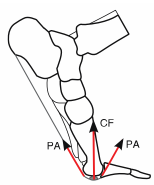
Christopher A. Garcia, SPT, Shannon L. Goebel, DPT, Mary K. Hastings, PT, DPT, ATC, Joseph W. Klaesner, PhD, and Michael J. Mueller, PT, PhD, FAPTA
Program in Physical Therapy, Washington University School of Medicine, Campus Box 8502, 4444 Forest Park Blvd, St. Louis, MO 63108-2212, USA

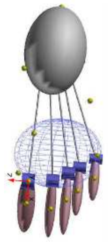
Results—Indicators of soft tissue stiffness (K_1 values) at the metatarsal heads and midfoot showed increases in stiffness of 81–88% (SD 20–33%) in the MPJ extension position compared with the MPJ neutral position. Soft tissue thickness measures at the metatarsal heads with the MPJ in neutral ranged from a mean of 8.9–13.5 mm and decreased, on average, by 8.8% (SD 2.9%) with MPJ extension.

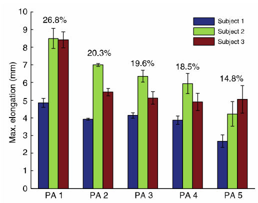
Conclusions—MPJ extension has a profound effect on increasing forefoot plantar soft tissue stiffness and a consistent but minimal effect on reducing soft tissue thickness. These changes may help transform the foot into a rigid lever at push-off consistent with the theory of the windlass mechanism.

Preloading of the PA in early stance and the role of the PA in sustaining the MTPJ in late stance have been highlighted. For the first time it has been possible to estimate the distribution of tension in the PA between its five longitudinal slips. **The maximum strain in the PA slips decreased from medial to lateral, confirming the role of the PA in sustaining the medial longitudinal arch.**

Caravaggi et al 2009







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Clinical Biomechanics 21 (2006) 194–203
CLINICAL BIOMECHANICS
www.elsevier.com/locate/clinbiomech

Effect of Achilles tendon loading on plantar fascia tension in the standing foot

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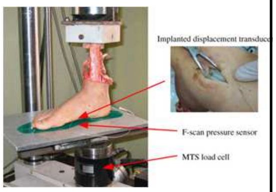
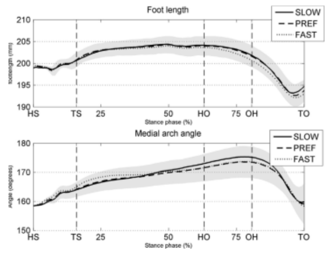
Increasing tension on the Achilles tendon is coupled with an increasing strain on the plantar fascia. Overstretching of the Achilles tendon resulting from intense muscle contraction and passive stretching of tight Achilles tendon are plausible mechanical factors for overstraining of the plantar fascia.



The foot lengthened during the weight acceptance phase of gait and shortened during propulsion. With increased walking speed, the foot elongated less after heel strike and shortened more during push off. The MLA angle and foot length curve were similar, except between 50% and 80% of the stance phase in which the MLA increases whereas the foot length showed a slight decrease. Conclusion: **Footlength seems to represent the Hicks mechanism in the foot and the ability of the foot to bear weight. At higher speeds, the foot becomes relatively stiffer, presumably to act as a lever arm to provide extra propulsion.**



Stolwijk et al 2013

Conclusie mbt normale biomechanica

- De laterale voorvoet volgt de achtervoet
- De eerste straal heeft zowel in het frontale vlak als in het sagittale vlak een eigen kinematica, waarbij de plantair flexie de hersupinatie van de achtervoet initieert.
- Het windlessfenomeen stabiliseert de voet in de propulsiefase

De propulsiefase speelt een belangrijke rol in de voetkinematica.