The Adult Acquired Flatfoot

PATHOMECHANICS

CLINICAL EVALUATION

TREATMENT GUIDELINES

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Studies of AFO Treatment of Adult Acquired Flatfoot

Chao W, Wapner KL, Lee Th, Adams J, Hecht PJ. Nonoperative management of posterior tibial tendon dysfunction. Foot Ankle Int. 17(12): 736-41, 1996.

Augustin JF, Lin SS, Berberian WS, Johnson JE. Nonoperative treatment of adult acquired flatfoot with the Arizona Brace. Foot Ankle Clin. 8 (3): 491-502, 2003.

Alvarez GR, Marini A, Schmitt C, Satlzman CL. Stage I and II posterior tibial tendon dysfunction treated by a structured nonoperative management protocol: an orthosis and exercise program. Foot Ankle Int. 27 (1): 2-8, 2006.

Lin JL, Balbas J, Richardson EG. Results of non-surgical treatment of stage II posterior tibial tendon dysfunction: a 7- to - 10 year follow up. Foot Ankle Int 29 (8): 781-786, 2008

Krause F, Bosshard A, Lehmann O, Weber M. Shell brace for stage II posterior tibial tendon insufficiency. Foot Ankle Int 29 (11): 1095-1100, 2008.

Gliding resistance of the posterior tibial tendon

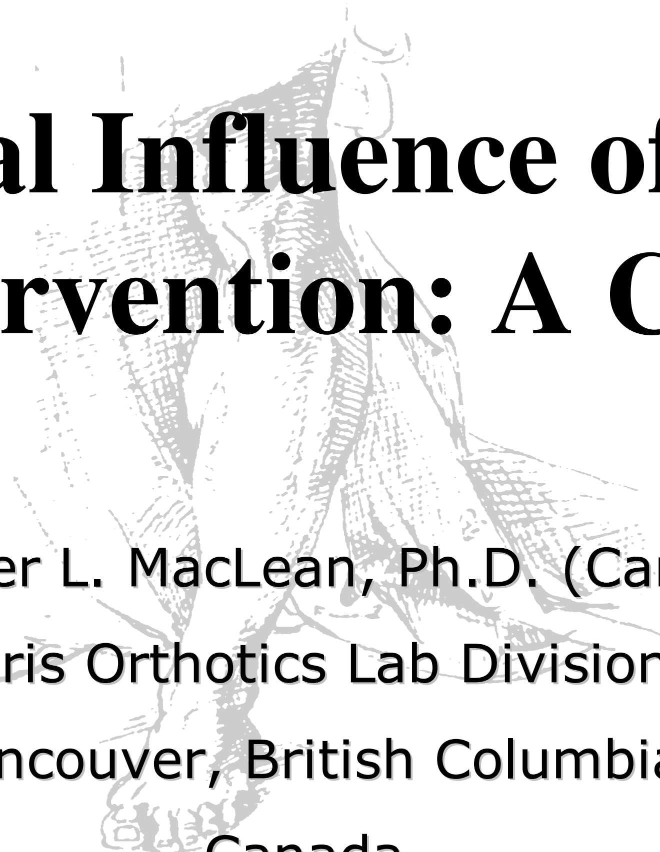
Foot Ankle Int. 2006 Sep;27(9):723-7. Uchiyama E, Kitaoka HB, Fujii T, Luo ZP, Momose T, Berglund LJ, An KN.Department of Anatomy, Sapporo University, Sapporo, Hokkaido, Japan.

BACKGROUND: Abnormal gliding of the posterior tibial tendon may lead to mechanical trauma, degeneration, and eventually posterior tibial tendon dysfunction. Our study analyzed the gliding resistance of the posterior tibial tendon in intact feet and in feet with simulated flatfoot deformity. METHODS: An experimental system was developed that allowed direct measurement of gliding resistance at the tendon-sheath interface. Seven normal fresh-frozen cadaver foot specimens were studied, and gliding resistance between the posterior tibial tendon and sheath was measured. The effects of ankle and hindfoot position and the effect of flatfoot deformity on gliding resistance were analyzed. Gliding resistance was measured for 4.9 N applied load to the tendon. RESULTS: Mean gliding resistance for the neutral position was 77 +/- 13.1 (x10(-2) N). Compared to neutral position, dorsiflexion increased gliding resistance and averaged 130 +/- 38.9 (x10(-2) N), and plantarflexion decreased gliding resistance and averaged 35 +/- 12.6 (x10(-2) N). Flatfoot deformity increased gliding resistance compared to normal feet, averaging 104 +/- 17.0 (x10(-2) N) for neutral, 205 +/- 55.0 (x10(-2) N) for dorsiflexion, and 58 +/- 21.3 (x10(-2) N) for plantarflexion. CONCLUSIONS: The findings indicate that patients with a preexisting flatfoot deformity may be predisposed to develop posterior tibial tendon dysfunction because of increased gliding resistance and trauma to the tendon surface.

Effects of foot orthoses on the work of friction of the posterior tibial tendon.

Clin Biomech (Bristol, Avon). 2009 Nov;24(9):776-80. Epub 2009 Aug 22. Hirano T, McCullough MB, Kitaoka HB, Ikoma K, Kaufman KR. Department of Anatomy, Sapporo University, Sapporo, Hokkaido, Japan.

Biomechanics Laboratory, Division of Orthopedic Research, Mayo Clinic, Rochester, MN 55095, USA.
BACKGROUND: Posterior tibial tendon dysfunction is a significant contributor to flatfeet. Non-operative treatments, like in-shoe orthoses, have varying degrees of success. This study examined changes to the work of friction of the posterior tibial tendon under three conditions: intact, simulated flatfoot, and flatfoot with an orthosis. It was hypothesized that work of friction of the posterior tibial tendon would significantly increase in the flatfoot, yet return to normal with an orthosis. Changes to bone orientation were also expected. METHODS: Six lower limb cadavers were mounted in a foot simulator, that applied axial and a posterior tibial tendon load. Posterior tibial tendon excursion, gliding resistance, and foot kinematics were monitored, and work of friction calculated. Each specimen moved through a range of motion in the coronal, transverse, and sagittal planes. FINDINGS: Mean work of friction during motion in the coronal plane were 0.17 N cm (SD 0.07 N cm), 0.25 N cm (SD 0.09 N cm), and 0.23 N cm (SD 0.09 N cm) for the intact, flatfoot, and orthosis conditions, respectively. Motion in the transverse plane yielded average WoF of 0.36 N cm (SD 0.28 N cm), 0.64 N cm (SD 0.25 N cm), and 0.57 N cm (SD 0.38 N cm) in the same three conditions, respectively. The average tibio-calcaneal and tibio-metatarsal valgus angles significantly increased in the flatfoot condition (5.8 degrees and 9 degrees , respectively). However, the orthosis did slightly correct this angle. INTERPRETATION: The prefabricated orthosis did not consistently restore normal work of friction, though it did correct the flatfoot visually. This implies that patients with flatfeet may be predisposed to developing posterior tibial tendon dysfunction due to abnormal gliding resistance, though bone orientations are restored.



Dynamical Influence of a Richie Brace Intervention: A Case Study

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Paris Orthotics Lab Division

Vancouver, British Columbia

Canada

Anatomy

- Posterior tibialis:
  - Origin:
    - Proximal, posterior aspects of the:
      - Tibia,
      - Fibula, and
      - Interosseous membrane.

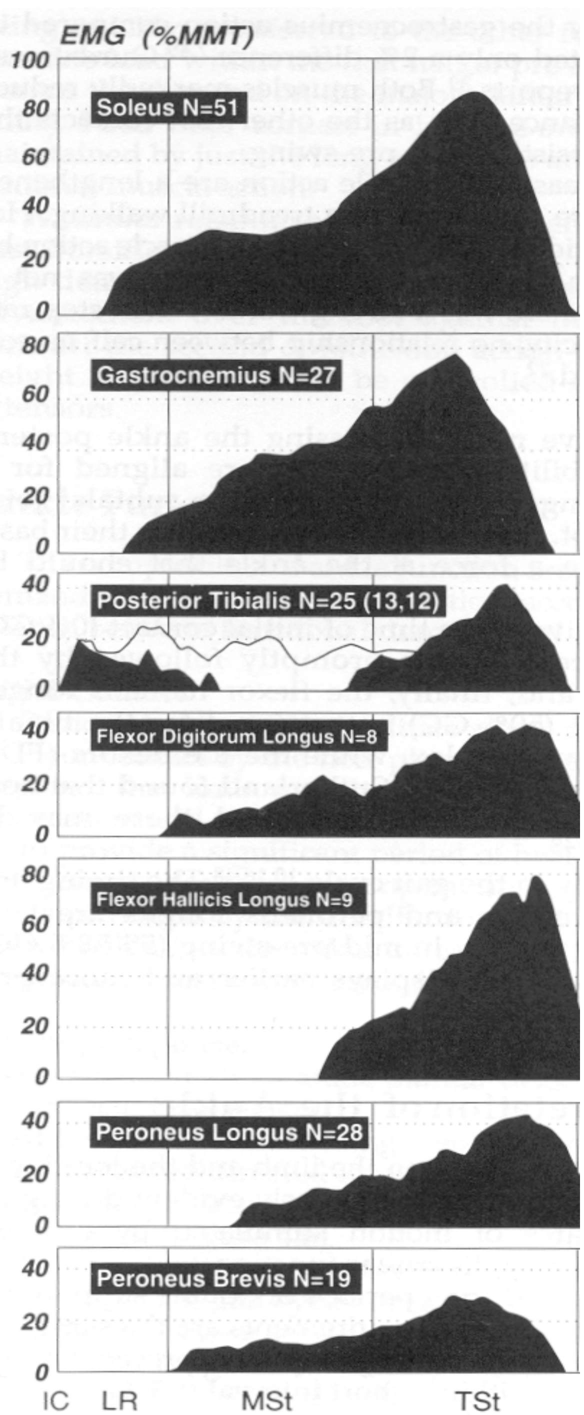
- Posterior tibialis:
  - Courses:
    - Inferiorly and passes around the medial malleolus, posteriorly.

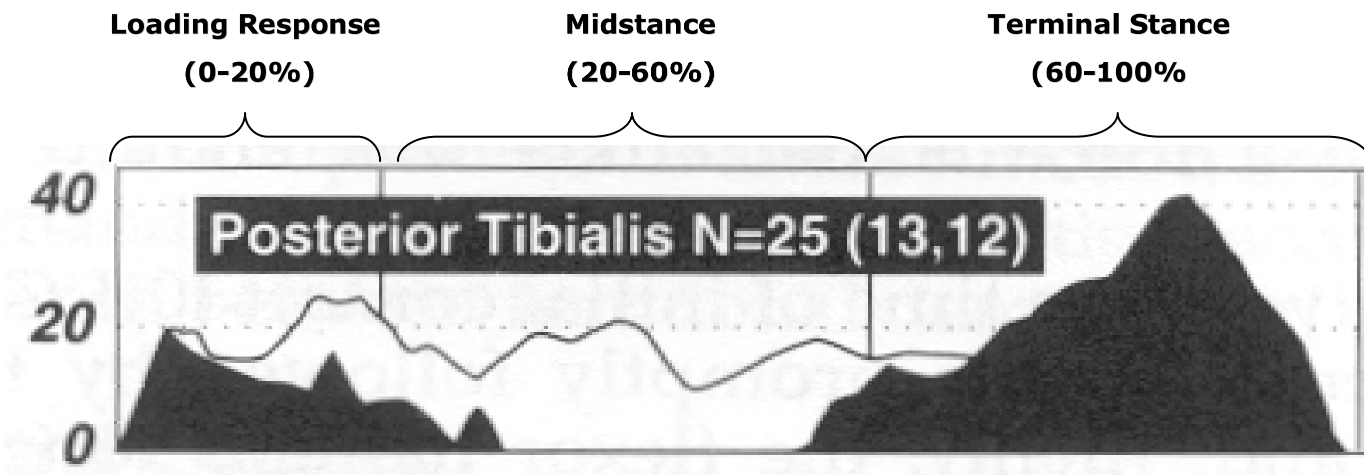
Anatomy

- Insertion:
  - Terminates with insertions on the:
    - Navicular tubercle,
    - Plantar aspect of the cuneiforms,
    - Bases of the metatarsals 1-3,
    - Cuboid, and
    - Calcaneus.

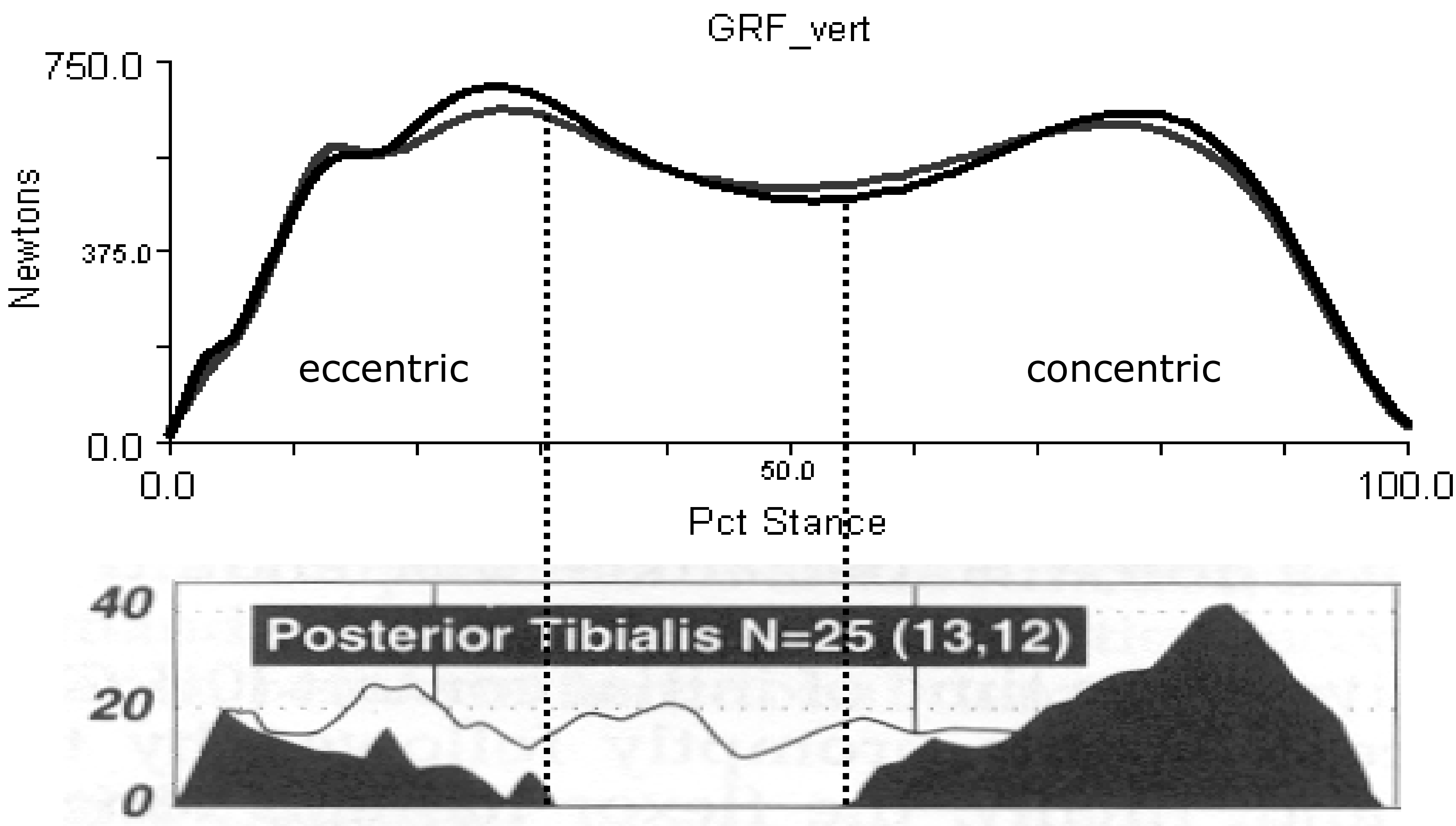
Function

- PT:
  - Eccentric:
    - Talocrural dorsiflexion,
    - Subtalar joint abduction and eversion, and
    - Midtarsal eversion, dorsiflexion and abduction.
  - Concentric:
    - Talocrural plantar flexion,
    - Subtalar joint adduction and inversion, and
    - Midtarsal adduction and inversion.


EMG (%MMT)
Soleus N=51
Gastrocnemius N=27
Posterior Tibialis N=25 (13,12)
Flexor Digitorum Longus N=8
Flexor Hallicis Longus N=9
Peroneus Longus N=28
Peroneus Brevis N=19
IC
LR
MSt
TSt


Loading Response
(0-20%)
Midstance
(20-60%)
Terminal Stance
(60-100%
Posterior Tibialis N=25 (13,12)
40
20
0

Perry, 1992



GRF_vert
750.0
375.0
0.0
Newtons
eccentric
concentric
0.0
50.0
100.0
Pct Stance
40
20
0
Posterior Tibialis N=25 (13,12)

Healthy vs. PTD Walking Kinematics

- PTD:
  - Rearfoot (RF relative to Leg):
    - SP:
      - ↓ plantar flexion at terminal stance.
    - FP:
      - no difference in rearfoot eversion/inversion.
    - TP:
      - ↑ abduction at terminal stance.

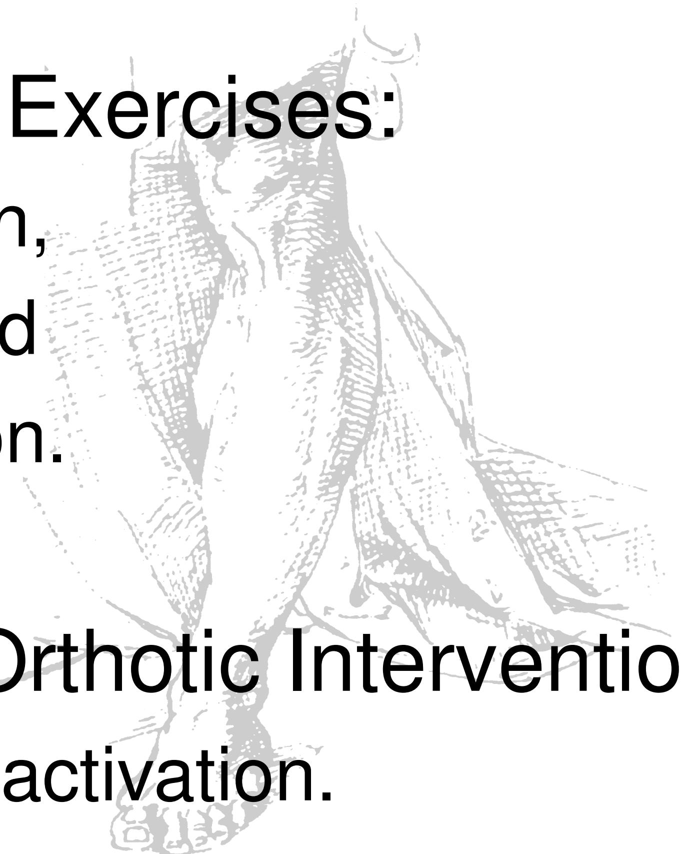
Rattanaprasert et al., 1999

Healthy vs. PTD Walking Kinematics

- PTD:
  - Forefoot (FF relative to RF):
    - SP:
      - ↓ dorsiflexion in early stance, and
      - marked ↑ in mid-late stance phase.
    - FR:
      - marked ↑ in eversion velocity from heel strike to 20% stance.
    - TP:
      - marked ↑ in FF abduction in terminal stance.

Rattanaprasert et al., 1999

Interventions



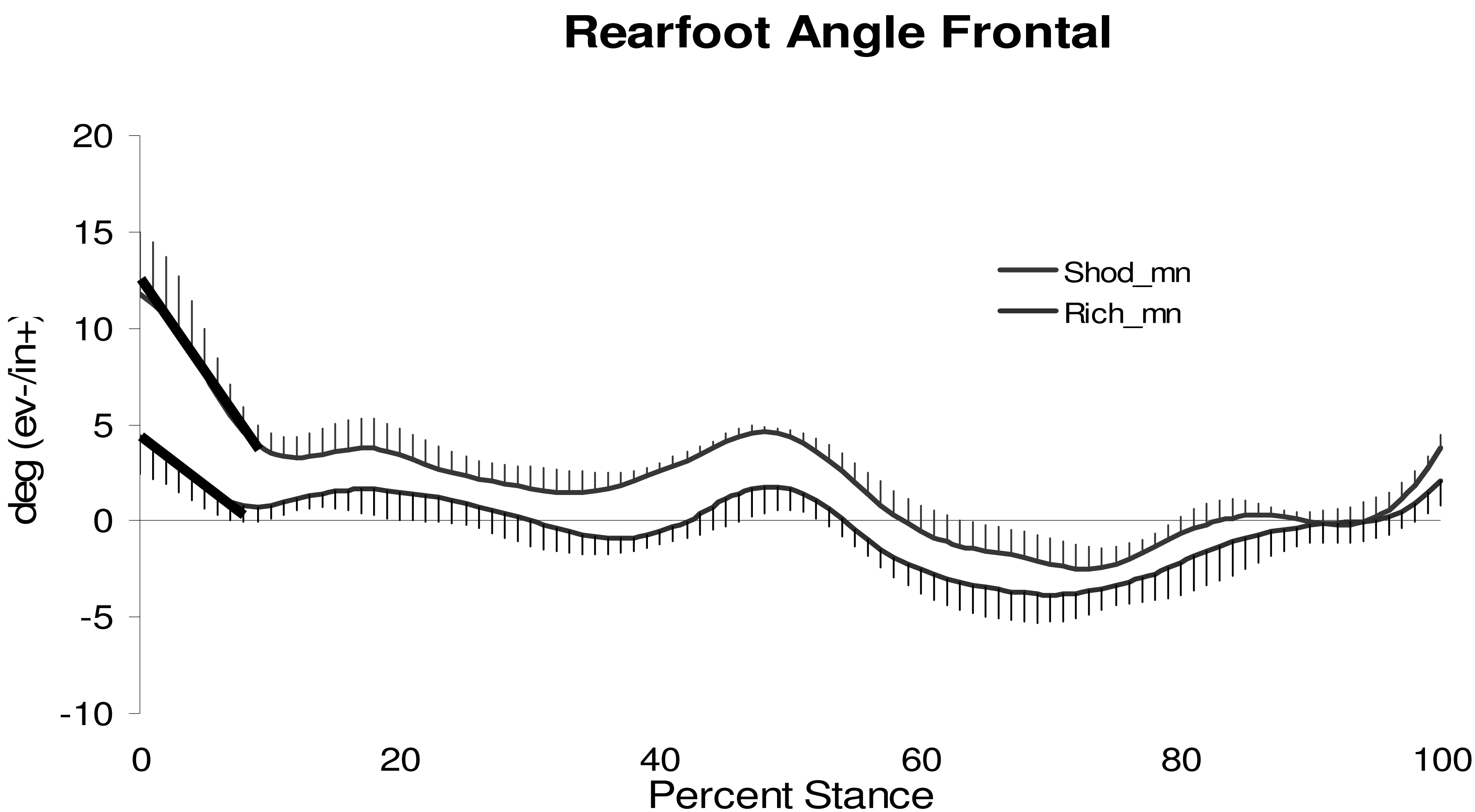
- Strengthening Exercises:
  - Foot adduction,
  - Heel raise, and
  - Foot supination.
- Custom Foot Orthotic Intervention:
  - Increased PT activation.

Kulig et al., 2004 & 2005

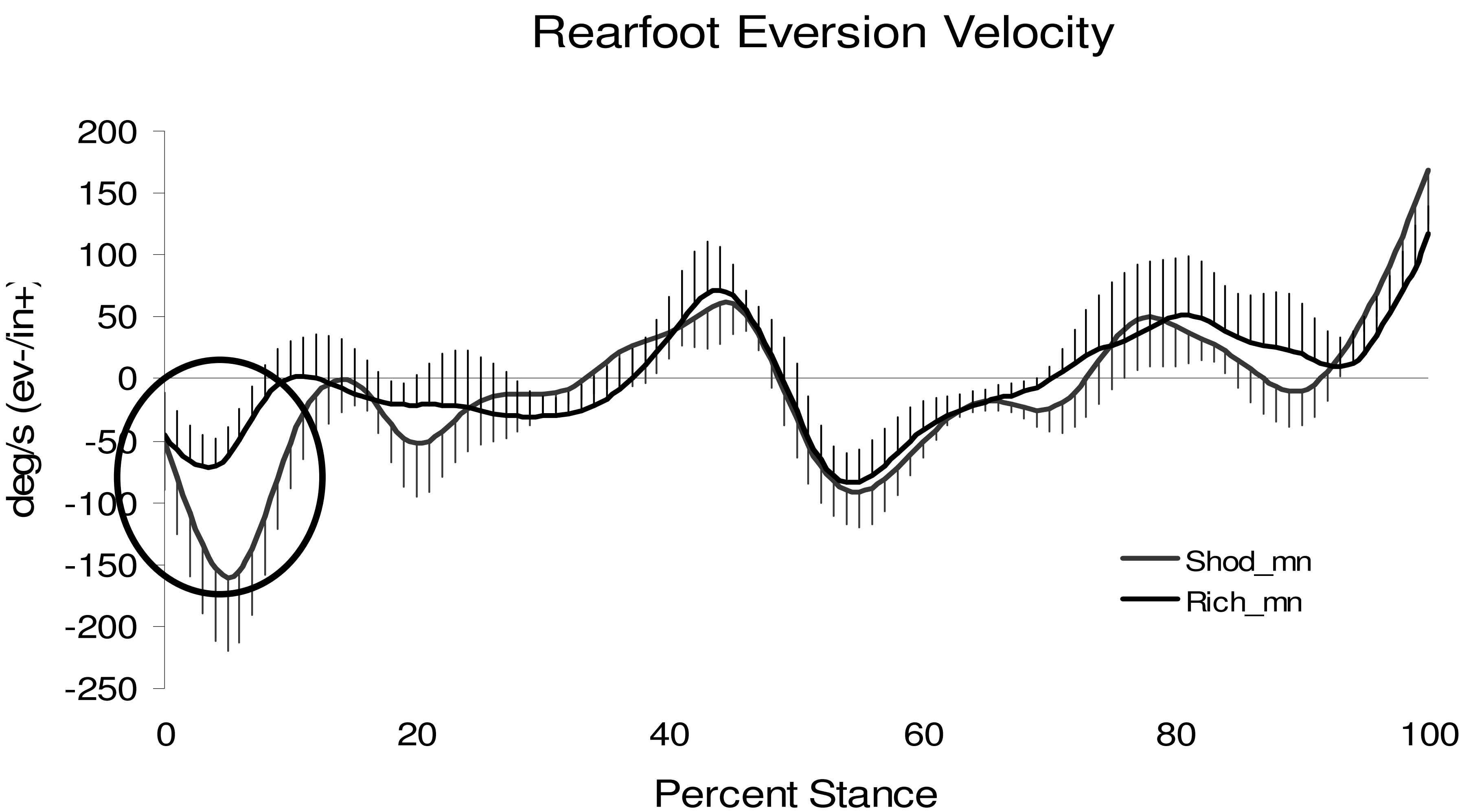
Case Description

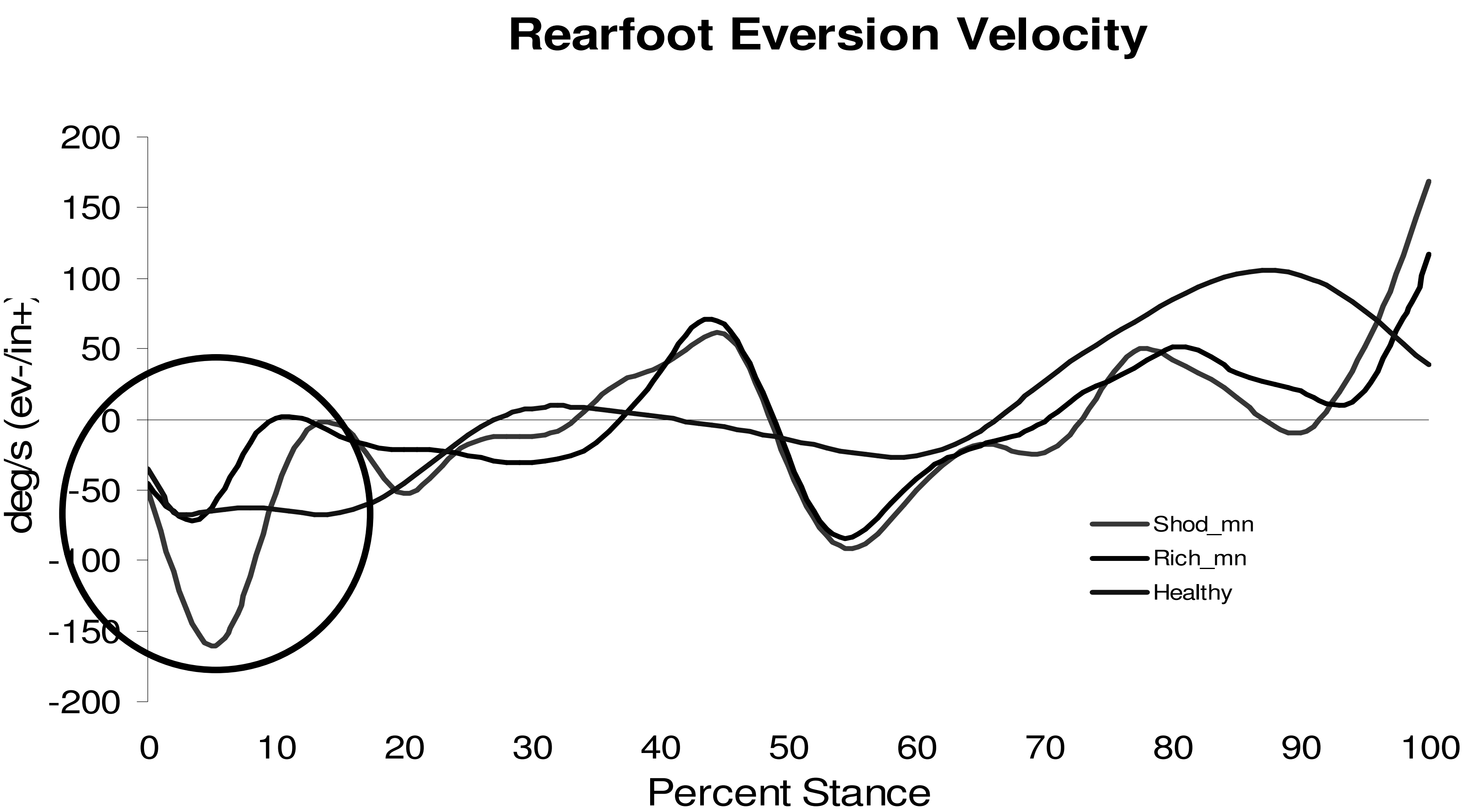
- 58-year old male,
- 82kg (180lbs) and 5’10”,
- Diagnosed with severe B/L PTTD by a DPM in Boston,
- Compared 4 conditions:
  - Shod,
  - Shod + Root Functional,
  - Shod + PTTD device, and
  - Shod + Richie Brace.

Rearfoot Analysis



Rearfoot Angle Frontal
20
15
10
5
0
-5
-10
deg (ev-/in+)
0
20
40
60
80
100
Percent Stance
Shod_mn
Rich_mn


Rearfoot Eversion Velocity
deg/s (ev-/in+)
200
150
100
50
0
-50
-100
-150
-200
-250
0
20
40
60
80
100
Percent Stance
Shod_mn
Rich_mn


Rearfoot Eversion Velocity
200
150
100
50
0
-50
-100
-150
-200
deg/s (ev-/in+)
0
10
20
30
40
50
60
70
80
90
100
Percent Stance
Shod_mn
Rich_mn
Healthy

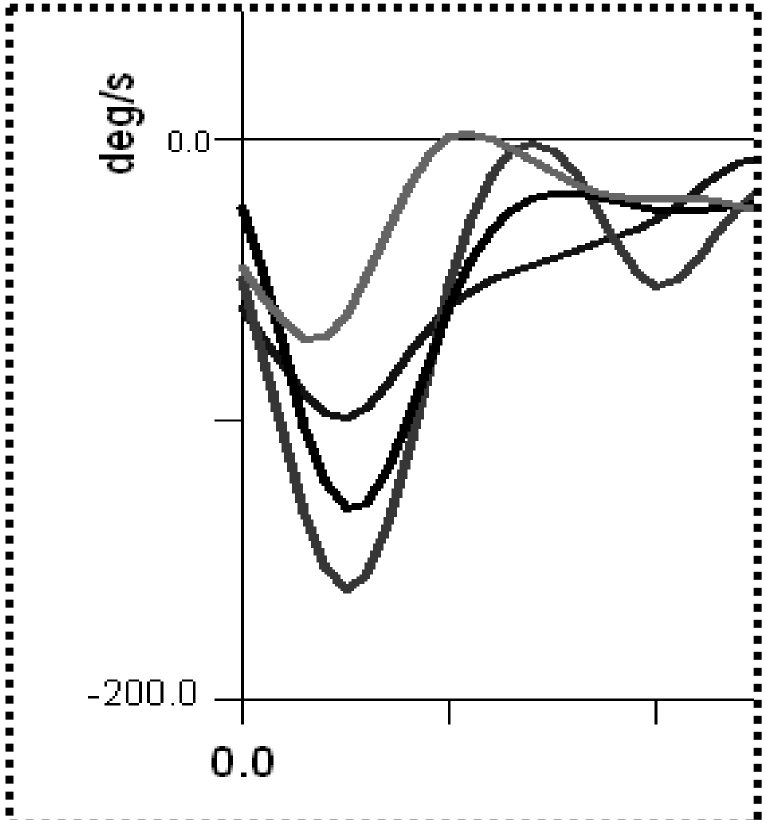
Rearfoot Eversion Velocity

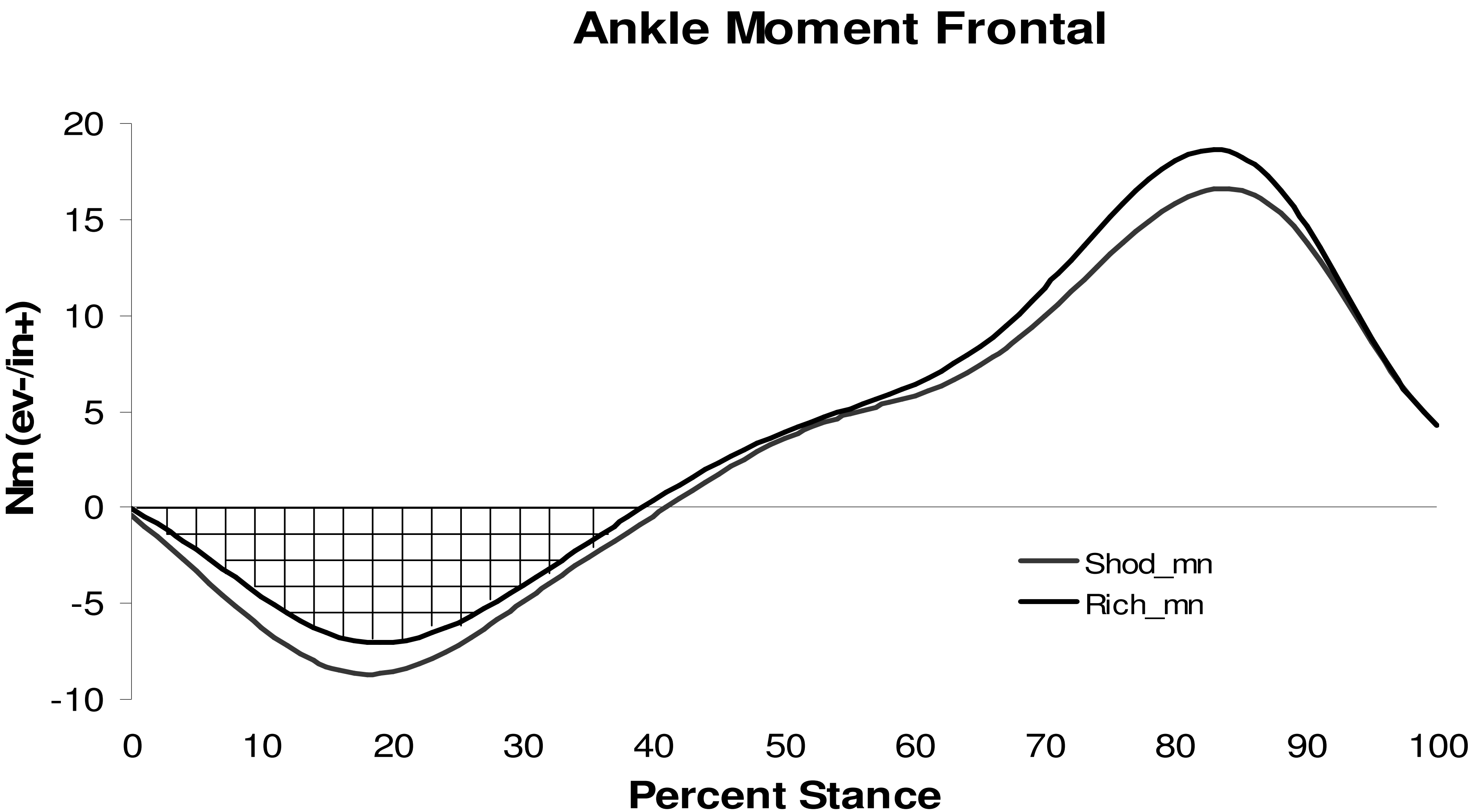
------ SHOD

----- ROOT

----- PTTD

----- RICH





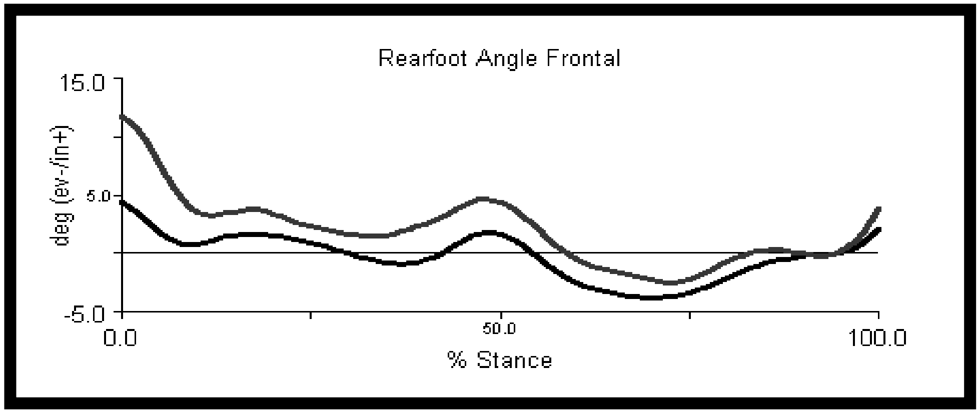
Ankle Moment Frontal
Nm(ev-/in+)
20
15
10
5
0
-5
-10
0
10
20
30
40
50
60
70
80
90
100
Percent Stance
Shod_mn
Rich_mn

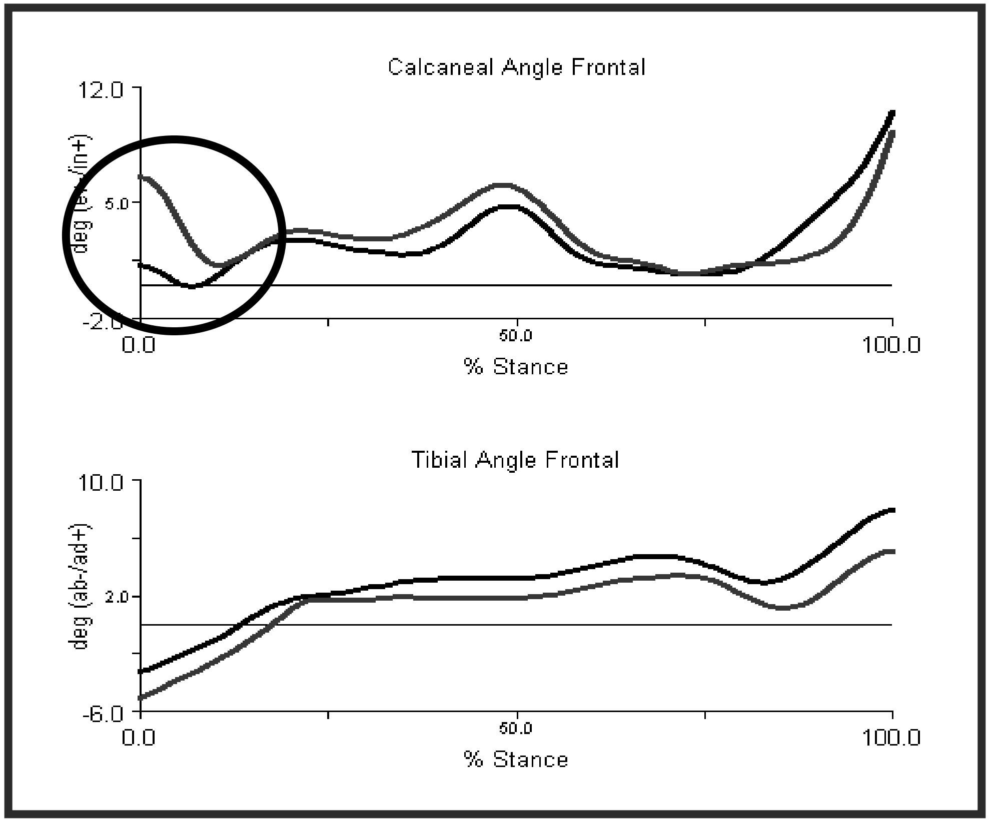
Impulse

- Angular impulse = integral(Moment) dt = change of angular momentum

- Typically, a reduction in the resultant joint moment and rotational joint impulse is associated with a reduction in joint loading (Nigg et al, 2004).

Rearfoot Angle Frontal





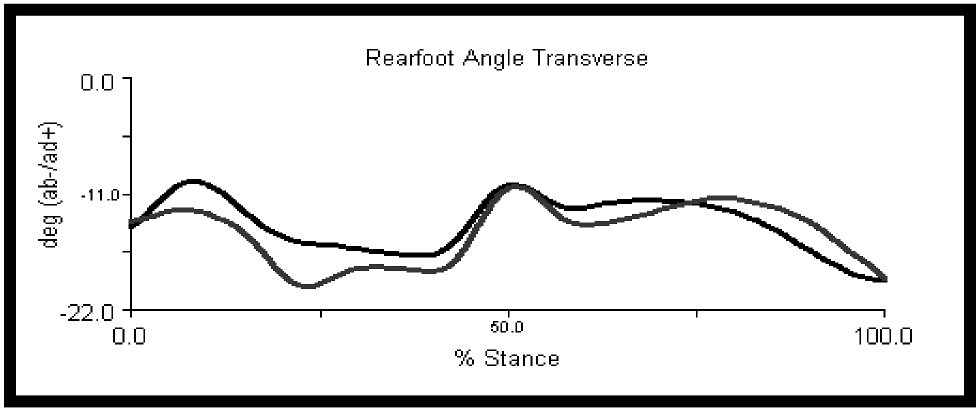
Rearfoot eversion excursion/ROM reduced, and

Rearfoot eversion increased throughout stance.

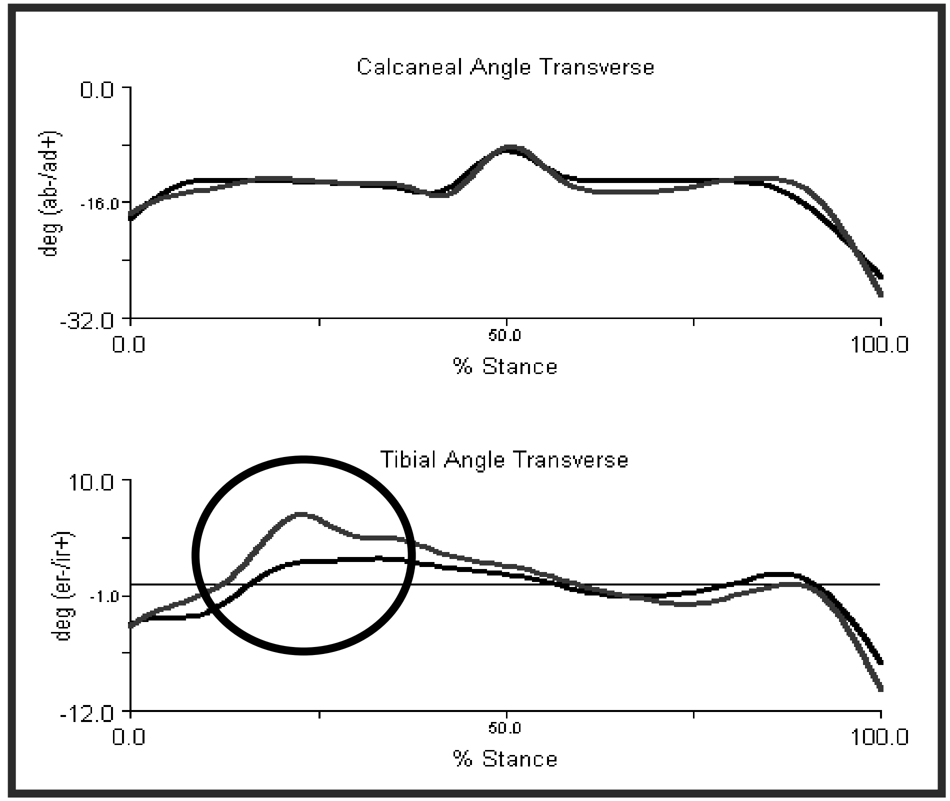
Calcaneal eversion velocity reduced.

Tibial adduction increased.

Rearfoot Angle Transverse

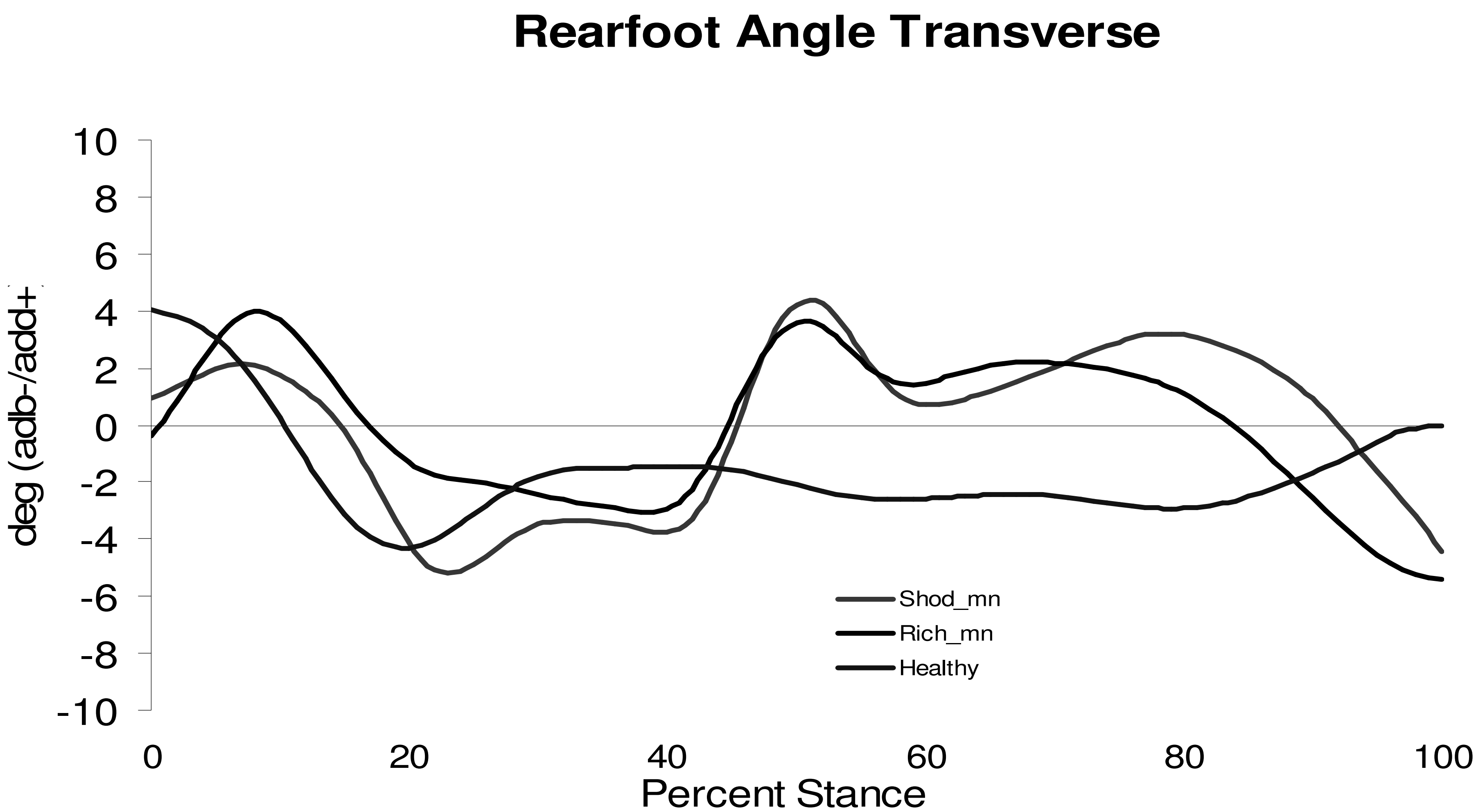


Rearfoot abduction angle reduced in initial 50% of stance.



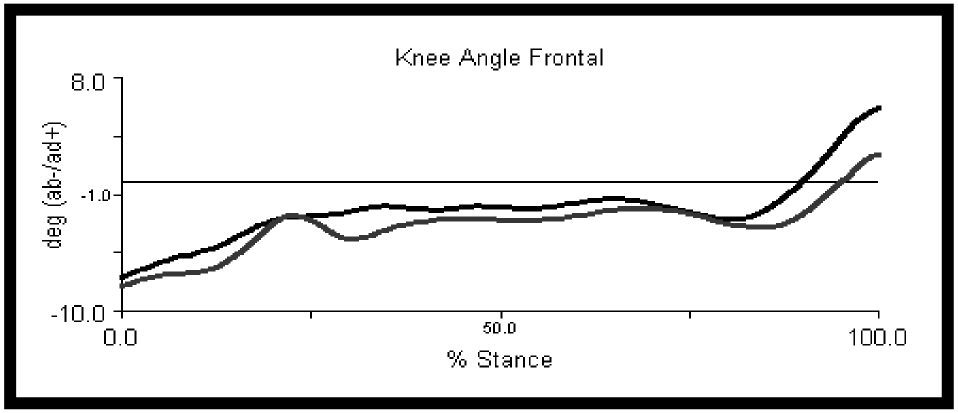
Calcaneal TP motion unchanged.

Tibial internal rotation reduced.

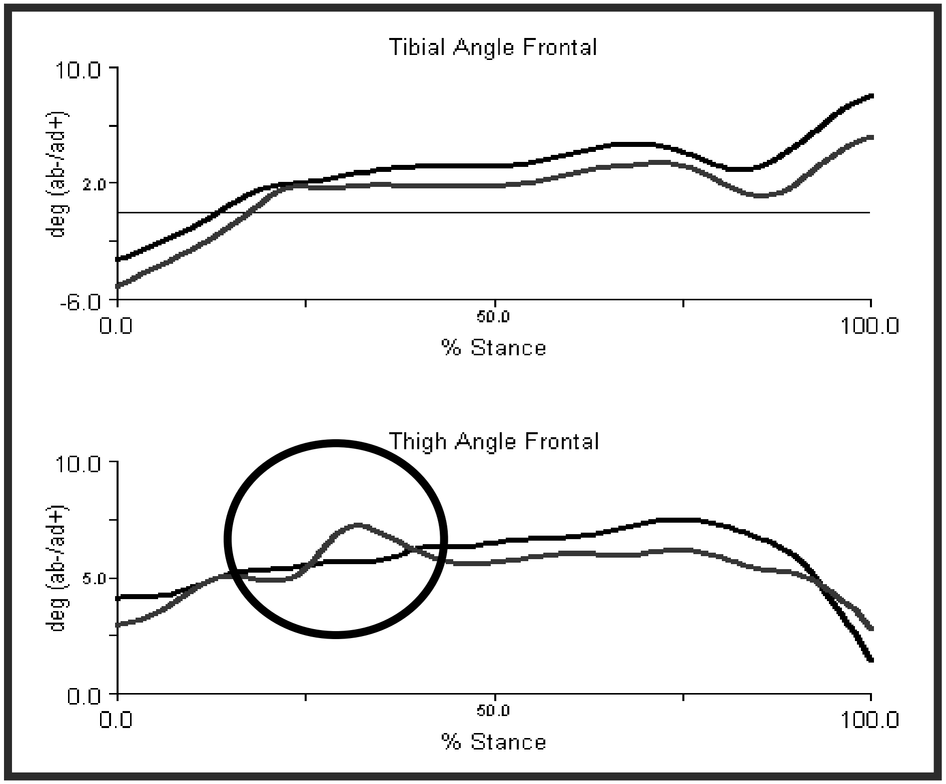

Rearfoot Angle Transverse
10
8
6
4
2
0
-2
-4
-6
-8
-10
deg (adb-/add+
0
20
40
60
80
100
Percent Stance
Shod_mn
Rich_mn
Healthy

Knee Analysis

Knee Angle Frontal



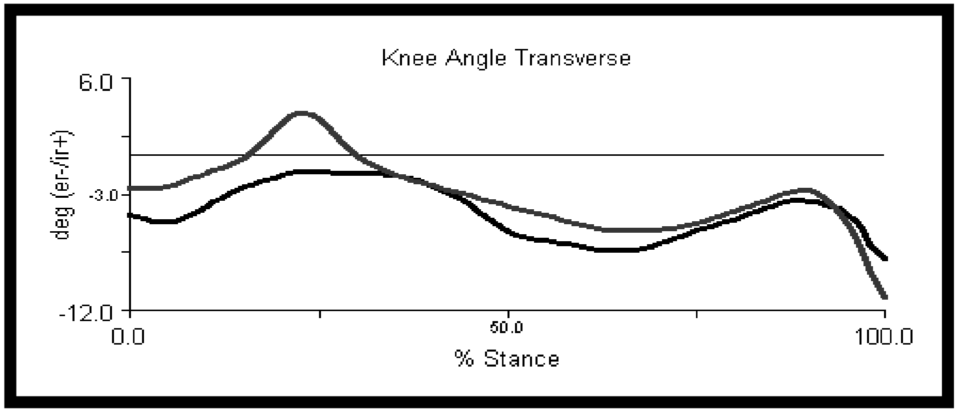
Knee abduction (valgus) angle reduced slightly (1-2°) throughout.



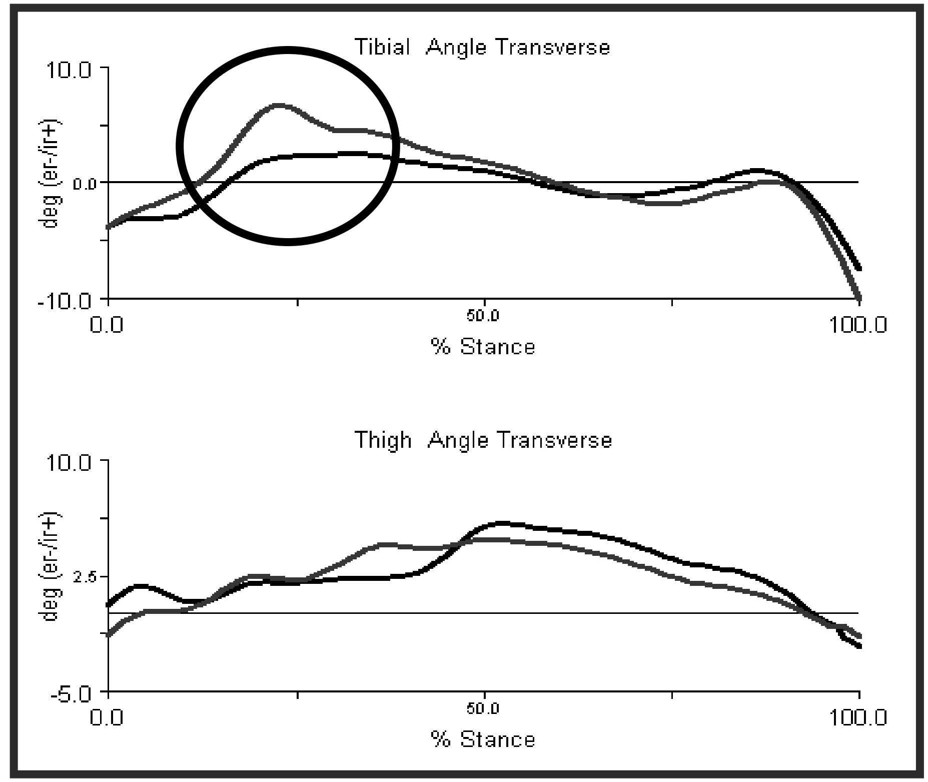
Tibial adduction increased.

Thigh adduction increased slightly (more fluid motion).

Knee Angle Transverse



Knee IR angle reduced during loading response.

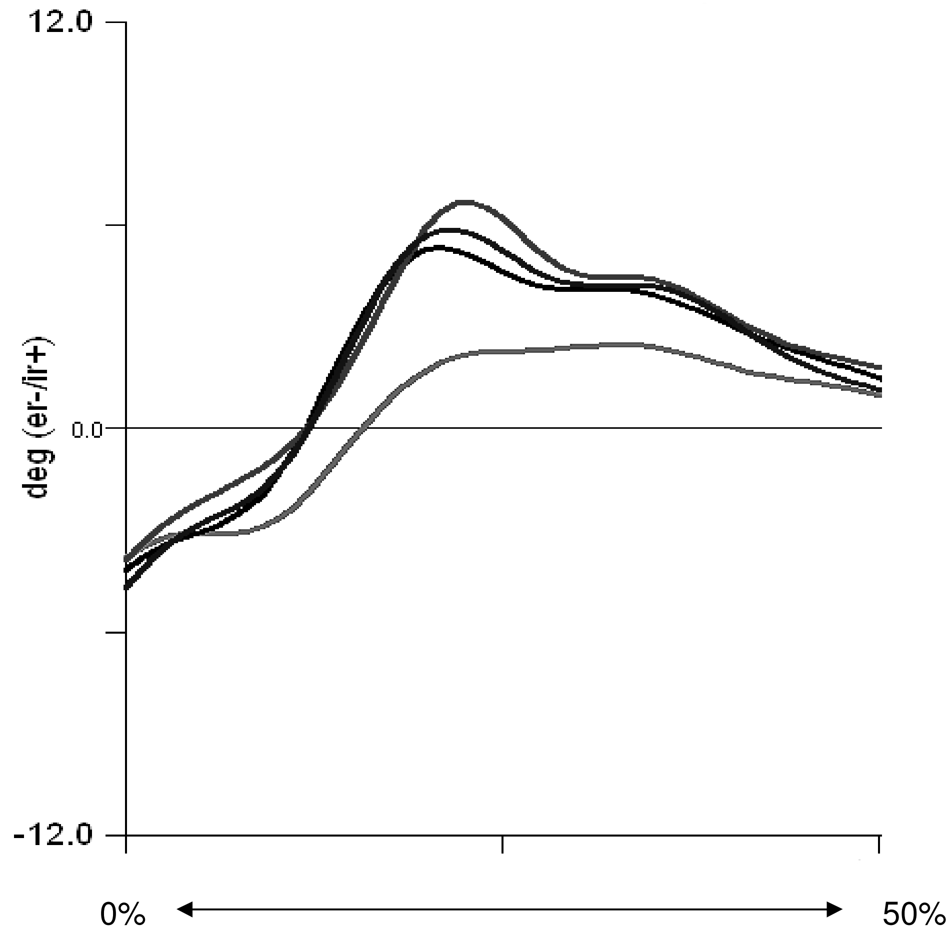


Tibial internal rotation (IR) reduced.

Thigh internal rotation unchanged.

Tibial Angle Transverse

------	SHOD
-----	ROOT
-----	PTTD
-----	RICH



Impulse

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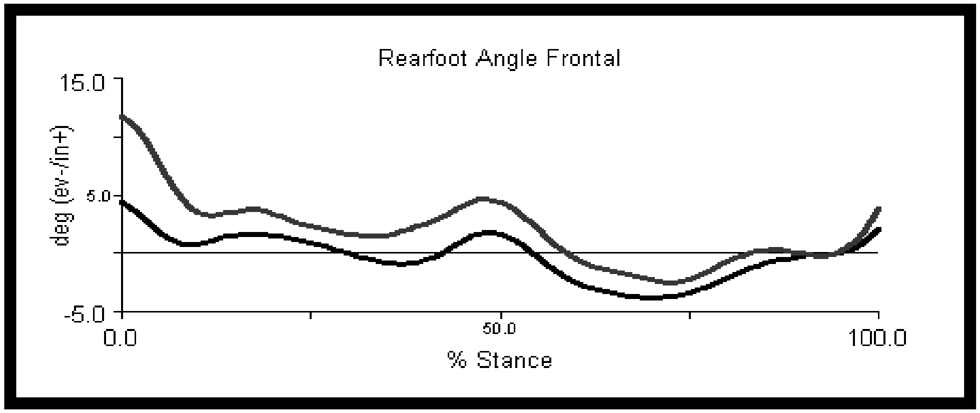
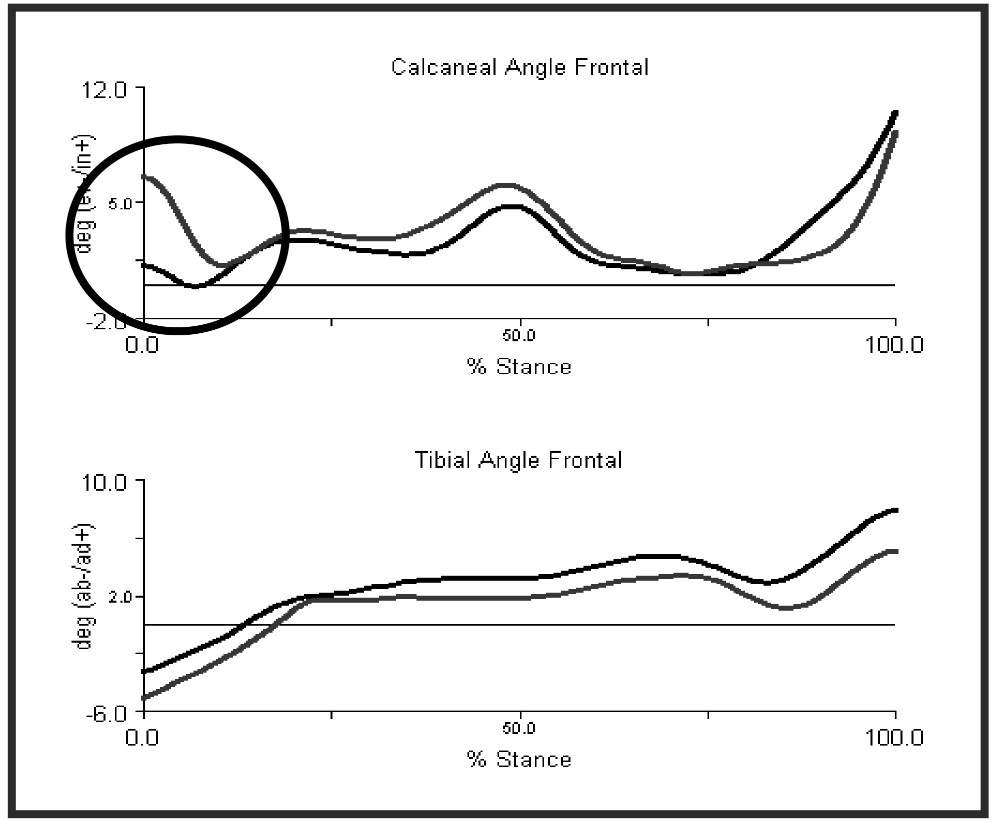
- Typically, a reduction in the resultant joint moment and rotational joint impulse is associated with a reduction in joint loading (Nigg et al, 2004).

Rearfoot Angle Frontal



Rearfoot eversion excursion/ROM reduced, and

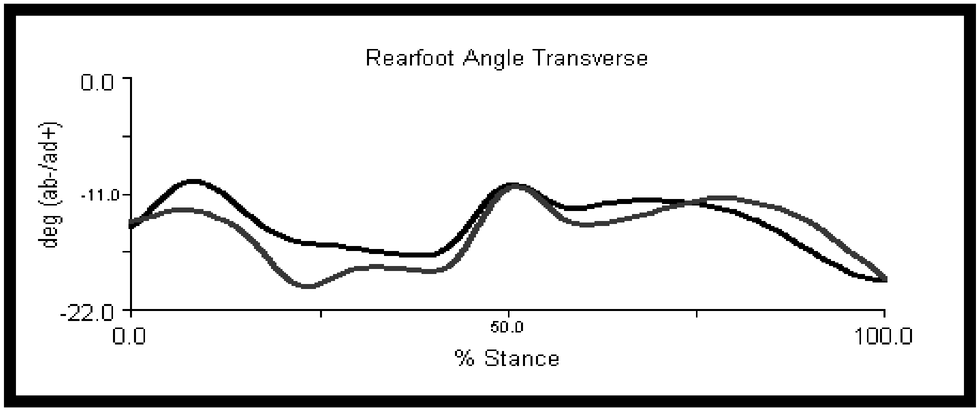
Rearfoot eversion increased throughout stance.



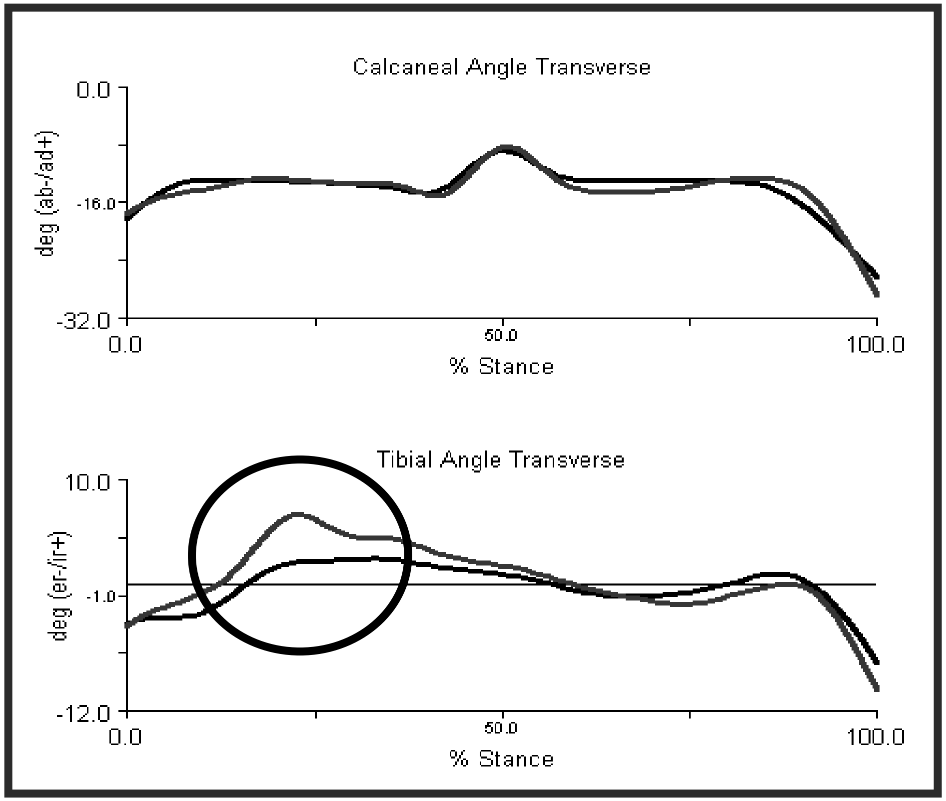
Calcaneal eversion velocity reduced.

Tibial adduction increased.

Rearfoot Angle Transverse

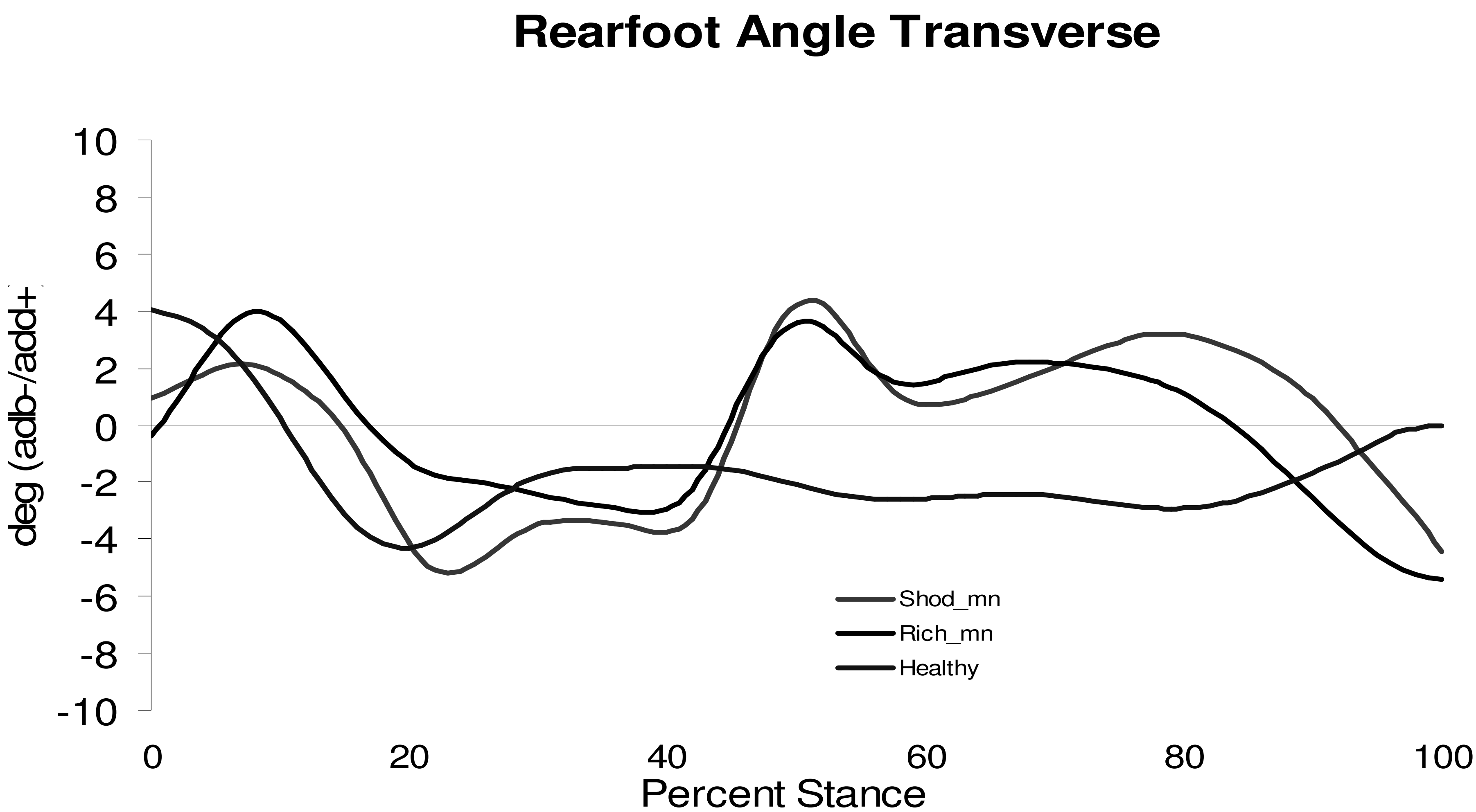


Rearfoot abduction angle reduced in initial 50% of stance.



Calcaneal TP motion unchanged.

Tibial internal rotation reduced.


Rearfoot Angle Transverse
10
8
6
4
2
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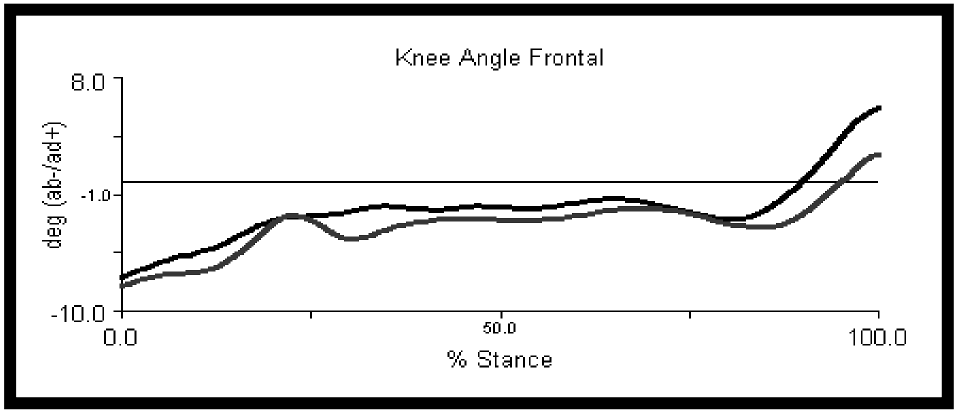
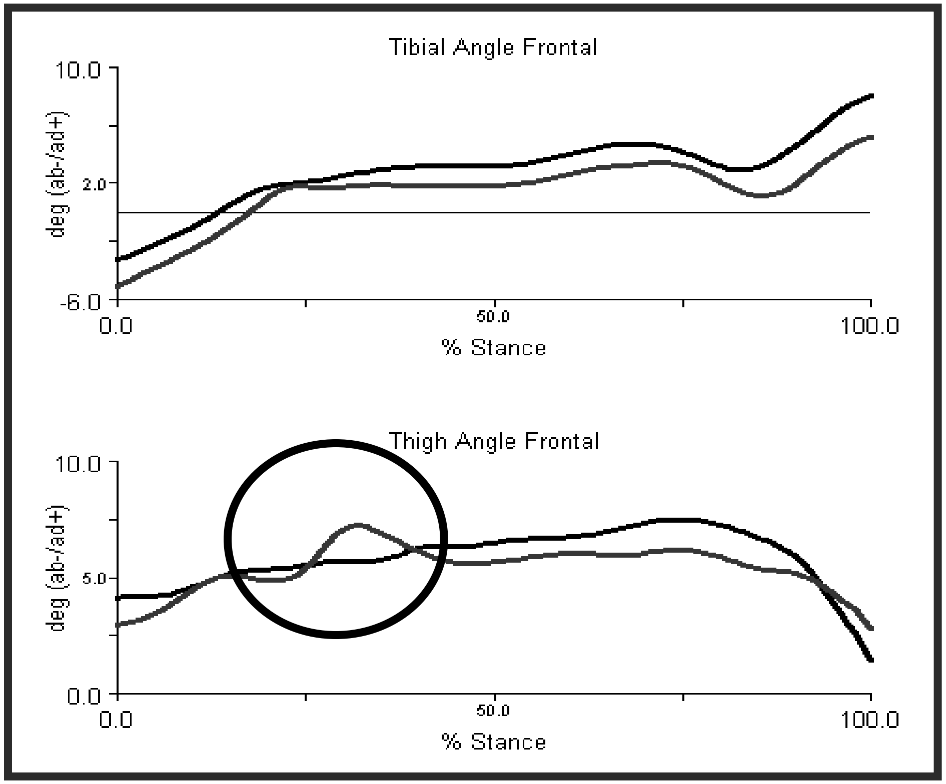
-2
-4
-6
-8
-10
deg (adb-/add+
0
20
40
60
80
100
Percent Stance
Shod_mn
Rich_mn
Healthy

Knee Analysis

Knee Angle Frontal



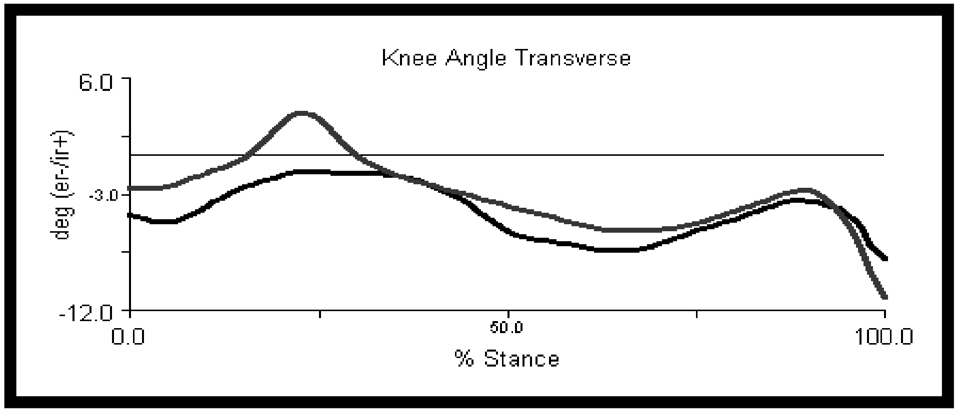
Knee abduction (valgus) angle reduced slightly (1-2°) throughout.



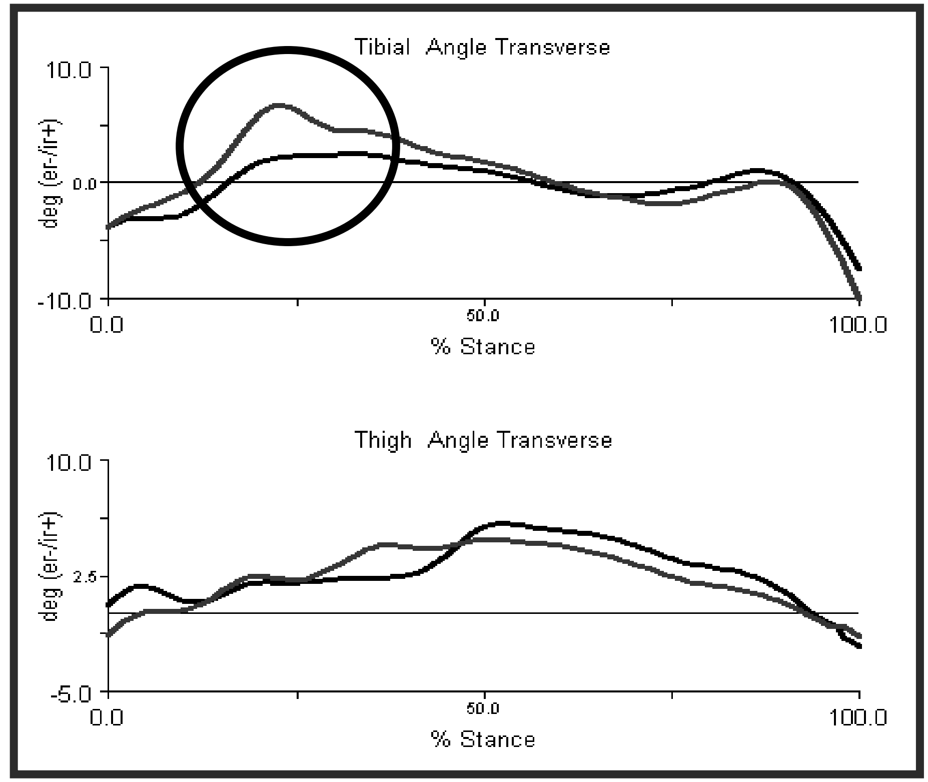
Tibial adduction increased.

Thigh adduction increased slightly (more fluid motion).

Knee Angle Transverse



Knee IR angle reduced during loading response.

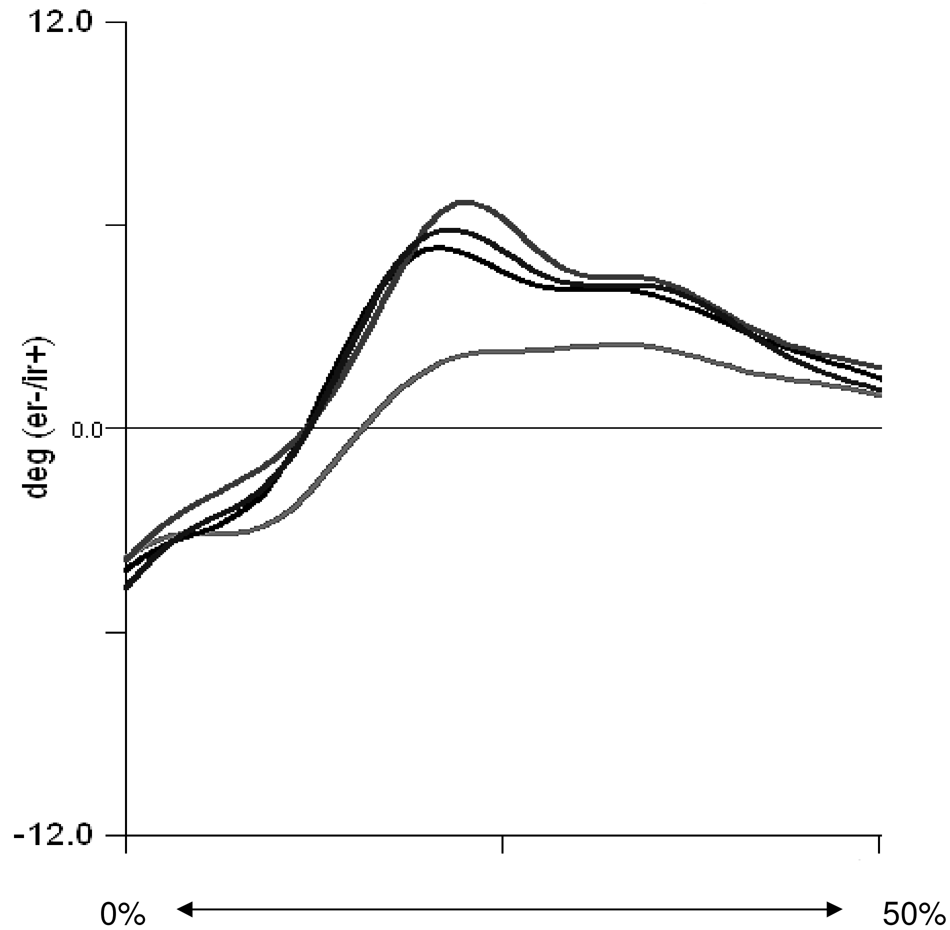


Tibial internal rotation (IR) reduced.

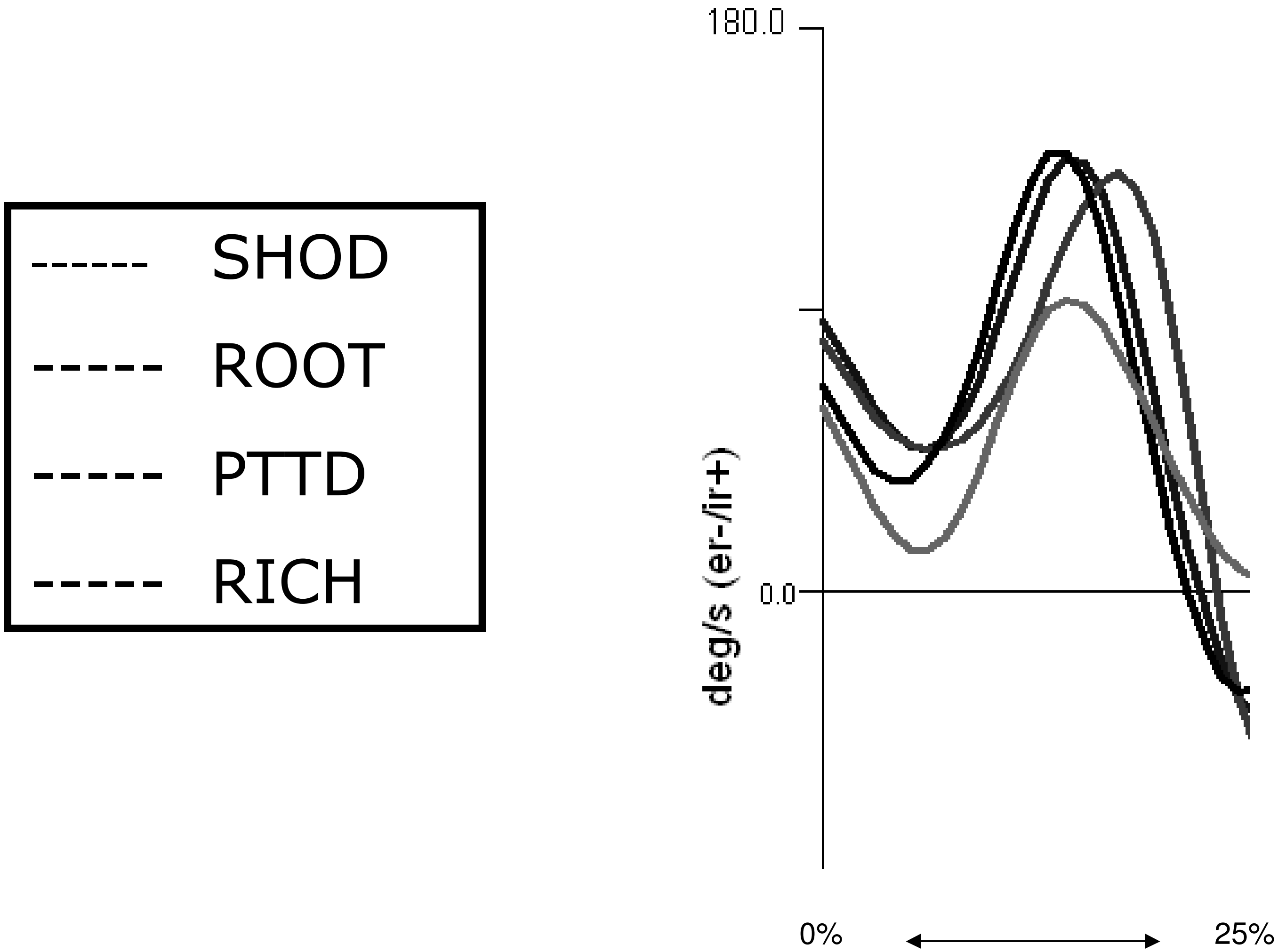
Thigh internal rotation unchanged.

Tibial Angle Transverse

------ SHOD
----- ROOT
----- PTTD
----- RICH



Tibial Velocity Transverse



Take Home Message

- In the case subject:

1. At the ankle, the subject exhibited:
   - ↓s in rearfoot eversion (pronation) velocity, excursion, moment and impulse.
   - Small ↑s in rearfoot eversion angle throughout stance.

Take Home Message

- In the case subject (cont'd):

2. At the knee, the subject exhibited:
    - ↓s in knee internal rotation,
    - ↓s tibial internal rotation angle and velocity, and
    - ↓s in knee abduction (valgus) of 1-2° which may be clinically significant.

Take Home Message

- In the case subject (cont'd):

  3. Sagittal plane dynamics were not influenced in this subject:
     - Terminal phase ankle plantar flexion unchanged, and
     - Terminal phase rearfoot adduction unchanged (Rattanaprasert et al., 1999).

Take Home Message

- More research required:

4. To investigate dynamics between RF and FF (information on TS is lacking):
   - Frontal plane: Is FF inversion increased?
   - Sagittal plane: Is FF plantar flexion increased?
   - Transverse: Is FF adduction increased?
   - Problem: Difficult to measure in-shoe…

Adult Acquired Flatfoot Etiology and Clinical Evaluation

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DEMOGRAPHICS

	Female	Male	Avg. Age
Holmes & Mann, 1992	51	16	57
Chao, 1996	37	12	66
Pomeroy, 1996	13	4	46
Kitaoka, 1997	18	3	60
Weil, 1999	11	2	61
Lombardi, 1999	12	2	48

Historical Overview

Early Reports

Key, 1953
Anzel, 1959
Kettelkamp, 1969

Tibialis Posterior Tendon Rupture

Mann & Specht, 1982
Jahss, 1982
Johnson, 1983
Fredenburgh, 1983

Adult Acquired Flatfoot

Q: What is the most powerful dynamic support of the arch of the foot?

A: The plantar fascia – via the windlass mechanism

Adult Acquired Flatfoot

Q: If the PT tendon is less significant, why would its loss lead to devastating collapse of the arch?

A: The loss of protection of the spring ligament complex leads to a cascade of ligamentous failure in the hindfoot and ankle.

Adult Acquired Flatfoot
Definition

A symptomatic, progressive flatfoot deformity resulting from loss of function of the tibialis posterior muscle/tendon and/or the loss of integrity of the ligamentous structures supporting the joints of the arch and hindfoot.

ELSEVIER
SAUNDERS

Clin Podiatr Med Surg
24 (2007) 617–644

CLINICS IN
PODIATRIC
MEDICINE AND
SURGERY

Biomechanics and Clinical Analysis of the Adult Acquired Flatfoot

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Adult-acquired flatfoot (AAF) is defined as a symptomatic, progressive deformity of the foot caused by a loss of dynamic and static supportive structures of medial longitudinal arch [1]. The name of this condition and its definition are the result of an accumulation of understanding of a pathology once thought to be merely an inflammation of the posterior tibial tendon.

AAF rarely was reported in the medical literature until the early 1980's. In 1983, Johnson [2] pointed out that symptomatic acquired flatfoot in adults caused by a rupture of the posterior tibial tendon was "not commonly recognized despite numerous reports describing the problem." Scrutiny of these reports published before 1982 underscore the early misconceptions and the evolution of understanding about the patho–etiology of adult acquired flatfoot deformity.

In their current concepts review of adult flatfoot caused by dysfunction of the posterior tibial tendon, Pomeroy and colleagues [3] trace the first reports in the literature to papers by Kulowski [4], Fowler [5], and Williams [6]. all of these were reports of patients with either tenosynovitis or tenovaginitis of the posterior tibial tendon. This represents an interpretation that papers reporting inflammation of the posterior tibial tendon were actually early reports of AAF deformity. Yet, none of these papers described a progressive planovalgus deformity associated with posterior tibial tendonitis.

The first paper documenting partial rupture of the posterior tibial tendon was published by Key in 1953 [7]. Again, progressive flatfoot deformity was not mentioned. In 1959, the incidence of posterior tibial tendon rupture treated at the Mayo Clinic was reported for the time period 1945 to 1954

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Adult Acquired Flatfoot

Pathomechamics

Loss of the dynamic and static supportive structures of the arch hindfoot and ankle

Adult Acquired Flatfoot

Dynamic supporting structures of the arch

PLANTAR APONEUROSIS

POSTERIOR TIBIAL TENDON

PLANTAR INTRINSIC MUSCULATURE

Static supportive structures of the arch

SPRING LIGAMENT COMPLEX

SUPERFICIAL DELTOID LIGAMENT

LONG AND SHORT PLANTAR LIGAMENTS

PLANTAR APONEUROSIS

Bracing the Adult Acquired Flatfoot

RECENT INSIGHTS

Not solely due to TPD

Adult Acquired Flatfoot

Isolated loss of the PT tendon without ligementous disruption will not lead to a progressive flatfoot deformity.

The adult acquired flatfoot deformity cannot be reproduced experimentally by releasing the tibialis posterior tendon alone.

Deland, J.T., Arnoczky, S.P., Thompson, F.M. Adult acquired flatfoot deformity at the talonavicular joint: Reconstruction of the spring ligament in an in vitro model. Foot and Ankle 13: 327, 1992

Ligament Attenuation in Flatfoot

Spring Ligament Complex

Plantar Aponeurosis

Deltoid

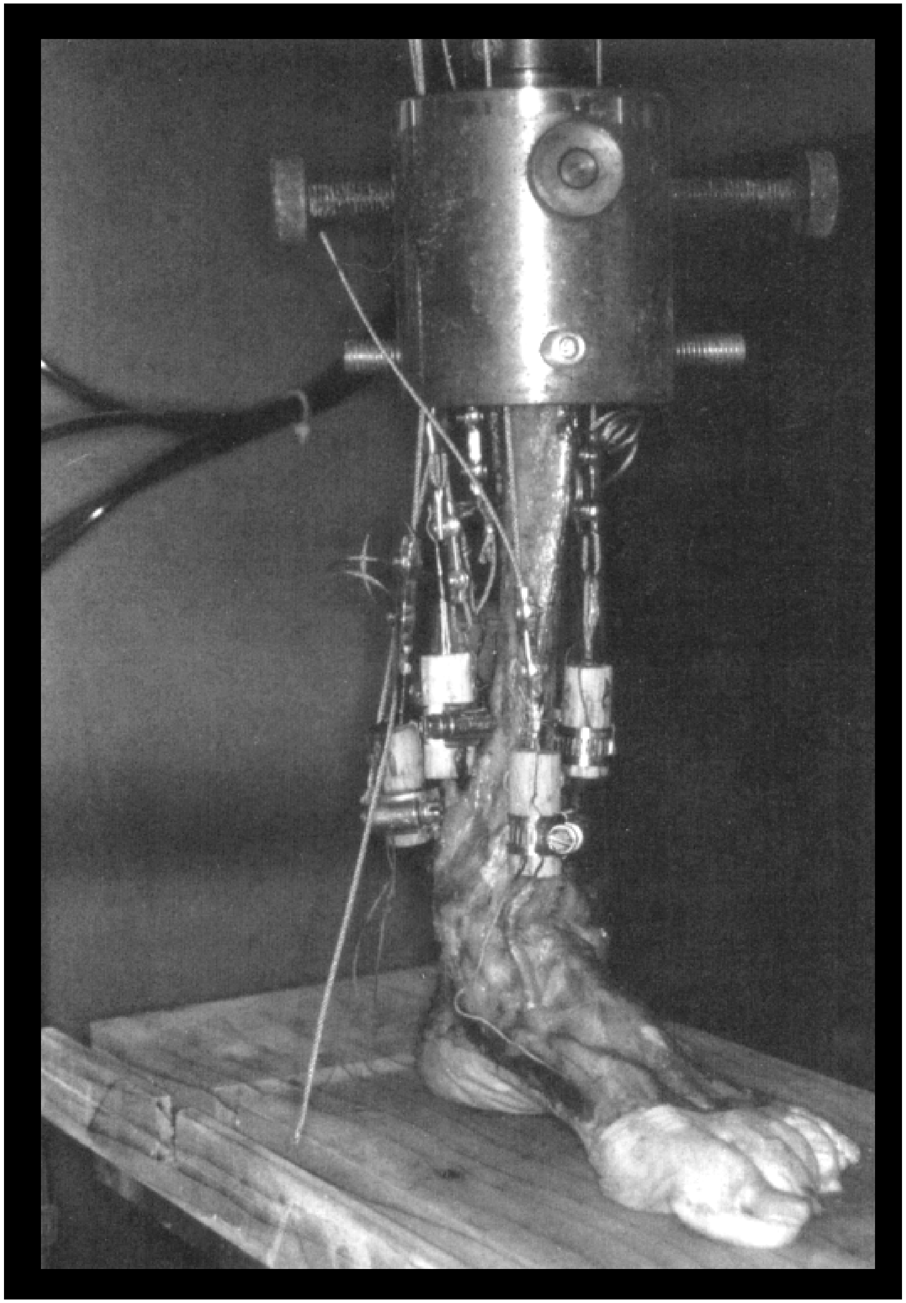
Talo-Calcaneal

Long & Short Plantar

Medial Calcaneo-Cuboid

Deland, 1992

Chu IN, Myerson MS, Nyska M, Parks BG: Experimental Flatfoot Model: The Contribution of Dynamic Loading. Foot Ankle Int. 22:220, 2001.



"In conclusion, we have shown that, to create flattening of the plantar arch, there is a need to cut the medial structures, including the spring and plantar ligaments and possibly the plantar fascia."

Chu IN, Myerson MS, Nyska M, Parks BG: Experimental Flatfoot Model: The Contribution of Dynamic Loading. Foot Ankle Int. 22:220, 2001.

Tendon vs Ligament

- Eight Lower Leg Specimens
- All tendons vs all minus PTT
- Create AAF: cutting spring lig.
- Restore PTT to AAF model

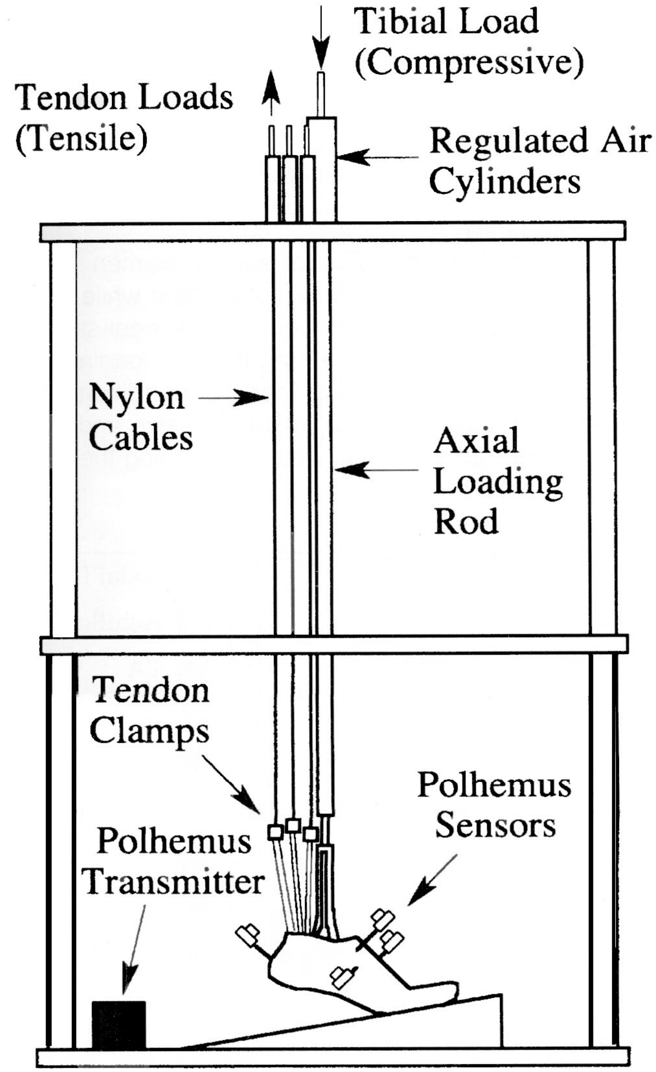
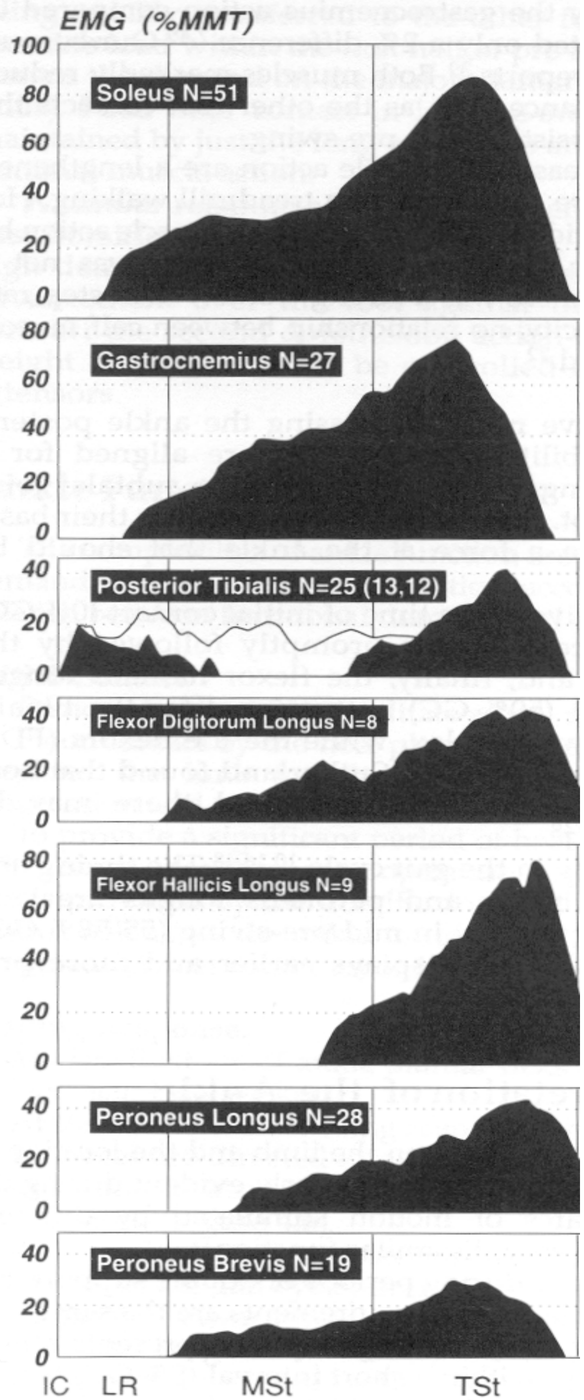


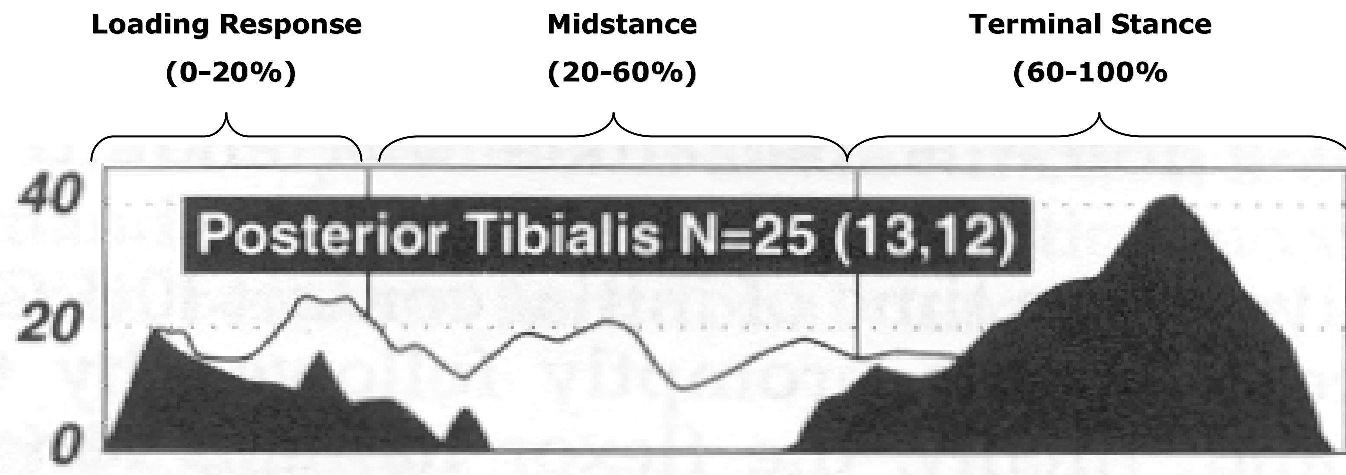
Fig. 1. Schematic diagram of custom acrylic foot-loading frame with foot shown loaded in the simulated heel rise condition.

Niki: H.N., Ching R.P., Kiser P., Sangeorzan B.J. "The Effect of Posterior Tibial Tendon Dysfunction on Hindfoot Kinematics." Foot and Ankle 22:292-300, 2001

- **Intact osteo-ligamentous structures can maintain alignment after initial loss of PTT**
- **With creation of a flatfoot (cut lig.) restoring PTT function could not significantly improve alignment**
- **PTT had greatest influence on hindfoot kinematics during heel rise**
- **“Bracing should provide support during heel rise.”**

Niki: H.N., Ching R.P., Kiser P., Sangeorzan B.J. “The Effect of Posterior Tibial Tendon Dysfunction on Hindfoot Kinematics.” Foot and Ankle 22:292-300, 2001


EMG (%MMT)
Soleus N=51
Gastrocnemius N=27
Posterior Tibialis N=25 (13,12)
Flexor Digitorum Longus N=8
Flexor Hallicis Longus N=9
Peroneus Longus N=28
Peroneus Brevis N=19
IC LR MSt TSt


Loading Response
(0-20%)
Midstance
(20-60%)
Terminal Stance
(60-100%
Posterior Tibialis N=25 (13,12)

Perry, 1992

What part of gait cycle is PT and ligament function most critical?

"In this study, strain in the deltoid ligament was shown to increase significantly during the heel rise portion of the joint cycle after a properly positioned triple arthrodesis was performed. This finding is supported by the fact that the posterior tibial tendon has been shown to be most active during early heel rise."

Song SJ, Lee S, O'Malley MJ et al: Deltoid ligament strain after correction of acquired flatfoot deformity by triple arthrodesis. Foot Ankle Int 21: 573-577 2000

- 17 Patients – TP tendon transfer
- 5 Year follow up
- 47% Had Grade 4-5 eversion
- No clinical flatfoot
- 6% Forefoot abduction
- 82% Single-heel rise

Yeap, JS, Singh D, Birch R: Tibialis Posterior Tendon Dysfunction: A Primary or Secondary Problem? Foot Ankle Int 22:51, 2001.

“The development of a flatfoot in tibialis posterior tendon dysfunction is therefore unlikely to be the result of lack of “sling” support on the medial longitudinal arch from the tibialis posterior tendon only.”

“Our hypothesis suggests that the treatment of Stage II tibialis posterior tendon dysfunction should be aimed primarily at correcting the biomechanics of the foot and not at tendon transfer….”

Yeap, JS, Singh D, Birch R: Tibialis Posterior Tendon Dysfunction: A Primary or Secondary Problem? Foot Ankle Int 22:51, 2001.

Bracing the Adult Acquired Flatfoot

RECENT INSIGHTS

- **Not solely due to TPD**
- **Pre-existing flatfoot**

Causative Factors

Congenital Pes Planus and TPD:	Incidence
Mann and Thompson (1985)	30%
Jahss (1991)	100%
Dyal et al (1997)	98%

Stages of TPD

from Johnson & Strom, Modified by Myerson et al.

STAGE	PATHOLOGY	CLINICAL SIGNS	REARFOOT
I.	Tenosynovitis	Swelling, Tenderness	Flexible
II.	Attenuation or Rupture	Archcollapse, FF abduction, too many toes can or cannot heelrise	Flexible
III.	Complete Rupture	Lateral foot pain increased heel valgus cannot heel rise	Rigid
IV.	Valgus talo crural jt.	DJD of Rearfoot Fibular Mall. Fx.	Rigid

Adult Acquired Flatfoot

- **Symptomatic vs. Asymptomatic Foot**

- **Radiographic Comparison?**

Dyal, CM, Feder J, Deland JT, Thompson FM: Pes planus in patients with posterior tibial tendon insufficiency: Asymptomatic vs. Symptomatic Foot (Dyal et al) : Foot and Ankle Int 18: 85-88, 1997

Radiographs of 43 pts. PTTD

	NORMAL	MILD DEFORMITY	MODERATE	SEVERE
Sx Feet:	12%	54%	30%	2%
Asx Feet:	7%	61%	23%	0%

"The inter observer measurements were found to be highly correlated to the P=0.0001 level in all cases. This indicates that the asymptomatic feet demonstrated values not so different from the symptomatic side."

Dyal, CM, Feder J, Deland JT, Thompson FM: Pes planus in patients with posterior tibial tendon insufficiency: Asymptomatic vs. Symptomatic Foot (Dyal et al) : Foot and Ankle Int 18: 85-88, 1997

Function of Tibialis Posterior

- **Plantarflexor of ankle ?**
- **Supinator of foot ?**
- **Restrain or "brake" internal leg rotation?**

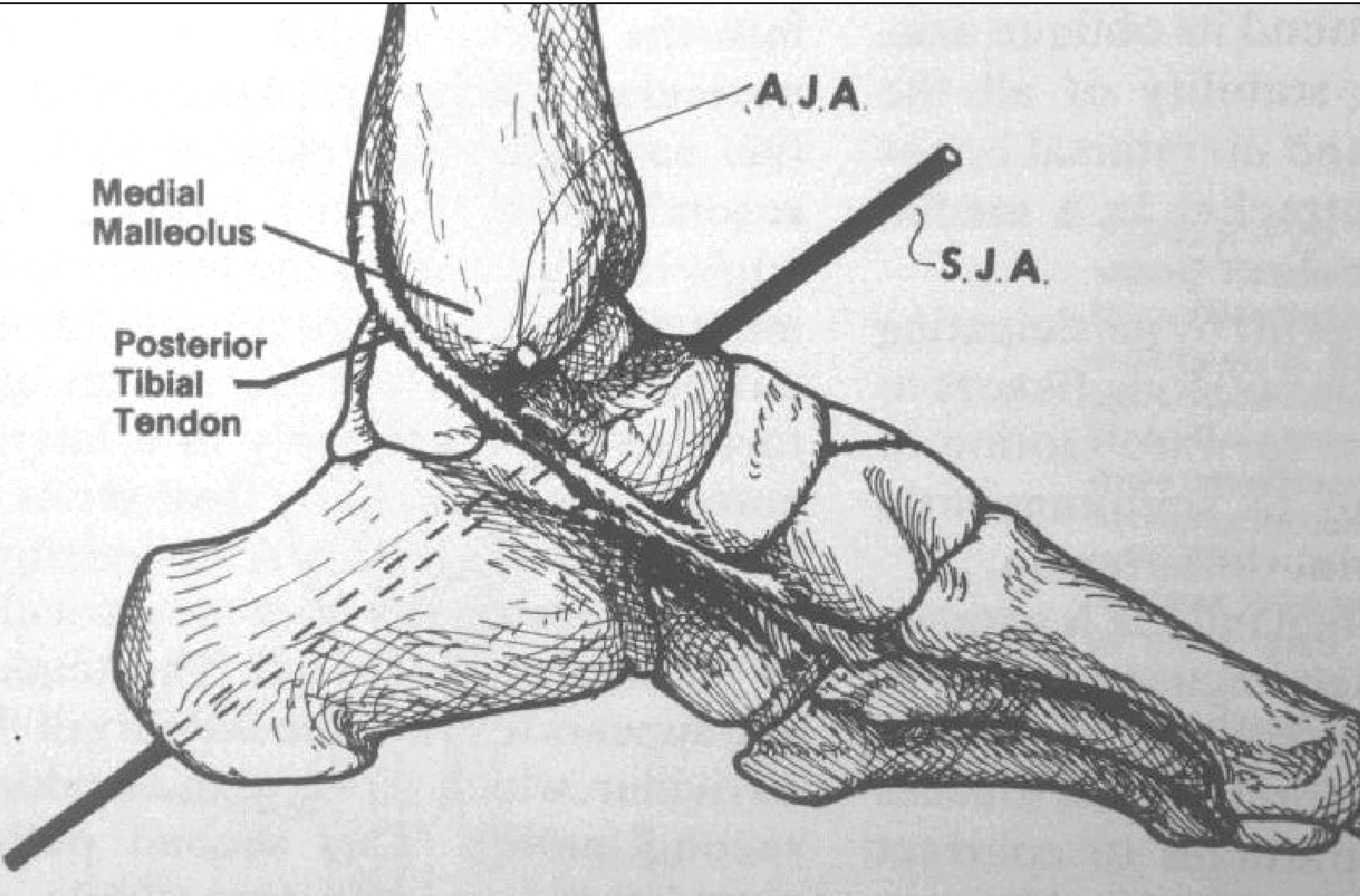


Fig. 8-22

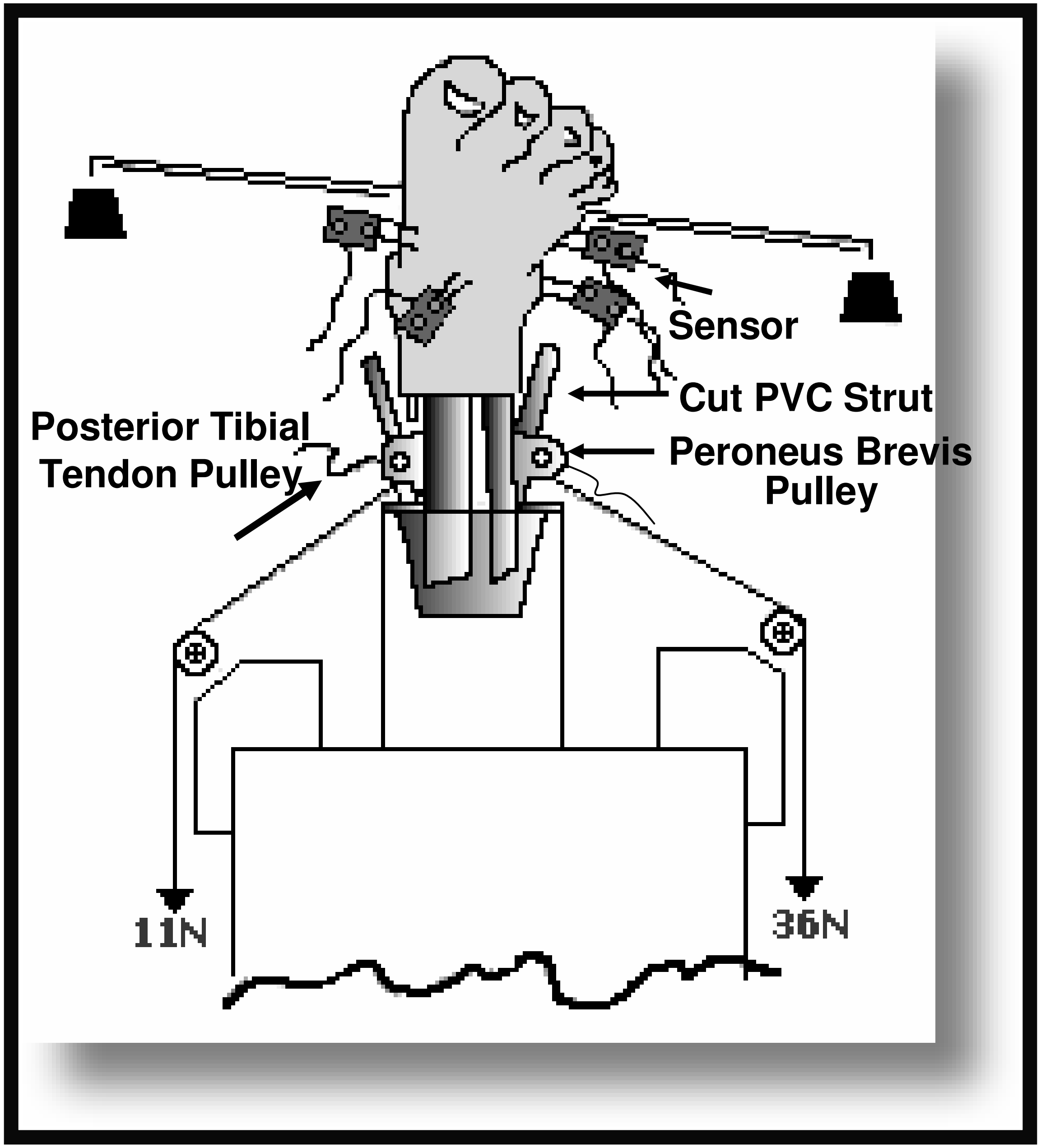


Illustration of the foot in the apparatus used to test the range of motion of the subtalar, talonavicular, and calcaneocuboid joints as well as excursion of the posterior tibial tendon

Hintermann & Nigg, 1994

Subtalar Supination

	Supination Moment Arm	Excursion (mm)
Tib. Post	1.0	20
FDL	.75	25
FHL	.62	29
TA	.59	38
Gastroc/Soleus	.24	44

Hintermann and Nigg, 1994

Ankle Flexion-Extension

	Moment Arm	Excursion
TA	High	High
FDL	High	High
TP	Low	Low

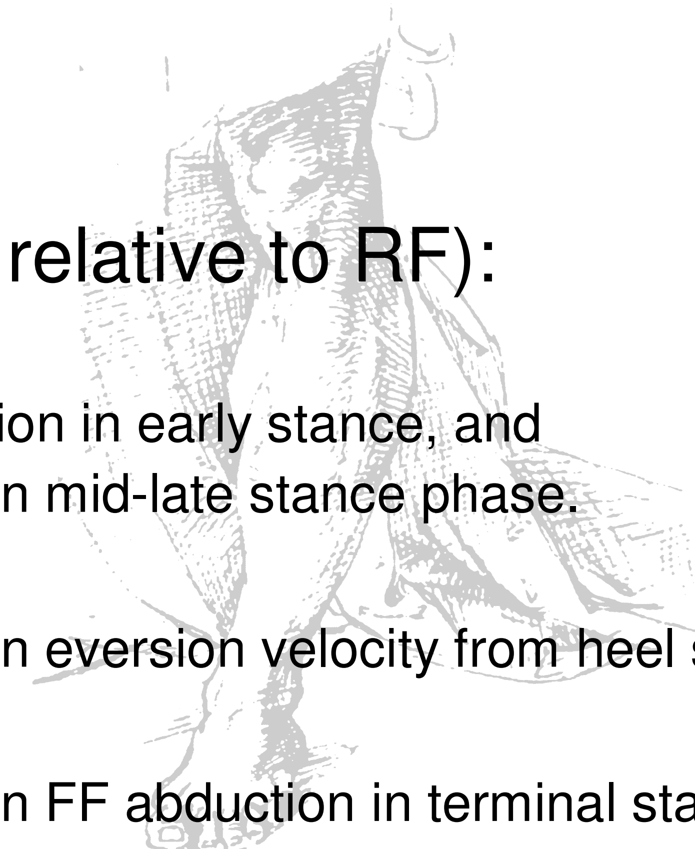
Hintermann, 1994

Ankle Plantarflexion Moment Arm

Posterior Tibial Tendon

Tendo Achilles

Healthy vs. PTD Walking Kinematics



- PTD:
  - Forefoot (FF relative to RF):
    - SP:
      - ↓ dorsiflexion in early stance, and
      - marked ↑ in mid-late stance phase.
    - FR:
      - marked ↑ in eversion velocity from heel strike to 20% stance.
    - TP:
      - marked ↑ in FF abduction in terminal stance.

Rattanaprasert et al., 1999

Single Foot Raise
In adult acquired flatfoot:

- **No restraint to MTJ**
- **Gastroc-Soleus plantarflexes rearfoot instead of met heads**
- **lack of leverage & pain inhibits heel lift**

FUNCTIONAL ANATOMY

Vascularity

Frey, JBJS 72A: 884, 1990

<u>TP Tendon</u>

- No mesotendon distally
- blood supply : PT & DP art.
- Hypovascular zone begins 40mm prox. to navicular, extends 14mm prox.

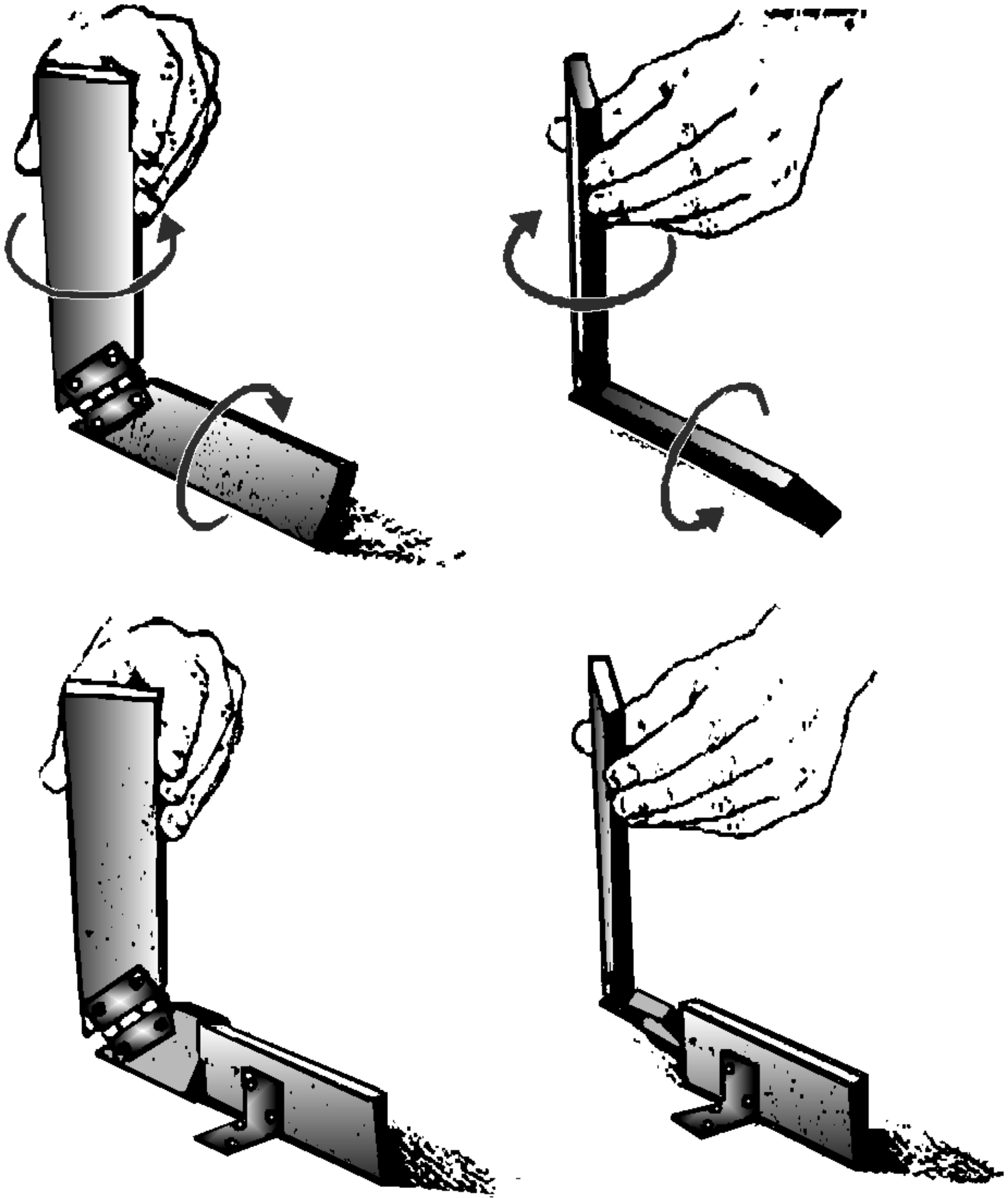
Tibialis Posterior Tendon

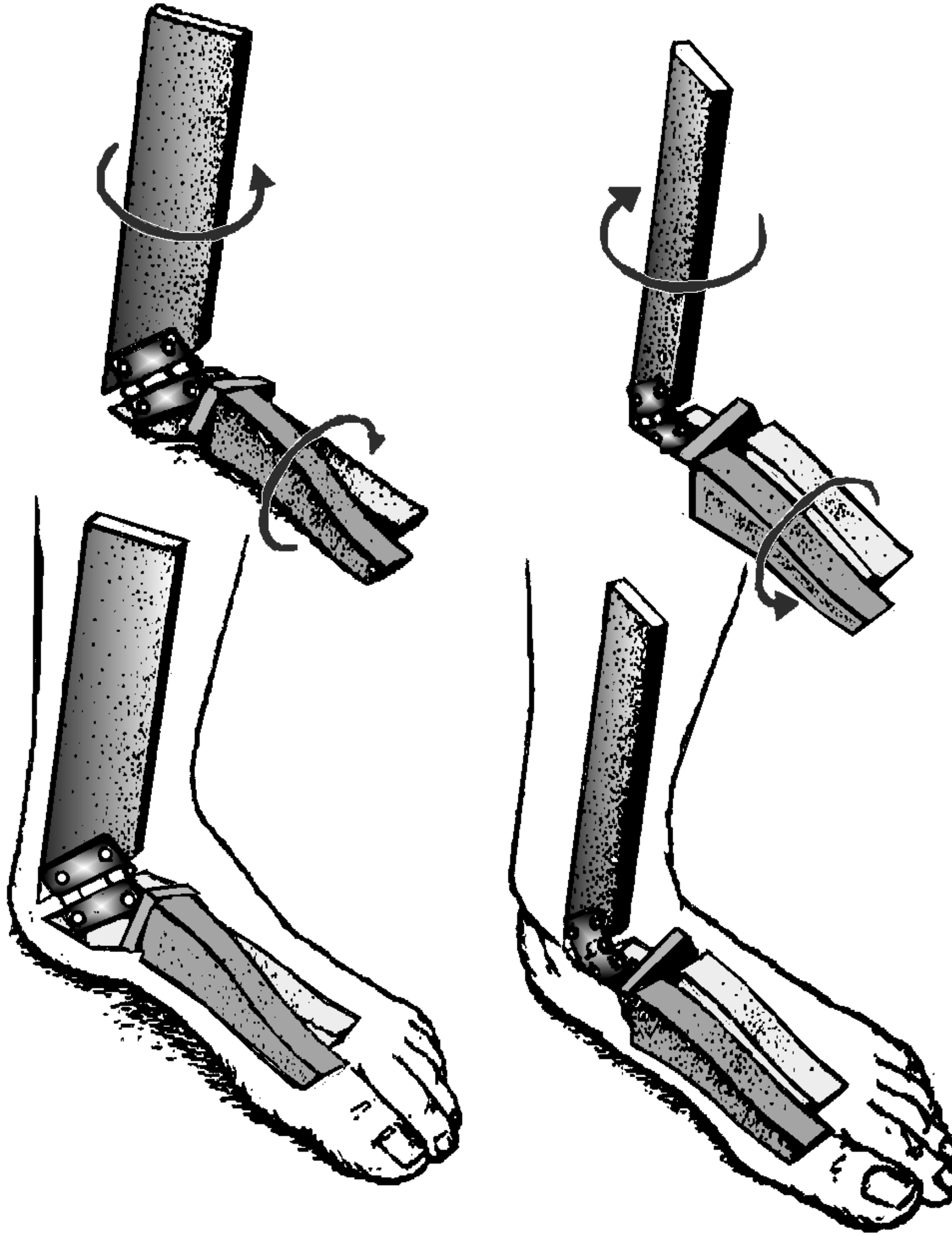
Insertions

Anterior -	**Navicular tuberosity** **N-C joint capsule** **1st cuneiform**
Middle -	**2nd cuneiform** **3rd cuneiform** **cuboid, PL tendon** **2nd, 3rd, 4th, 5th mets**
Posterior-	**Sustentaculum Tali**

“the present study, however, reveals that the tibialis posterior muscle in man has a multi pennate origin from the fibula, and that the fibular sided fibers of the muscle are very numerous but very short. On this account, the fibular-sided fibers of the muscle are more powerful than the tibial”

Morimoto, I. Notes on architecture of tibialis posterior muscle in man. Acta Anat Nippon 58:74-80, 1983





Two Lever Theory

“Between these two unequal levers (unequal in bulk, length and strength) lies the talus. When the foot is dorsiflexed at the ankle, the talus becomes firmly lodged in the tibiofibular socket and serves as part of the proximal lever or the leg”

Kelikian, 1985

Transverse Plane

Internal rotation of tibia =

Internal rotation of talus

Interventions

- Strengthening Exercises:
  – Foot adduction,
  – Heel raise, and
  – Foot supination.
- Custom Foot Orthotic Intervention:
  – Increased PT activation.

Kulig et al., 2004 & 2005

WHAT EXERCISE ISOLATES, AND ACTIVATES THE TIBIALIS POSTERIOR BEST?

- **Foot Adduction**
- **Foot Plantarflexion - Inversion**
- **Single foot heel rise**

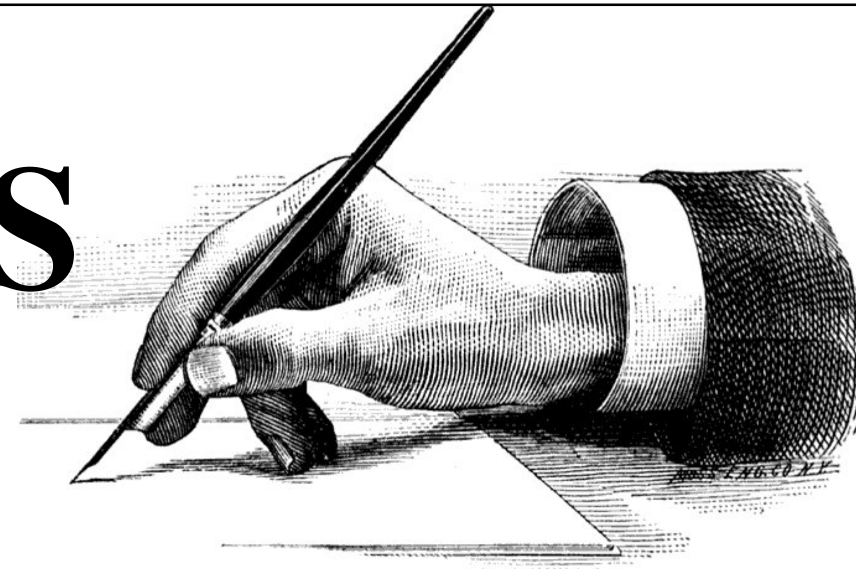
Kulug K et al: Selective activation of tibialis posterior: Evaluation by magnetic resonance imaging. Med Sci Sports Exer Vol 36, No.5, pp. 862-867, 2004

MRI: measures changes in muscle activation

- **Measures changes associated with cell metabolism and muscle fluid uptake**
- **Signal intensity changes with increased lactate, phosphate and sodium**
- **Verified by comparison EMG recordings**
- **T2 weighted images: increased water content=lighter image=increased muscle activity**
- **Signal intensity can be measured objectively with cursor and software**

Kulug K et al: Selective activation of tibialis posterior: Evaluation by magnetic resonance imaging. Med Sci Sports Exer Vol 36, No.5, pp. 862-867, 2004

RESULTS



TP	Increased SI	Increased SI (other muscles)
Adduction	50%	Less than 5%
Heel raise	27%	Soleus 35%, PL 57%, Gastroc 99%
Suppination	26%	Less than 10%

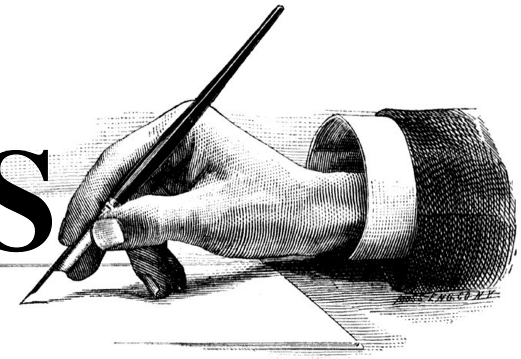
Kulug K et al: Selective activation of tibialis posterior: Evaluation by magnetic resonance imaging. Med Sci Sports Exer Vol 36, No.5, pp. 862-867, 2004

Do foot orthoses improve recruitment of the Tibialis Posterior?

- **6 ASx subjects with pes plano valgus**
- **Foot adduction exercises barefoot vs Superfeet pre-fab orthosis**
- **MRI after 3 sets of 30 exercises**

Kulig et al: Effect of foot orthoses on tibialis posterior activation in persons with pes planus. Med Sci Sports Exerc., Vol 37, No 1, pp. 24-29, 2005

RESULTS



"A comparison of the signal intensities recorded after each exercise condition identified that tibialis posterior activity was nearly twofold higher when exercising with an orthosis compared with barefoot (54 vs 29% Signal Intensity)"

"From the results of this study we suggest that people with pes planus wear a foot orthosis, even while performing the adduction exercises"

Kulig et al: Effect of foot orthoses on tibialis posterior activation in persons with pes planus. Med Sci Sports Exerc., Vol 37, No 1, pp. 24-29, 2005

Nonsurgical management of posterior tibial tendon dysfunction with orthoses and resistive exercise: a randomized controlled trial.

Kulig K, Reischl SF, Pomrantz AB, Burnfield JM, Mais-Requejo S, Thordarson DB, Smith RW

Kulig et al. *PHYS THER.*2009; 89: 26-37

BACKGROUND AND PURPOSE: Tibialis posterior tendinopathy can lead to debilitating dysfunction. This study examined the effectiveness of orthoses and resistance exercise in the early management of tibialis posterior tendinopathy. SUBJECTS: Thirty-six adults with stage I or II tibialis posterior tendinopathy participated in this study. METHODS: Participants were randomly assigned to 1 of 3 groups to complete a 12-week program of: (1) orthoses wear and stretching (O group); (2) orthoses wear, stretching, and concentric progressive resistive exercise (OC group); or (3) orthoses wear, stretching, and eccentric progressive resistive exercise (OE group). Pre-intervention and post-intervention data (Foot Functional Index, distance traveled in the 5-Minute Walk Test, and pain immediately after the 5-Minute Walk Test) were collected. RESULTS: Foot Functional Index scores (total, pain, and disability) decreased in all groups after the intervention. The OE group demonstrated the most improvement in each subcategory, and the O group demonstrated the least improvement. Pain immediately after the 5-Minute Walk Test was significantly reduced across all groups after the intervention. DISCUSSION AND CONCLUSION: People with early stages of tibialis posterior tendinopathy benefited from a program of orthoses wear and stretching. Eccentric and concentric progressive resistive exercises further reduced pain and improved perceptions of function.

Adult Acquired Flatfoot

Stage II Disease: Critical Changes

- Progressive ligament rupture

- Loss of movement transfer

Spring Ligament Complex

- **38 fresh frozen cadaver dissections**
- **Details of ligament components**
- **Relationship to TP tendon**
- **Relationship to T-N joint**
- **Histology, microvascularity, biomechanics**

Davis WH, Sobel M, DiCarlo EF, Torzill: PA: Gross, Histological and microvascular anatomy and biomechanical testing of the spring ligament complex. Foot and Ankle 17: 95, 1996

Components Spring Ligament Complex

1. Superomedial calcaneonavicular ligament (SMCN)

Origin: sup. med. sust. tali and

Includes: tri art facet ant edge of ant facet of calc.

Insertion: Sup, med & inferior art. Surface of navicular

Funct: medial & plantar art. sling for talar head (load bearing

Components Spring Ligament Complex

<u>3. Posterior tibial tendon</u>

2 attachments to SMCN ligament:

Superior

Inferior

Function:

prevent medial/plantar talar head migration

Components Spring Ligament Complex

4. Superficial deltoid ligament

Components: **Ant. tibiotalar, tibionavicular, tibiocalcaneal**

Insert: **entire length SMCN lig.**

Funct: **form concavity around head of talus**

Function of Spring Ligament Complex

(Davis, et al, 1996)

1. Create a talar acetabulum
2. Restrain multi-planar talar motion
3. No elastin - no “spring”
4. Functions as “articular sling”
5. Cannot hold up arch alone

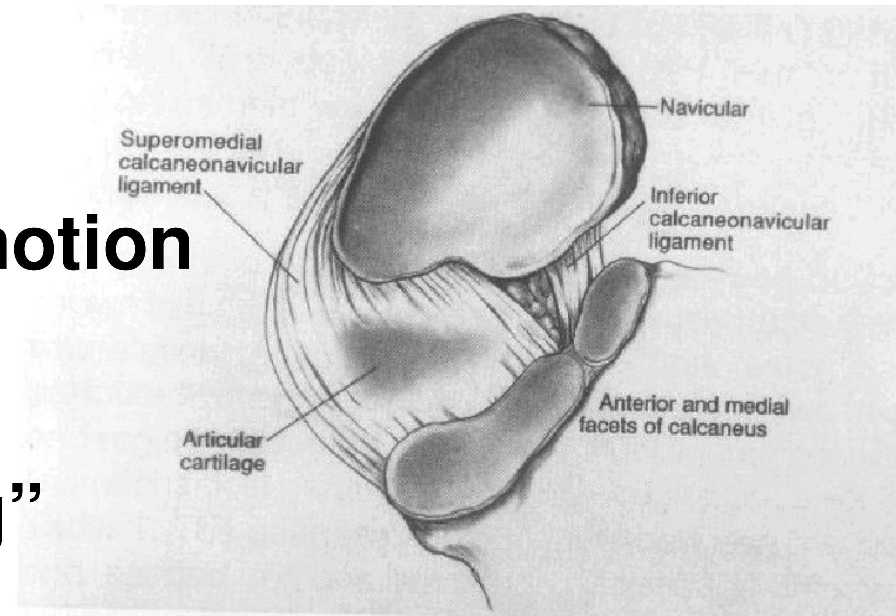


Fig. 4. Artist’s rendition of the SMCN ligament and ICN ligament with the bony components (right foot with talus removed).

Spring Ligament Tears

Classification

1. **Longitudinal Tear or partial tear: located at midsubstance, origin or insertion**
2. **Tear with stretch (lax)**
3. **Complete rupture**

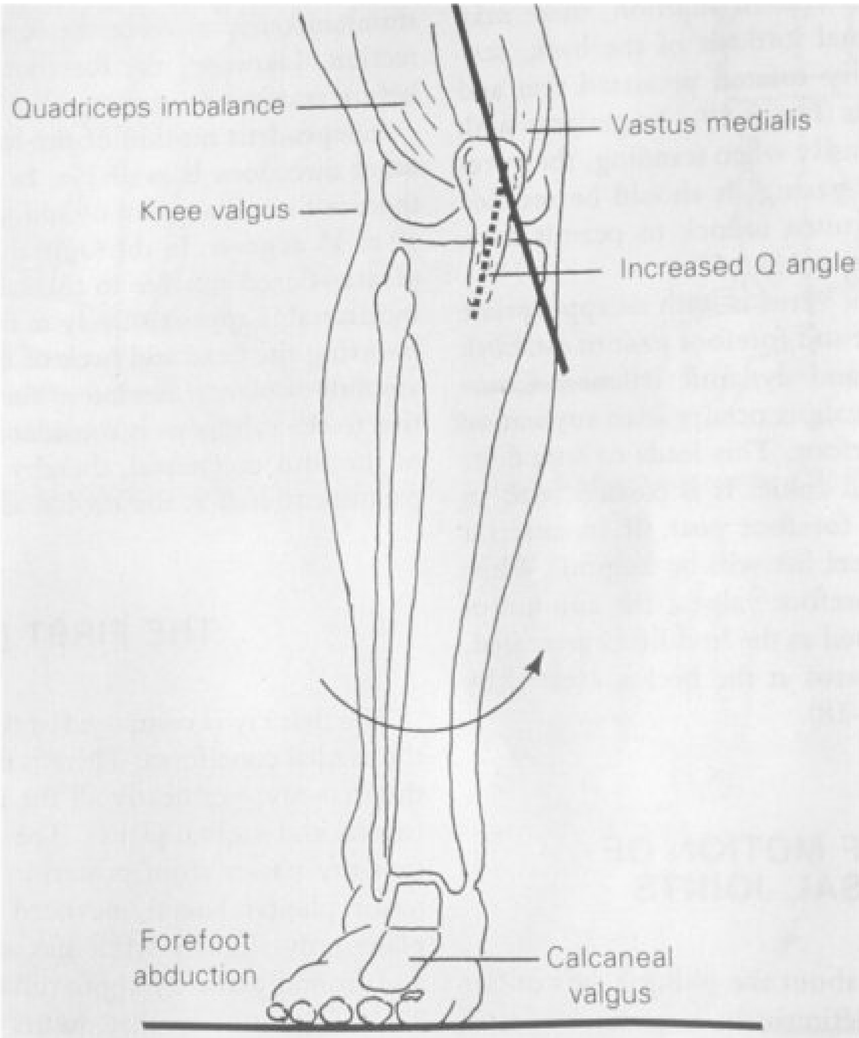
Gazdaj A. Cracchiolo A: Posterior tibial tendon rupture: Evaluation of spring ligament pathology and clinical assessment of tendon transfer and ligament repair. JBJS, 1997

Bracing the Adult Acquired Flatfoot

RECENT INSIGHTS

- Not solely due to TPD
- Pre-existing flatfoot
- Tibia is dominant lever
- Pivotal joint is Talo-Navicular
- Ligament Disruption = Movement Transfer Disruption

Movement Coupling



Between two body segments a motion occurring about one axis of rotation relative to a simultaneous rotation about a second axis.

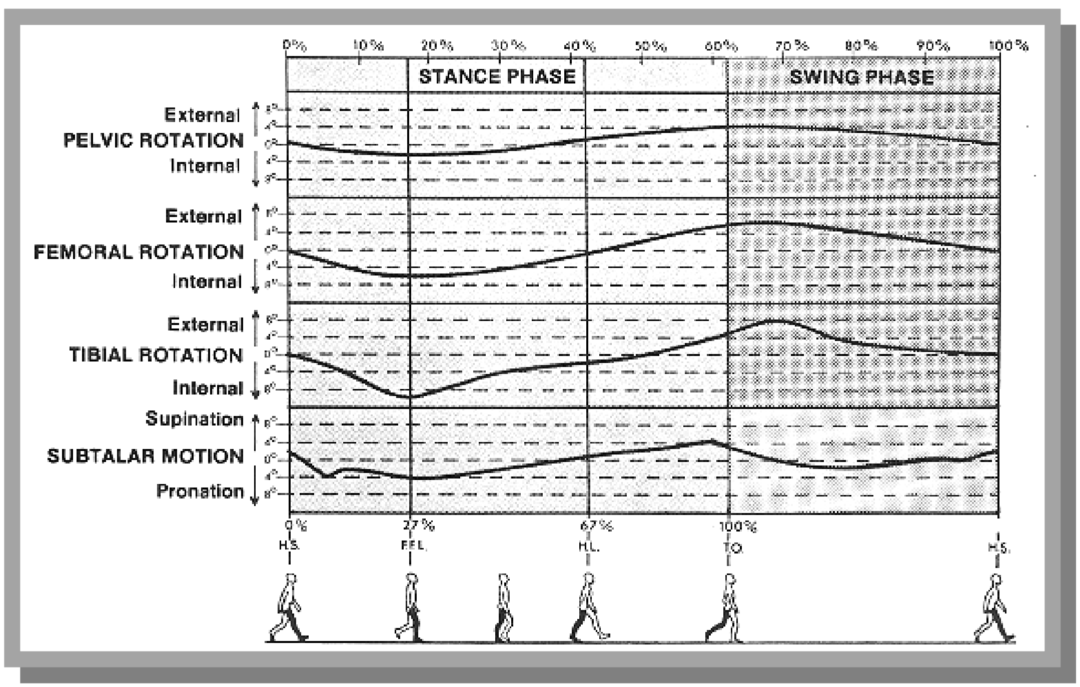
COUPLING

Foot Pronation ⟷ Leg Rotation

MOVEMENT COUPLING

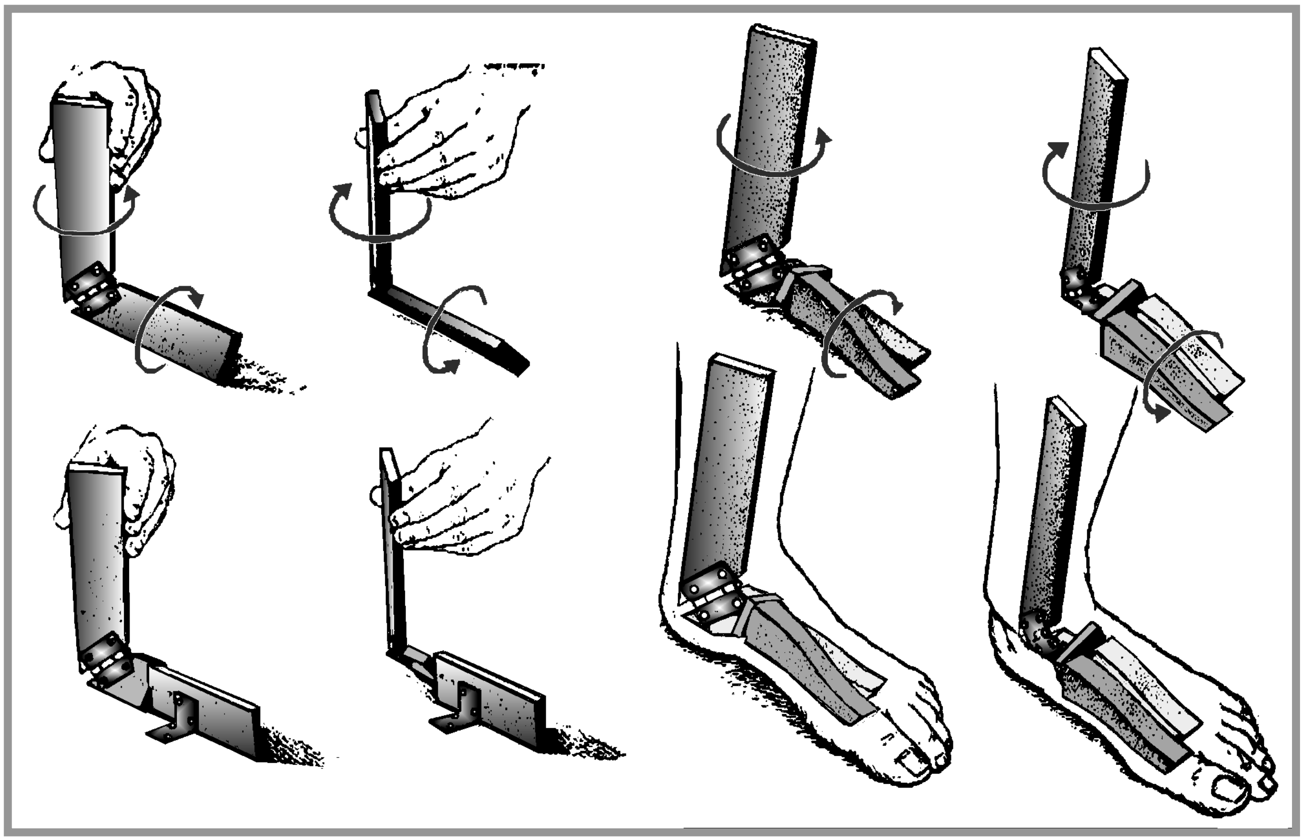
$$\text{Coupling Coefficient} = \frac{\text{Rotation (Axis A)}}{\text{Rotation (Axis B)}}$$

$$\text{1:1 Ratio} = \frac{\text{High Coupling Coefficient}}{\text{“Rigid Coupling”}}$$



Mitered Joint Model

- 1:1 Coupling int/ext : inv/ev
- Transformation at subtalar joint



Movement Transfer: Calcaneus ⟷ Tibia

AUTHOR	TRANSFER COEFFICIENT
Olerud, Rosendahl	0.42
Hintermann, Nigg	0.46 (ev), 0.74 (inv)
Lundberg	0.2

In Vitro Study

- **14 cadaver specimens**
- **Measurements of foot inversion/eversion to tibial rotation**
- **In a neutral ankle position**

transfer co-efficients ranged between 0.14 and 0.66 "It can be concluded that the ankle joint complex does not act as a universal joint"

Hintermann B., Nigg BM, Sommer C, Cole CO. Transfer of movement between calcaneus and tibia in vitro. Clin Biomech 9:349-355, 1994.

Movement Coupling

How can the tibia externally rotate while the calcaneus remains everted (does not move)?

- **Tibia can internally rotate on talus**
- **Rearfoot complex can internally rotate as one unit on the forefoot (transverse plane MTJ motion)**

Transverse Plane Movements In Gait

Ankle

18°   McCullough, Burge

15°   Nester

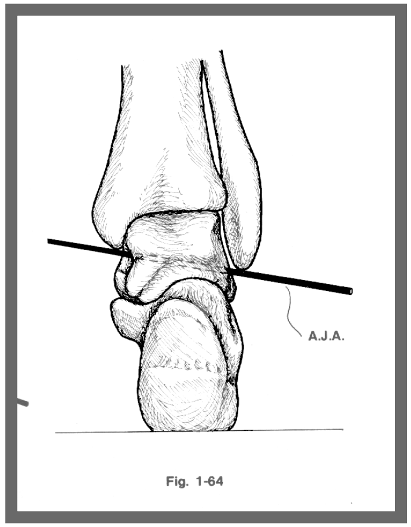
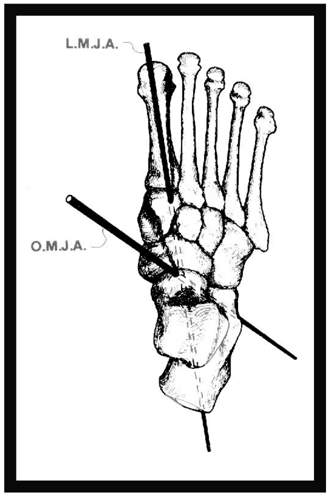


Fig. 1-64

Midtarsal

10.6°   Nester



Transverse Plane Motion at the Ankle Joint

- **In vivo kinematic study, 25 subjects**
- **Static and dynamic conditions**
- **Mean Ankle/STJ ROM:**

27.2˚ transverse plane
7.6˚ frontal plane

- **Ankle transverse ROM: >15˚**

Nester CJ, Findlow AF, Bowker P. Bouden PD: Transverse Plane Motion at the Ankle Joint. Foot and Ankle Int. 24:164-168, 2003.

Transverse Plane Motion at the Ankle Joint

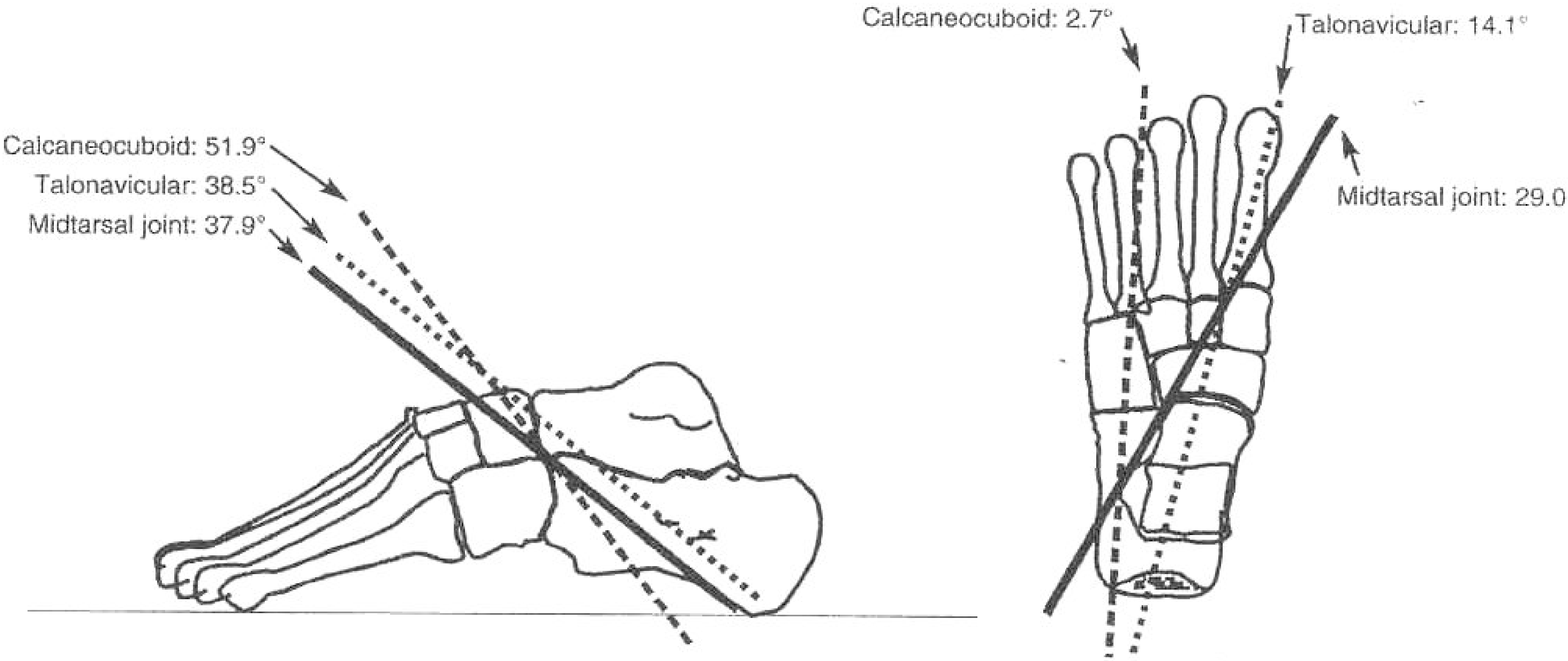
"…the ankle and subtalar joints contribute approximately equal amounts of transverse plane motion to the overall function of the ankle/subtalar complex."

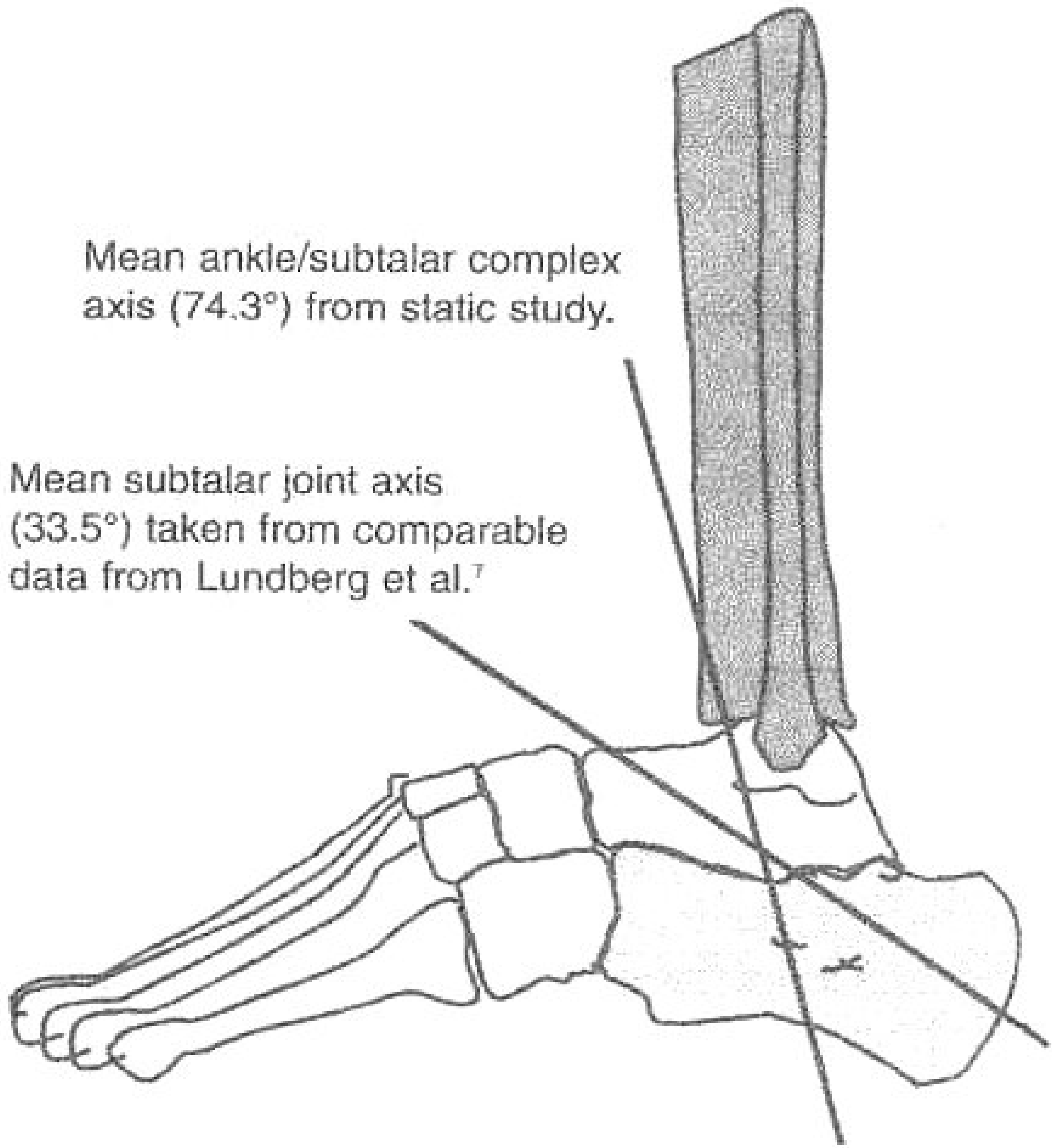
Nester CJ, Findlow AF, Bowker P. Bouden PD: Transverse Plane Motion at the Ankle Joint. Foot and Ankle Int. 24:164-168, 2003.

Transverse Plane Motion at the Ankle Joint

"The angulation of the ankle/subtalar axis to the transverse plane calculated from the data from the static study was consistently high, ranging from 53.2° to 88.9°, and this reflects the predominance of transverse plane motion at the complex."

Nester CJ, Findlow AF, Bowker P. Bouden PD: Transverse Plane Motion at the Ankle Joint. Foot and Ankle Int. 24:164-168, 2003.


Calcaneocuboid: 51.9°
Talonavicular: 38.5°
Midtarsal joint: 37.9°
Calcaneocuboid: 2.7°
Talonavicular: 14.1°
Midtarsal joint: 29.0°


Mean ankle/subtalar complex
axis (74.3°) from static study.
Mean subtalar joint axis
(33.5°) taken from comparable
data from Lundberg et al.[7]

Movement Coupling

There is significant evidence to suggest that ligaments rather than articular surfaces are responsible for the movement transfer coupling mechanisms between the foot and the leg.

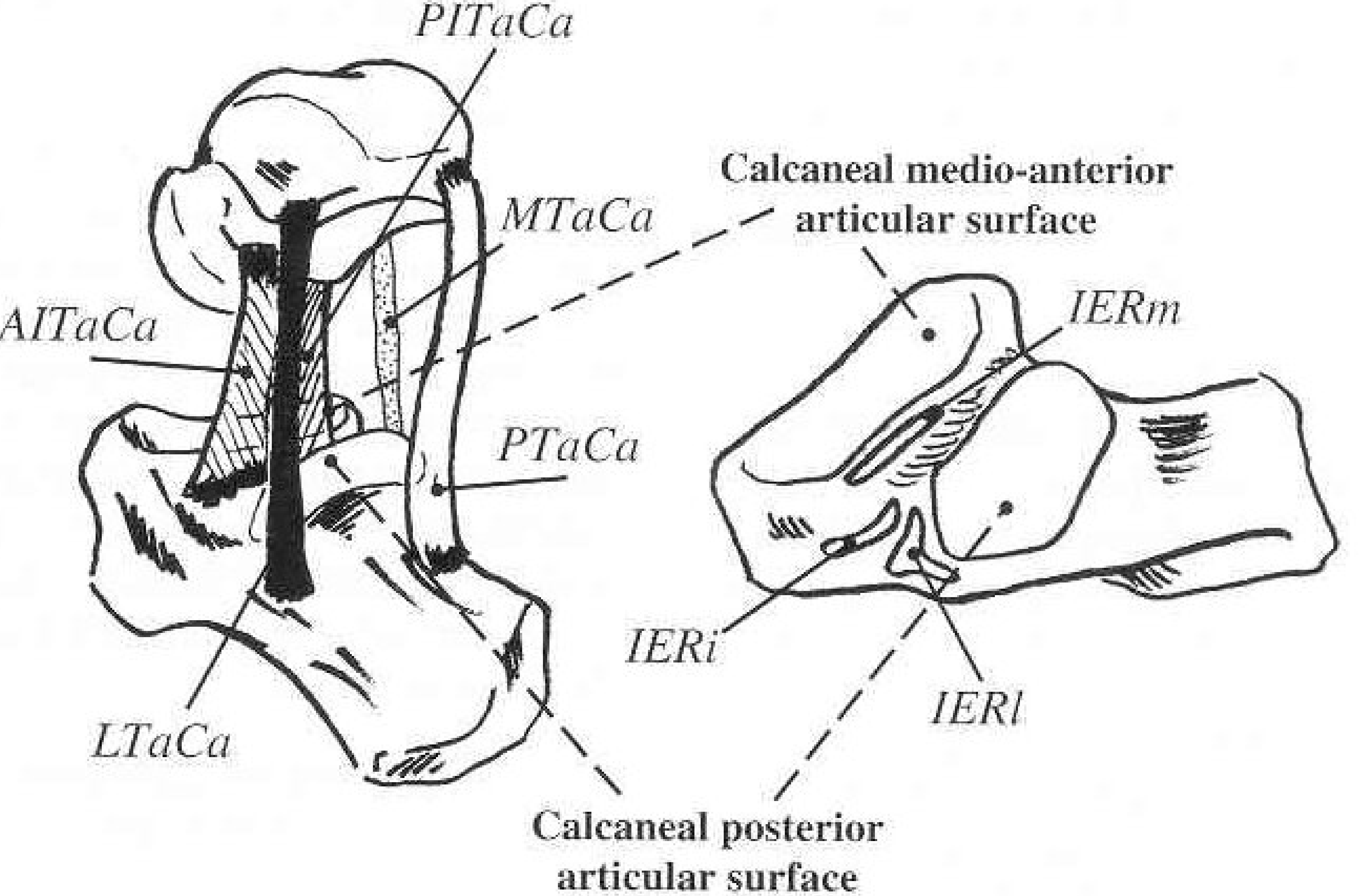
Hintermann, Sommer, and Nigg, 1995
Himtermann, Nigg and Cole, 1994
Hintermann, Nigg, Cole and Sommer, 1994

Movement Coupling

- 8 cadaver models
- 0N, 200N, 400N, & 600N loads
- Sequential ligament release:

ATF
CF
PTF
Deltoid
STJ Interosseus

Hintermann, B., Sommer, C., and Nigg B.M.: Influence of ligament transection on tibial and calcaneal rotation with loading and dorsi-plantar flexion. Foot and Ankle 16:567, 1995


PITaCa
Calcaneal medio-anterior articular surface
MTaCa
IERm
AITaCa
PTaCa
IERi
IERl
LTaCa
Calcaneal posterior articular surface

Movement Coupling

- 8 cadaver models
- 0N, 200N, 400N, & 600N loads
- Sequential ligament release:

ATF
CF
PTF
Deltoid
STJ Interosseus

Hintermann, B., Sommer, C., and Nigg B.M.: Influence of ligament transection on tibial and calcaneal rotation with loading and dorsi-plantar flexion. Foot and Ankle 16:567, 1995

Movement Transfer

Effects of Ligament Transection:

DF Ankle $\longrightarrow$ Tib Rot $\longrightarrow$ Calc Inv-Ev

Transect: **Lat Lig : No Change**

Deltoid : Sig loss Mov Trans

Deltoid & Interosseos : Total loss Mov Trans

Hintermann B., Sommer C. Nigg B: Influence of ligament transection on tibial and calcaneal rotation with loading and dorsiflexion – plantarflexion. Foot and Ankle 16:567-571, 1995.

Movement Coupling

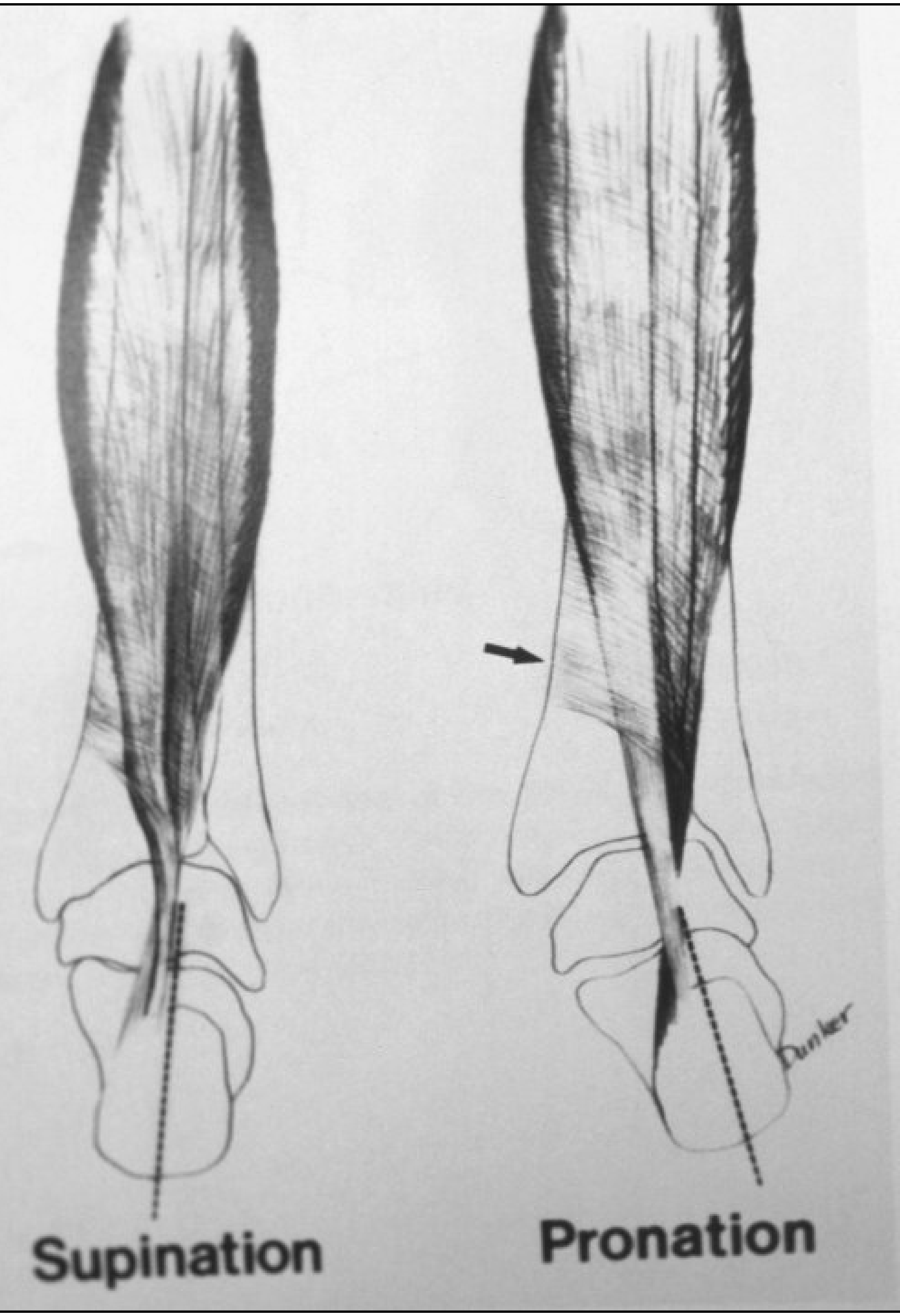
"These results indicate that the foot becomes partially mechanically disconnected from the tibia by transection of the medial ankle ligaments and even further disconnected after transection of the subtalar interosseous ligament."

Hintermann, B., Sommer, C., and Nigg B.M.: Influence of ligament transection on tibial and calcaneal rotation with loading and dorsi-plantar flexion. Foot Ankle 16:567, 1995

Forces Causing Flatfoot

1. Axial load
2. Gastroc – Soleus
3. Other muscles (incl. PB)

Kitaoka, 1997


Supination
Pronation

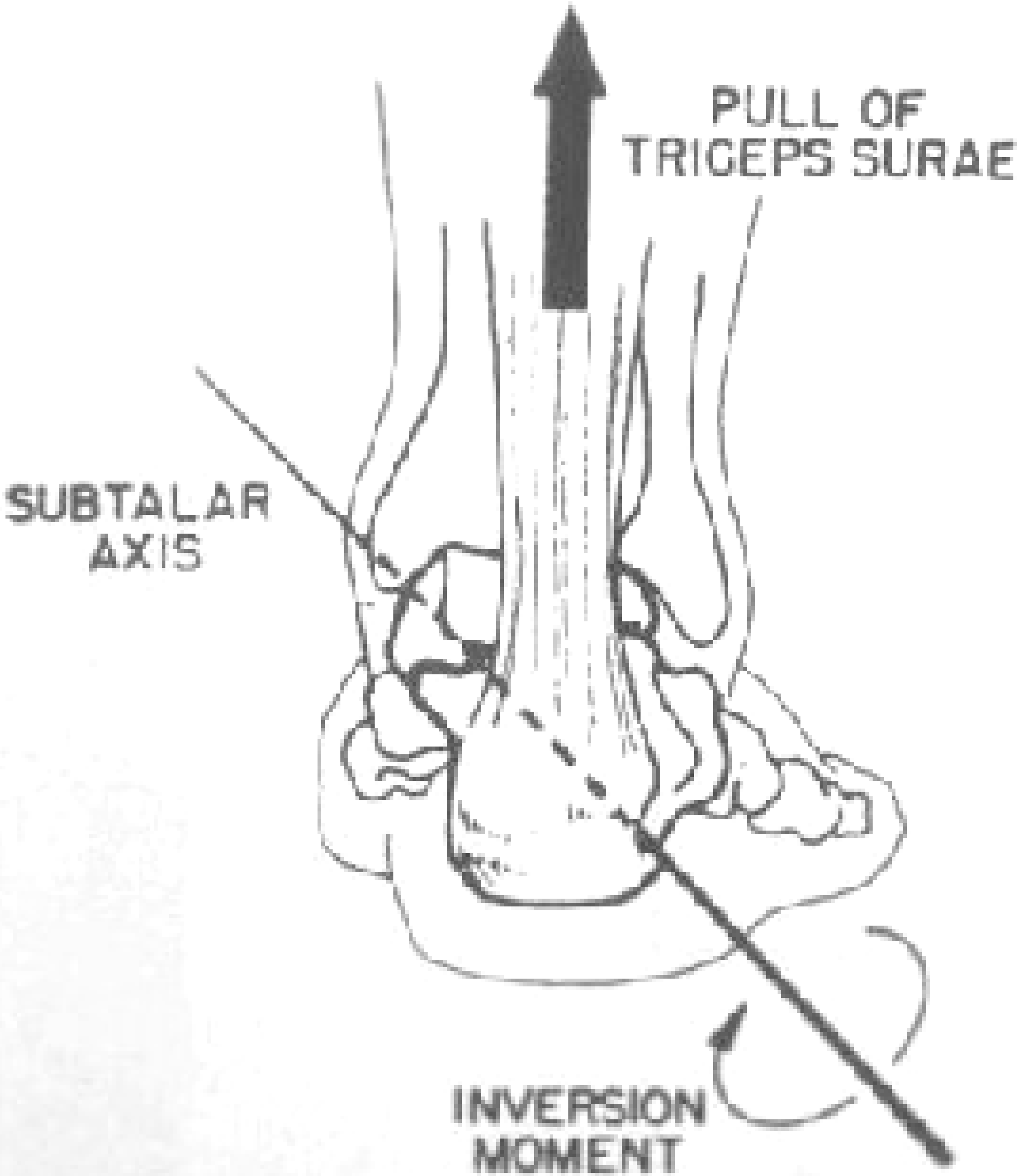
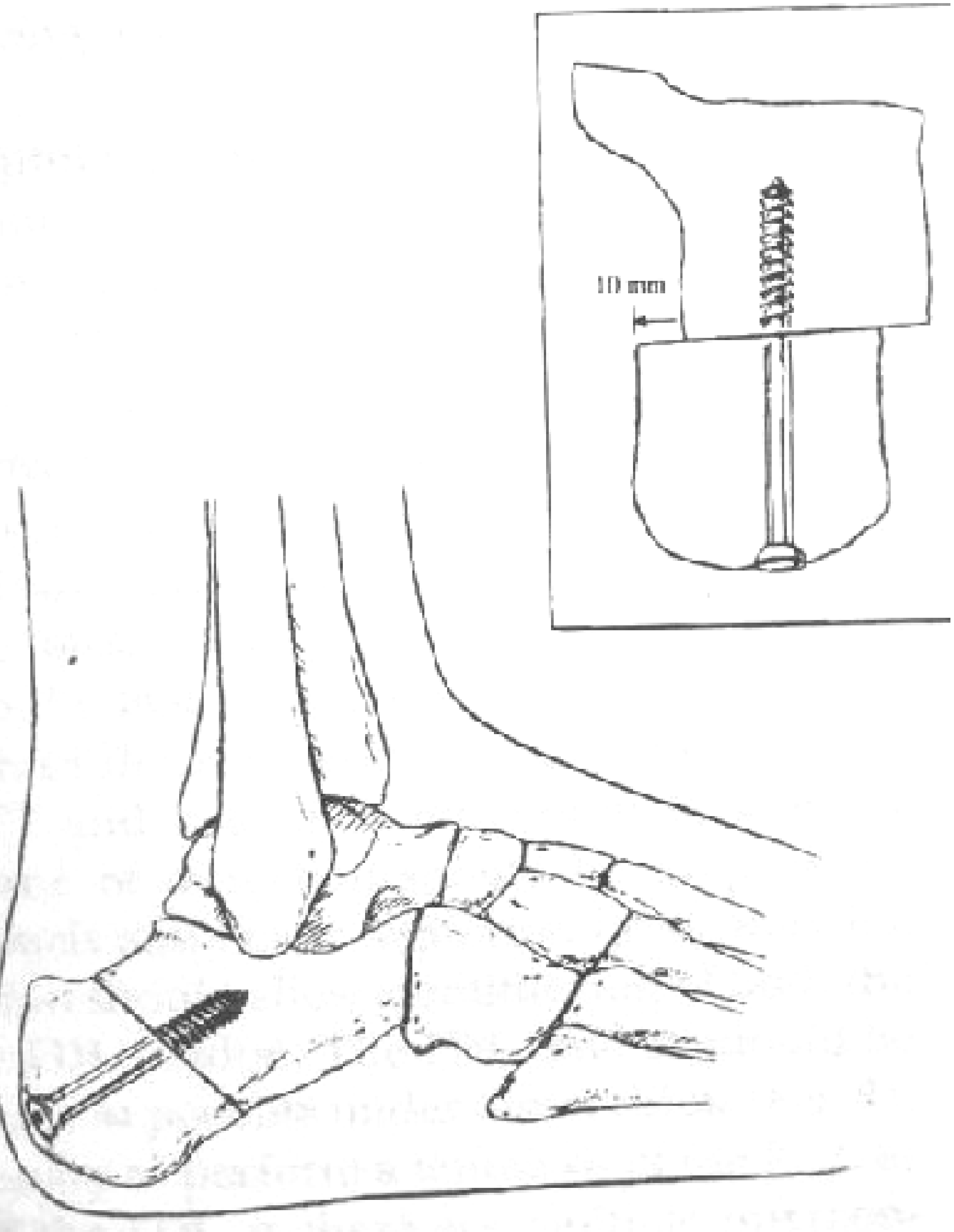
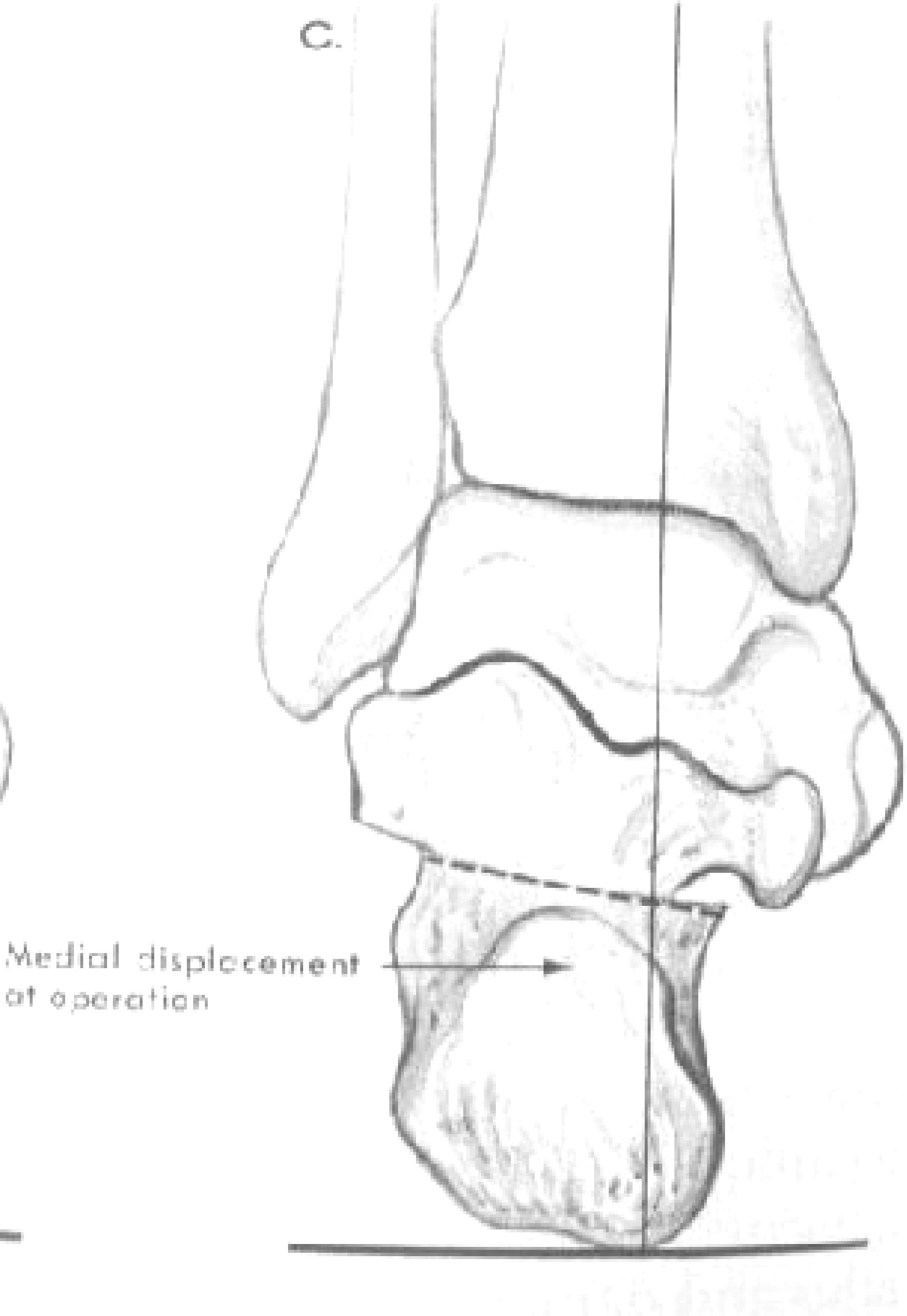


FIG. 10-A


10 mm


C.
Medial displacement
at operation

Medial Displacement
Calcaneal Osteotomy

- Reduces flatfoot force of achilles

  (Nyska, Parks, Chu, Myerson, 2001)

- GRF directed medial, decrease length of SMCN ligament

  (Otis, 1999)

- Decreased deltoid lig. Strain

  (Resnick, 1995)

Combination Procedures

Medial Displacement Calc. Ostectomy and FDL Transfer

18 Pts, 54 yrs. Of age. F/U: 20 mos.

Talar 1st Met: 21° $\longrightarrow$ 8°

T-N Coverage: 34° $\longrightarrow$ 21

Lat. Talar 1st Met: -22° $\longrightarrow$ -9°

Subjective Improvement: No data

Myerson, et al. 1995

Medial Displacement / Calcaneal Osteotomy

- 10 cadaver specimens
- Physiologic loads: PL, PB, FHL
  FDL, Achilles
- AP & Lat Radiographs
- Flatfoot: Cut PTT, spring lig, pl fascia
  with 7,000 axial comp. cycles

Nyska M., Parks B.G., Chu I.T., Myerson M.S. "The Contribution of the Medial Calcaneal Osteotomy to the Correction of Flatfoot Deformities." Foot and Ankle 22:278, 2001.

Medial Displacement / Calcaneal Osteotomy

Results

Flatfoot without Achilles
vs.
Flatfoot with Achilles load
vs.
Flatfoot with Achilles load with MDCO

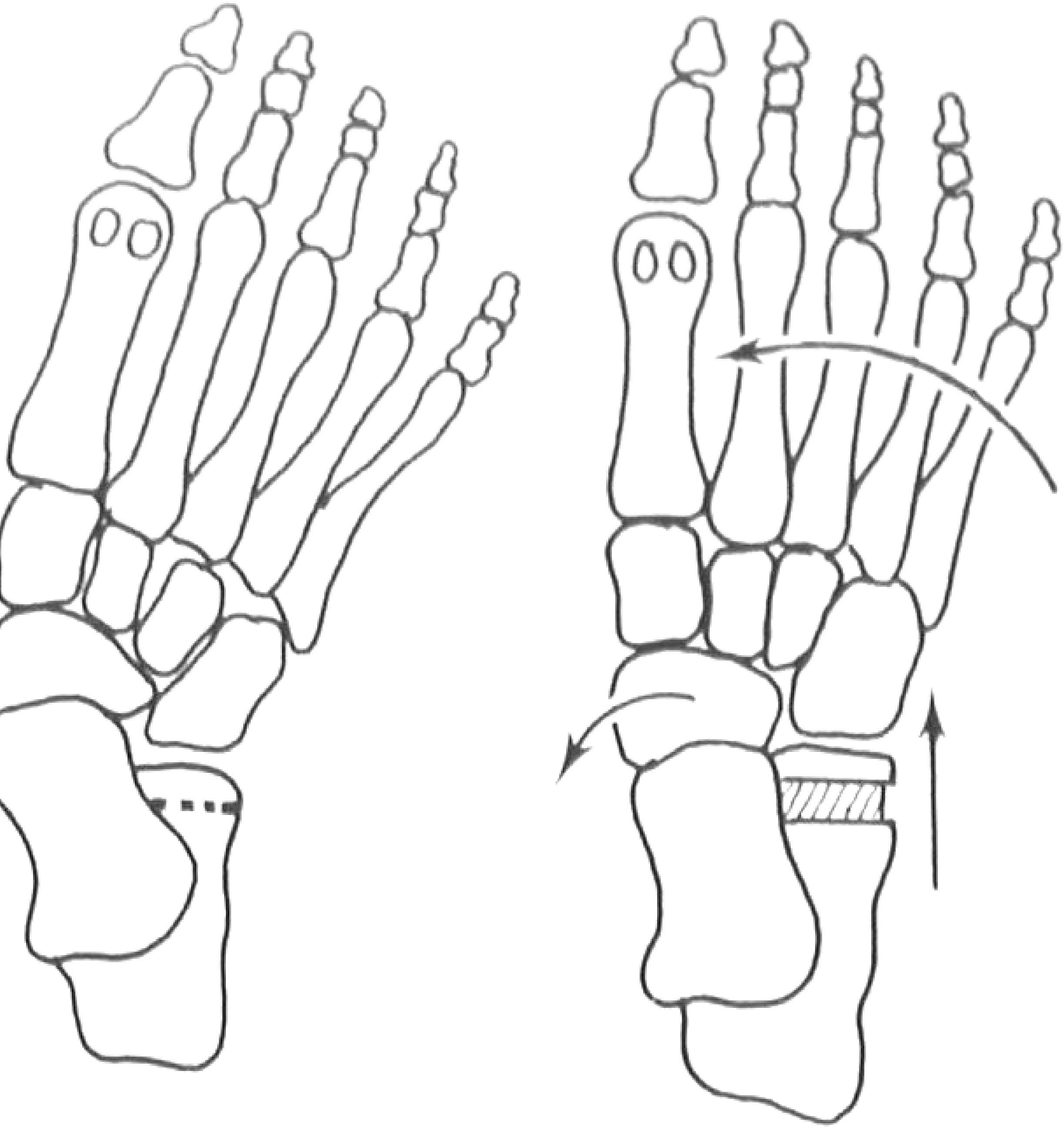
Significant improvement of: cuniform height, T-N angle
Talar – 1st met angle

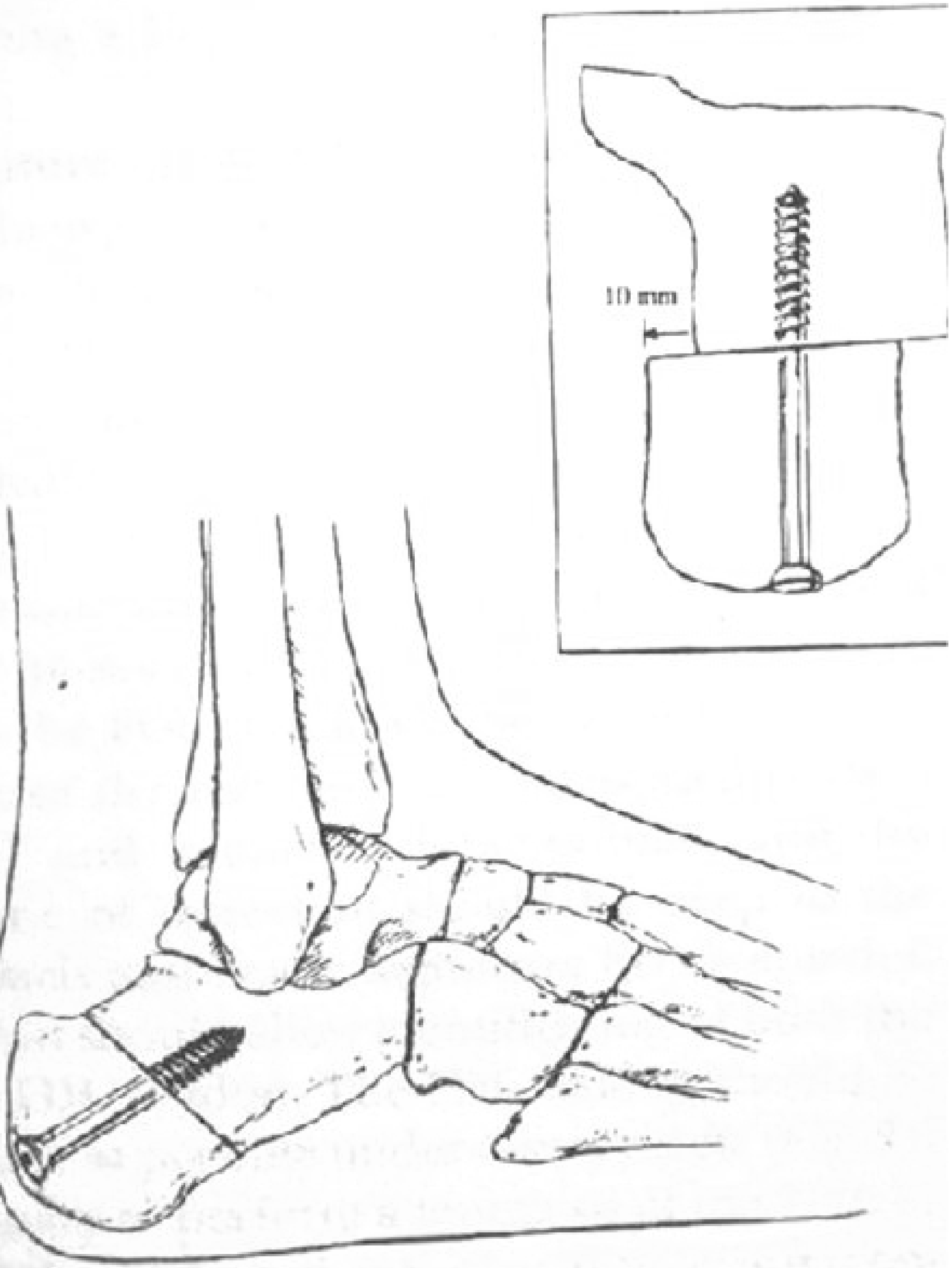
"Loading of the Achilles increased the deformity. MDCO significantly decreased the arch flattening effect of the achilles."

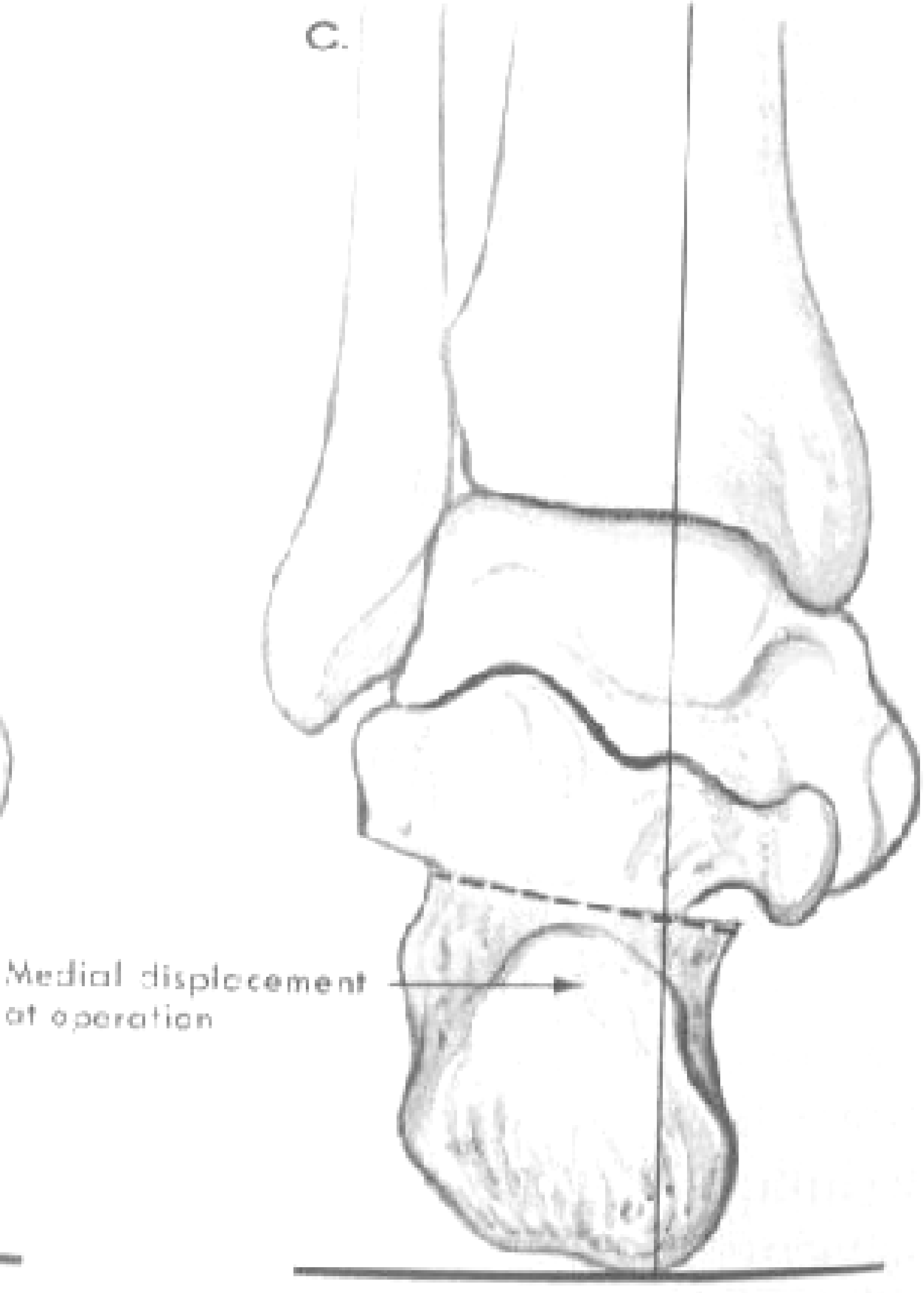
Nyska M., Parks B.G., Chu I.T., Myerson M.S. "The Contribution of the Medial Calcaneal Osteotomy to the Correction of Flatfoot Deformities." Foot and Ankle 22:278, 2001.

Adult Acquired Flatfoot

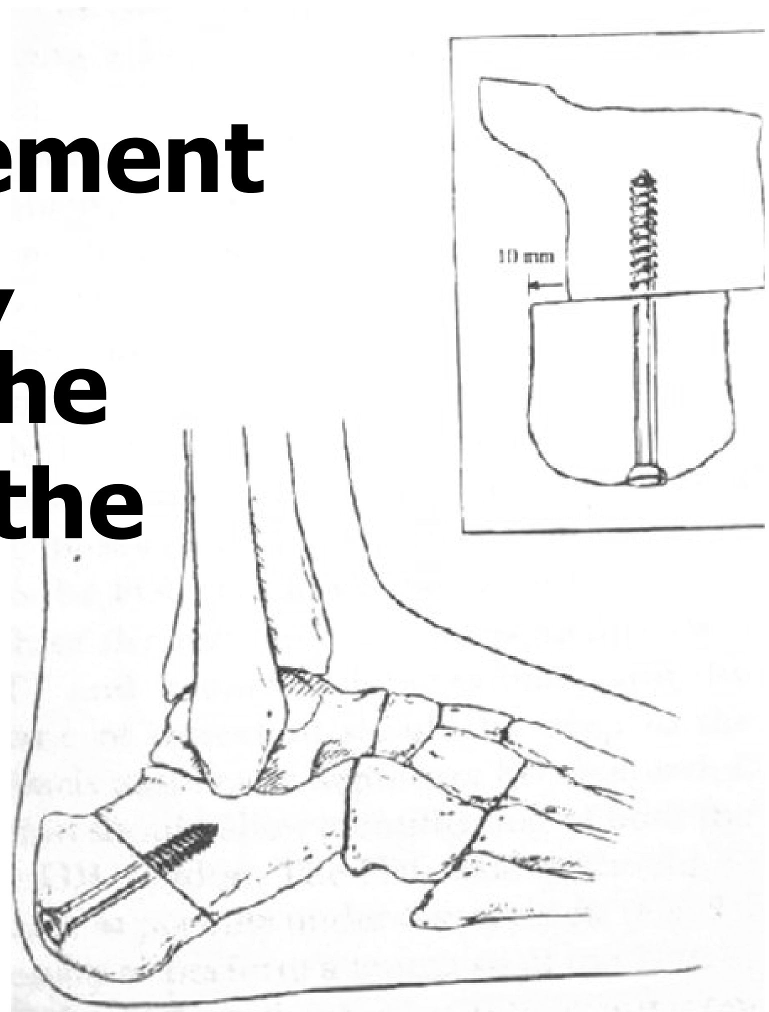
Ligament Insufficiency: Why does it matter?




10 mm


C.
Medial displacement
at operation

- **After medial displacement calcaneal osteotomy, strain decreased at the attachment point of the deltoid ligament**



Resnick RB, Jahss MH, Choveka J et al: Deltoid ligament forces after tibialis posterior tendon rupture: effects of triple arthrodesis and calcaneal displacement osteotomies. Foot Ankle Int 16: 14-20, 1995

"The results favor medializing the calcaneus following arthrodesis to protect the deltoid complex."

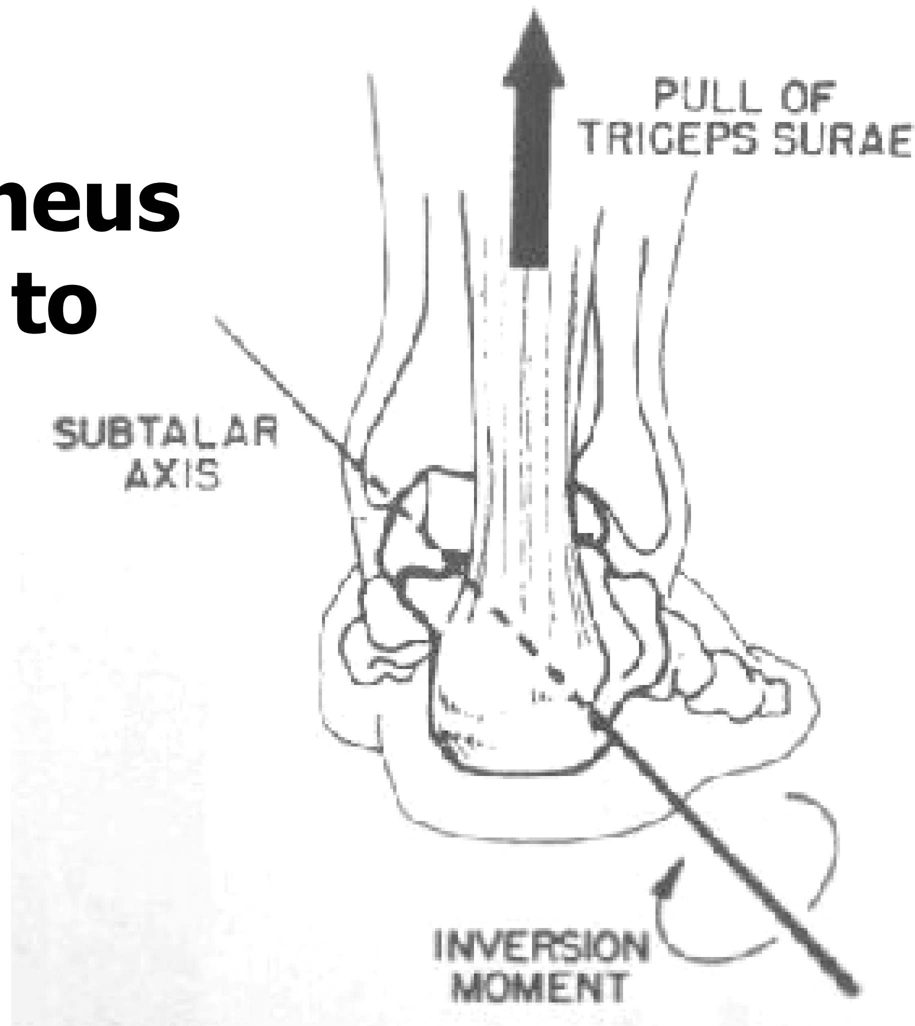
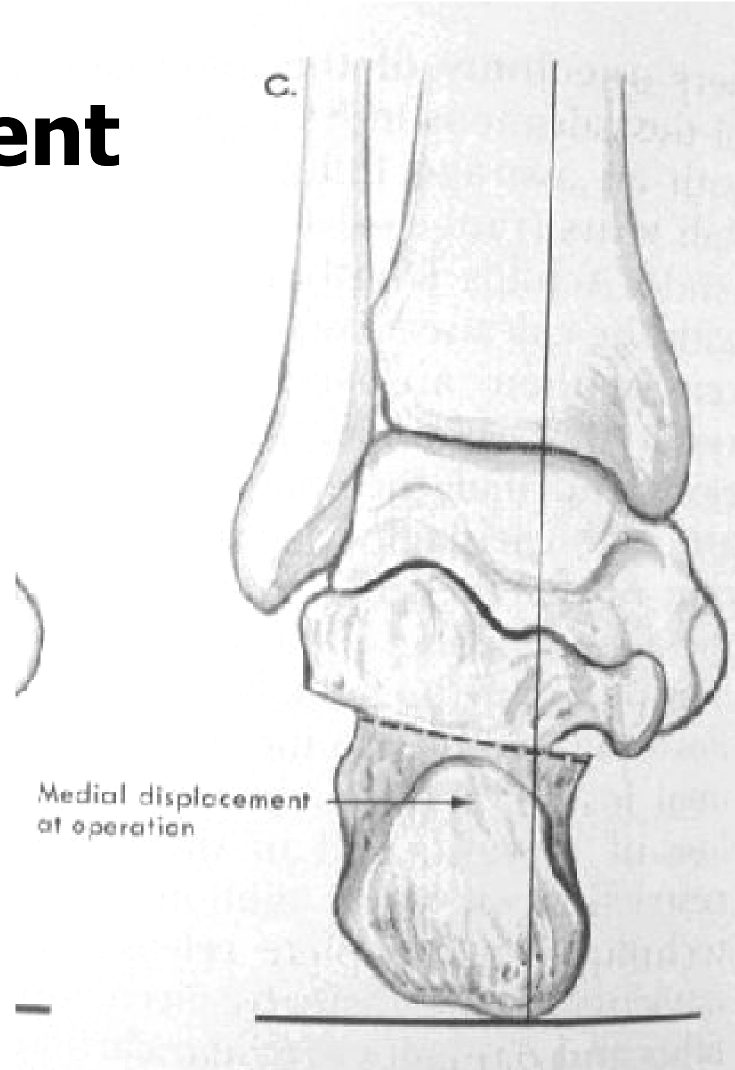


FIG. 10-A

Song SJ, Lee S, O'Malley MJ et al: Deltoid ligament strain after correction of acquired flatfoot deformity by triple arthrodesis. Foot Ankle Int 21: 573-577. 2000

“The medial displacement calcaneal osteotomy resulted in decreased length and, likely, less tension in the spring ligament.”

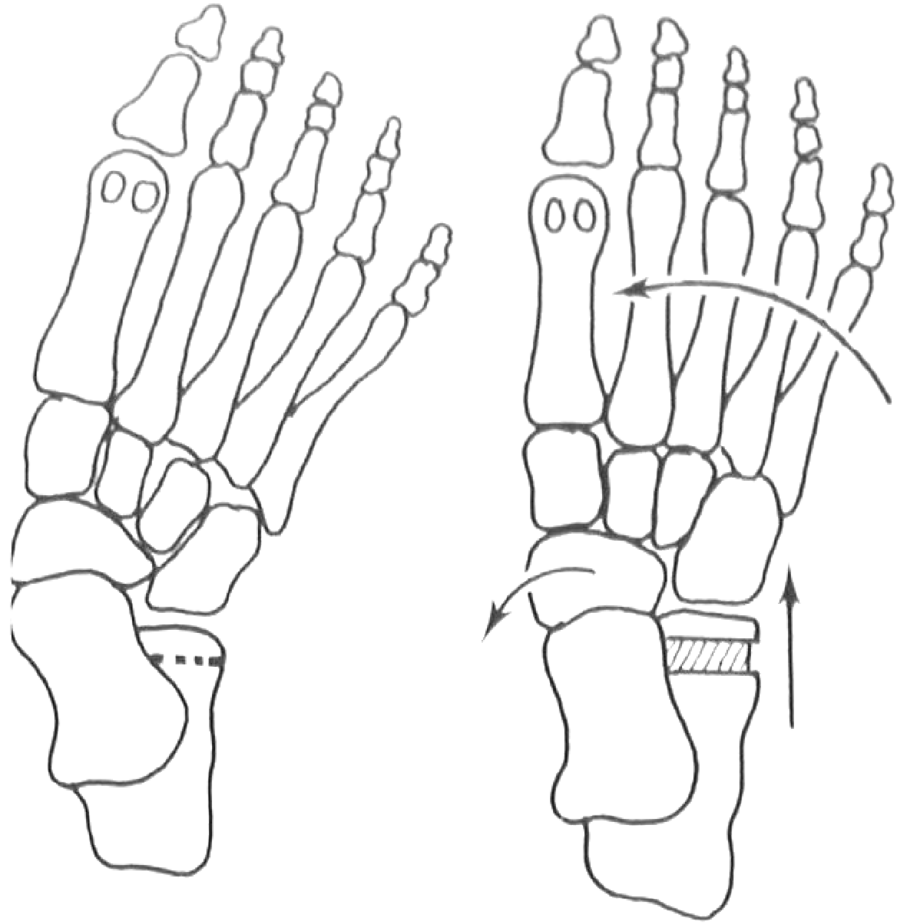


Otis JC, Deland JT, Kenneally S et al: Medial arch strain after medial displacement calcaneal osteotomy: An in vitro study. Foot Ankle Int 20:222-226, 1999

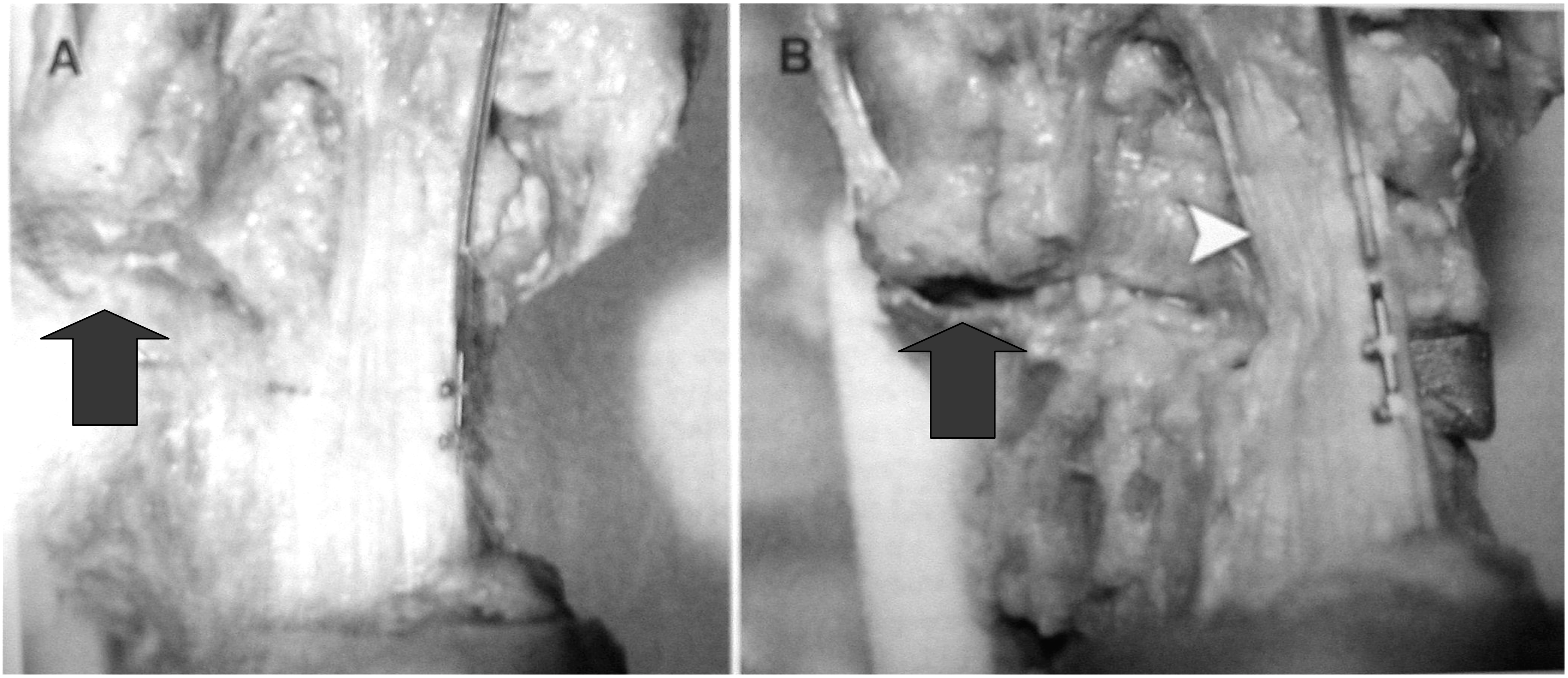
"With less stress on the ligament, plication of the ligament could be performed to help correct deformity, theoretically without increasing load in this ligament."

Otis JC, Deland JT, Kenneally S et al: Medial arch strain after medial displacement calcaneal osteotomy: An in vitro study. Foot Ankle Int 20:222-226, 1999

"The results of this study suggest that (lateral column lengthening) may not be counted on to decrease spring ligament tension below normal levels."



Otis JC, Deland JT, Kenneally S et al: Medial arch strain after lateral column lengthening: An in vitro study. Foot Ankle Int 20: 797-802. 1999



Before Evans Graft

After Evans 8mm Wedge

DiNucci, KR, Christensen, JC, Christensen, Kris A: Biomechanical Consequences of Lateral Column Lengthening of the Calcaneus: Part I. Long Plantar Ligament Strain. Journal of Foot Ankle Surg 43: 10-15 2004

"Therefore, after a simulated subtalar fusion, the (spring) ligament is still responsive to load and not as protected as after simulated talonavicular fusion."

Otis JC, Deland JT, Kenneally S et al: Medial arch strain after lateral column lengthening: An in vitro study. Foot Ankle Int 20: 797-802. 1999

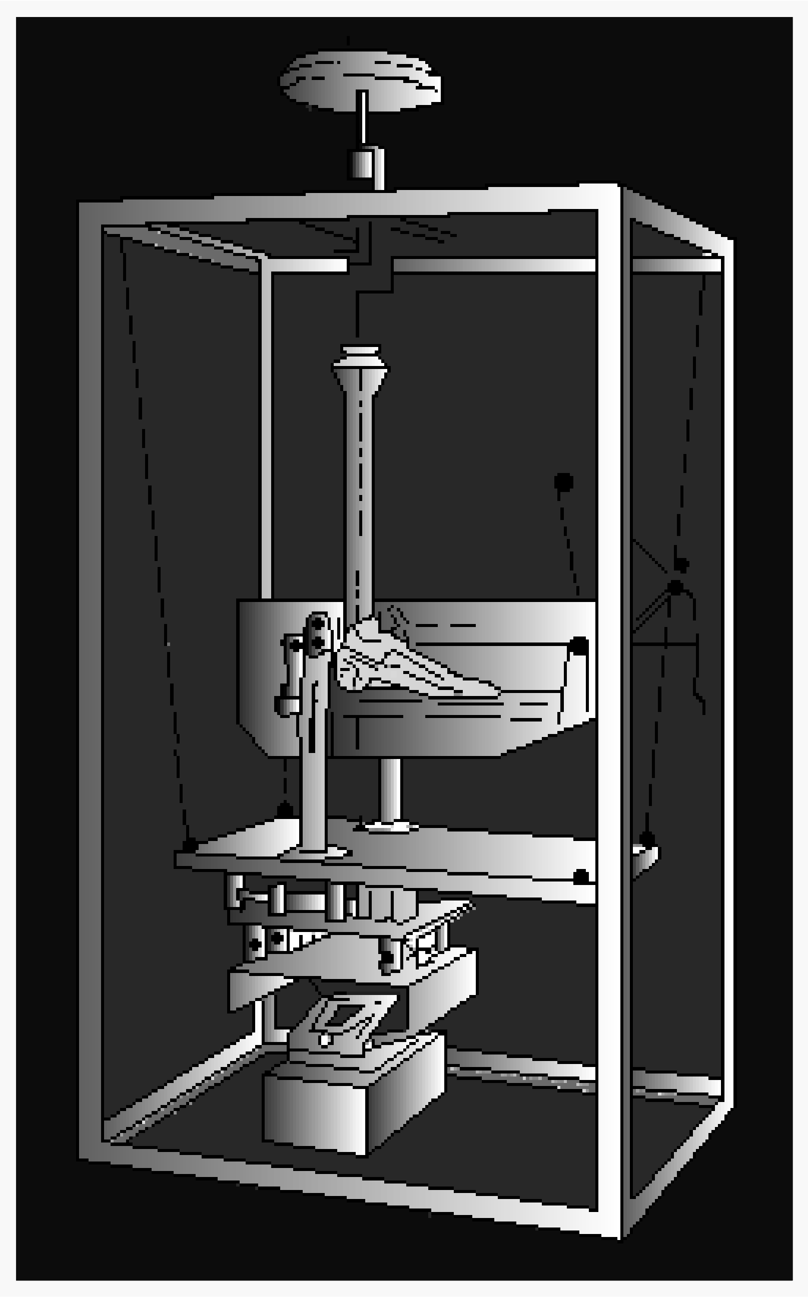
Pathomechanics of the Adult Acquired Flatfoot

RECENT INSIGHTS

- **Not solely due to TPD**
- **Pre-existing flatfoot**
- **Tibia is dominant lever**
- **Pivotal joint is Talo-Navicular**

Movement Coupling

Insight provided by experimental studies of tarsal joint fusion



HINTERMANN B, NIGG BN: INFLUENCE OF ARTHRODESES ON KINEMATICS OF THE AXIALLY LOADED ANKLE COMPLEX DURING DORSIFLEXION/PLANTARFLEXION. FOOT & ANKLE 16: 633, 1995.

The illustration shows the experimental setup(EI=eversion-inversion; DP=dorsiflexion/plantarflexion; TR=tibial rotation)

Tibial Rotation with Axial Loads

Ankle Load (600 N)	*Int Tibial Rotation*
Normal	**2.2°**
Ankle fused	**1.7°**
STJ fused	**1.4°**
T-N fused	**0.9°**
STJ & T-N fused	**0°**

Hintermann and Nigg, 1995

Motion after Arthrodesis

Joint Fused	Retained ROM	Excursion of TP
T-N	10% STJ, 10% CC	25% retained
C-C	100% STJ, 67% TN	73%
STJ	26% TN 56% CC	46%

Astion DJ, Deland JT, Otis JC: Motion of the hindfoot after simulated arthrodesis. JBJS 79-A: 241, 1997

ARTHRODESIS

- 5 cadaver specimens
- Sequential ligament release: flatfoot
- Radiographic measurement of selective hindfoot fusions
- T-N joint played pivotal role in correction

O'Malley, MJ Deland JT, Kyung-Tai Lee: Selective hindfoot arthrodesis for the treatment of adult acquired flatfoot deformity: An in vitro study. Foot and Ankle 16:413, 1995.

Correction of Flatfoot

Radiograph	Pre Release	Fusion of: C-C	STJ	T-N	TRIPLE
Lat T-N angle	0	23°	37°	3°	3°
A-P T-N angle	0	6°	10°	-1°	0
Hindfoot valgus angle	0	13°	19°	3°	2°

O'Malley et al, 1995

Reduction of Motion at:

Fuse Joint:	C - C	STJ	T - N
C - C	98%	N.S.	N.S.
STJ	N.S.	98%	60%
T - N	98%	98%	98%

Wulker N, Stukenborg C, Savory KM, Alfke D: Hindfoot motion after isolated and combined arthrodeses: Measurements in anatomic specimens. Foot Ankle 21:921, 2000.

“In the present study, arthrodesis of the talonavicular joint almost completely eliminated motion at the other hindfoot joint. The reduction of hindfoot motion was far greater than the following fusion of the subtalar and calcaneal cuboid joint”

"It can be assumed that the talonavicular joint participates in all hindfoot motions more than the two other major hindfoot joints. It thus appears that the talonavicular joint is the keystone to motion at the hindfoot"

Wulker N, Stukenborg C, Savory KM, Alfke D: Hindfoot motion after isolated and combined arthrodeses: Measurements in anatomic specimens. Foot Ankle 21:921, 2000.

Medial Calcaneal Displacement

- **129 Patients.**
- **Mean follow up, 5.2 years post op**
- **118 Patients entirely satisfied, 7 patients partially satisfied, 4 patients dissatisfied.**
- **125 Patients (97%) experienced pain relief.**
- **121 Patients (94%) showed improvement of function.**

Myerson MS, Badekas A, Schon LC: Treatment of stage II posterior tibial tendon deficiency with flexor digitorum longus tendon transfer and calcaneal osteotomy. Foot & Ankle Int, 25: 445-450

Medial Calcaneal Displacement

"With completely ruptured tendons, fibrotic muscles, torn or incomplete ligaments, and typically more substantial preoperative deformity and dysfunction, a more guarded prognosis would be appropriate with this procedure."

"The best way to study this proc would be to derive a sub classification of stage II deformity. A new system that looks at clinical features and radiographic angles may provide a better means of separating early stage II from late stage II deformity."

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Stages of TPD

from Johnson & Strom, Modified by Myerson et al.

STAGE	PATHOLOGY	CLINICAL SIGNS	REARFOOT
I.	Tenosynovitis	Swelling, Tenderness	Flexible
II.	Attenuation or Rupture	Archcollapse, FF abduction, too many toes can or cannot heelrise	Flexible
III.	Complete Rupture	Lateral foot pain increased heel valgus cannot heel rise	Rigid
IV.	Valgus talo crural jt.	DJD of Rearfoot Fibular Mall. Fx.	Rigid

ACFAS Practice Guideline: Adult Flatfoot

PTTD – Stage 2A

"Stage 2A is usually characterized by medial rearfoot pain, edema, and tenderness along the course of the posterior tibial tendon and mild valgus of the heel, with or without lowering of the medial longitudinal arch. There may be some abduction of the forefoot on the rearfoot. Although patients with stage 2A PTTD may be able to perform a single heel raise, they are more likely to have difficulty and pain completing this maneuver. Subtalar joint motion is supple with increased eversion."

Journal of Foot and Ankle Surgery Vol 44, 2: 78-113, March-April, 2005.

ACFAS Practice Guideline: Adult Flatfoot

PTTD – Stage 2B

"The findings in 2B PTTD are similar to those in Stage 2A, with the addition of lateral pain (sinus tarsi, subfibular, cuboid), more severe valgus deformity, collapse of the medial longitudinal arch and obvious abduction of the forefoot on the rearfoot. Forefoot supinatus may be present in Stage 2B."

Journal of Foot and Ankle Surgery Vol 44, 2: 78-113, March-April, 2005.

CONSERVATIVE TX

Stage I :	Cast Immobilization
Stage I & mild Stage II :	Semi-rigid orthosis in running shoe
Stage II :	UCBL orthosis
Stage III :	Short articulated AFO
Stage IV :	Medial T-strap double upright orthosis or a patellar-tendon bearing orthosis

S. Ferra J.J., Rosenberg G.A. Nonoperative Treatment of Posterior Tibial Tendon Pathology. Foot and Ankle Clinics 2:261, 1997

Goals of Non-Operative Treatment

Primary: **Decrease pain and edema**

Allows further diagnostic work up

More accurate impression casting

More accurate shoe fitting

Secondary: Improve mobility prevent further disability

Adult Acquired Flatfoot: Treatment Guidelines

Phase I

P ROTECTION

R EST

I CE

C OMPRESSION

E LEVATION

Adult Acquired Flatfoot: Treatment Guidelines

Phase II

Clinical Tests for Ligament Integrity of the Hindfoot

Ligaments Intact: Custom Functional Foot Orthosis
Ligaments Disrupted: Custom Ankle Foot Orthosis

Stage II: Articulated Hinged AFO

Stage II and IV: Solid AFO

Adult Acquired Flatfoot: Treatment Guidelines

Phase II

Stage II and III: Goal to move from AFO to FO

Functional Rehabilitation Program

- **Foot Adduction concentric exercises**
- **Balance and Proprioception**

Adult Acquired Flatfoot: Treatment Guidelines Phase II

Shell: Semi-Rigid to Flexible

Casting: Neutral Suspension Cast
MUST REDUCE SUPPINATUS

Prescription:

20-26 mm Heel Cup
6 mm medial heel skive
Lateral Flange
Accommodate T-N joint

ANKLE SPRAIN

Initial Treatment:

P ROTECTION

R EST

I CE

C OMPRESSION

E LEVATION

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from Johnson & Strom, Modified by Myerson et al.

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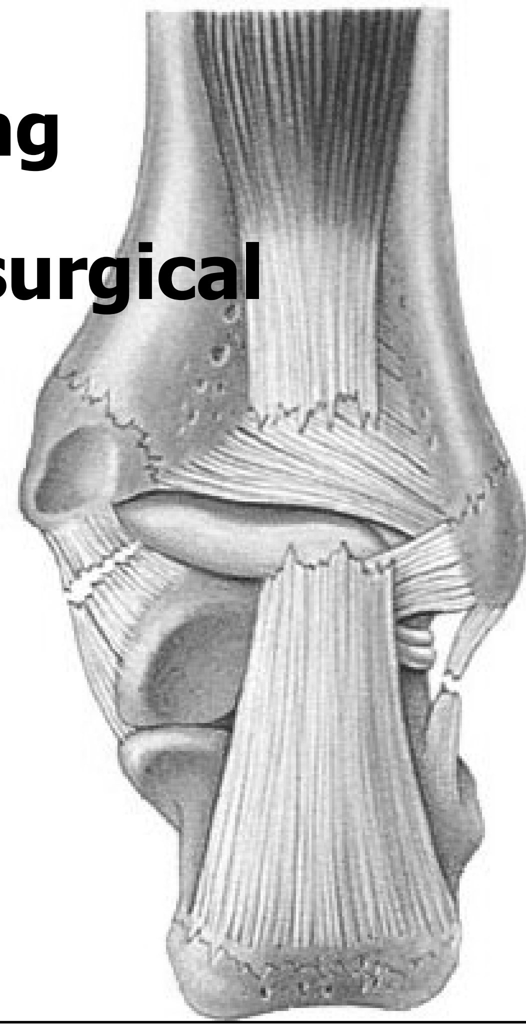
RECOMMENDATIONS

- Need clinical tests for ligament rupture in hindfoot

- Future research in movement coupling

- Research into role of ligaments and surgical reconstruction

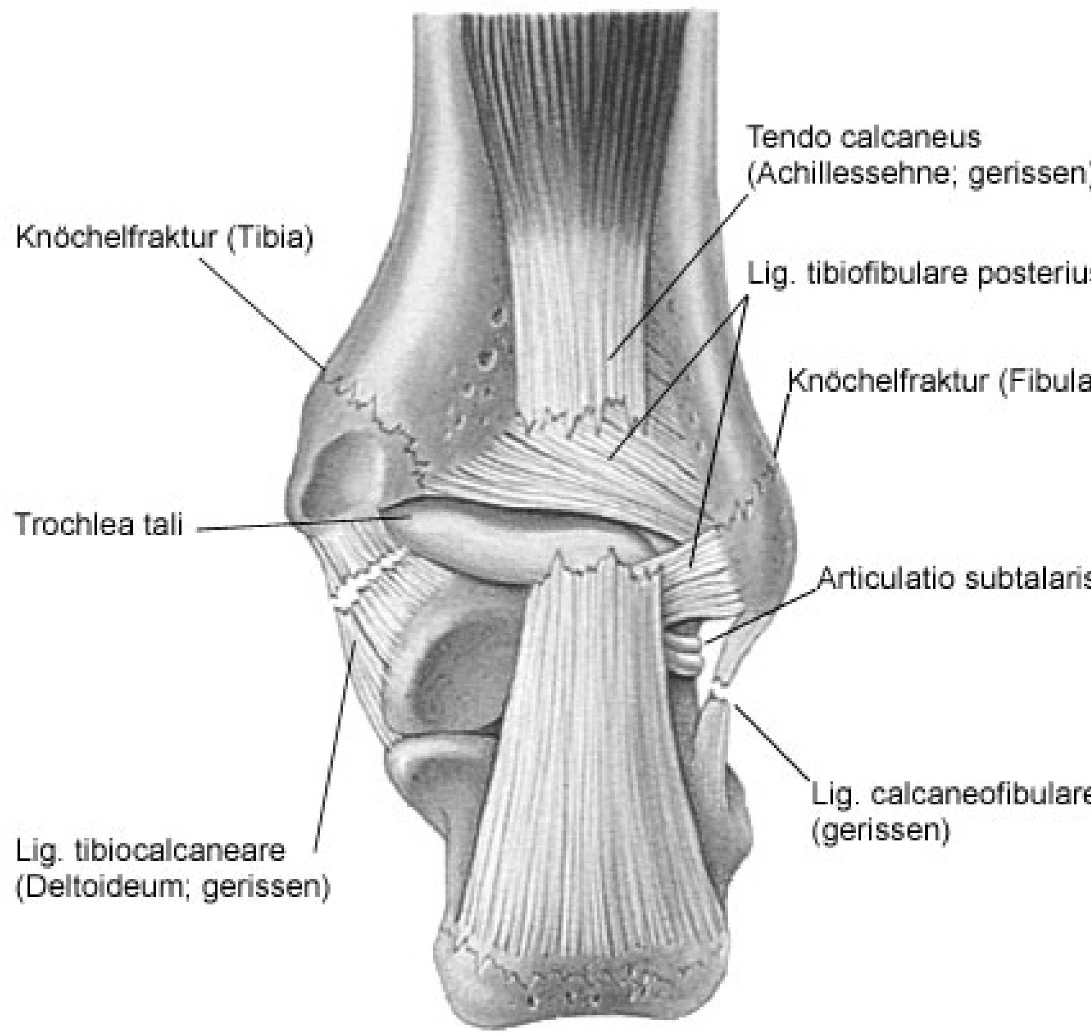


After PTT Rupture:

-Which ligaments rupture?

-What sequence?

-How do you assess?



	STAGE I	STAGE II LIG INTACT	STAGE II LIG DISRUPT	STAGE III RIGID DEFORMITY	STAGE IV
Pain, Swelling Medial Ankle	✓	✓	✓	LATERAL FOOT PAIN	LATERAL FOOT PAIN
Visible Valgus progression L v. R		✓	✓	✓	✓
Unable to Independent Heel Rise			✓	✓	✓
Loss Grade of Inversion Strength			✓	✓	✓
First Metatarsal Rise – Positive			✓	✓	✓
Hubscher Maneuver Pos. for lig Disrupt			✓	✓	✓
Supination Lag Positive			✓	✓	✓
Rigid Hindfoot				✓	✓
Valgus Talo-Crural Joint					✓

Single Foot Raise

In adult acquired flatfoot:

- **No restraint to MTJ**
- **Gastroc-Soleus plantarflexes rearfoot instead of met heads**
- **lack of leverage & pain inhibits heel lift**

MANUAL MUSCLE TESTING

Tibialis Posterior

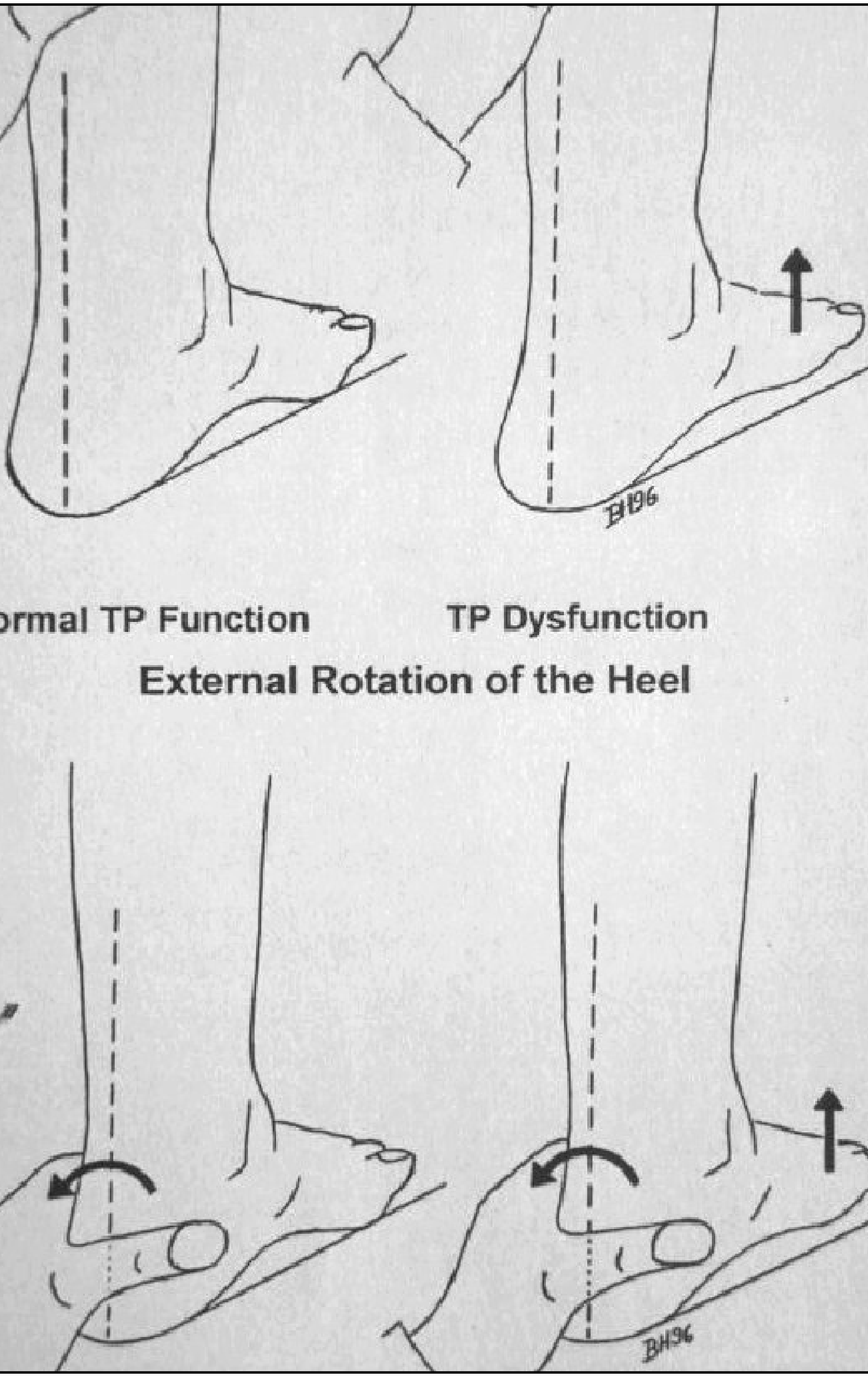
- **Plantarflexed foot**
- **Press against plantar half of 1st met head**
- **Patient actively inverts**

FIRST METATARSAL RISE *

Synovitis	1
Attenuation	6
Long. Tears	3
Mid-substance	5
Complete rupture	6

** positive in all 21 feet*

Hintermann B, Gachter A: The First Metatarsal Rise Sign: A Simple, Sensitive Sign of Tibialis Posterior Tendon Dysfuntion. Foot Ankle 17:237, 1996


ormal TP Function
TP Dysfunction
External Rotation of the Heel
BH96
BH96

FIRST METATARSAL RISE *

Synovitis	1
Attenuation	6
Long. Tears	3
Mid-substance	5
Complete rupture	6

** positive in all 21 feet*

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SUPINATION LAG

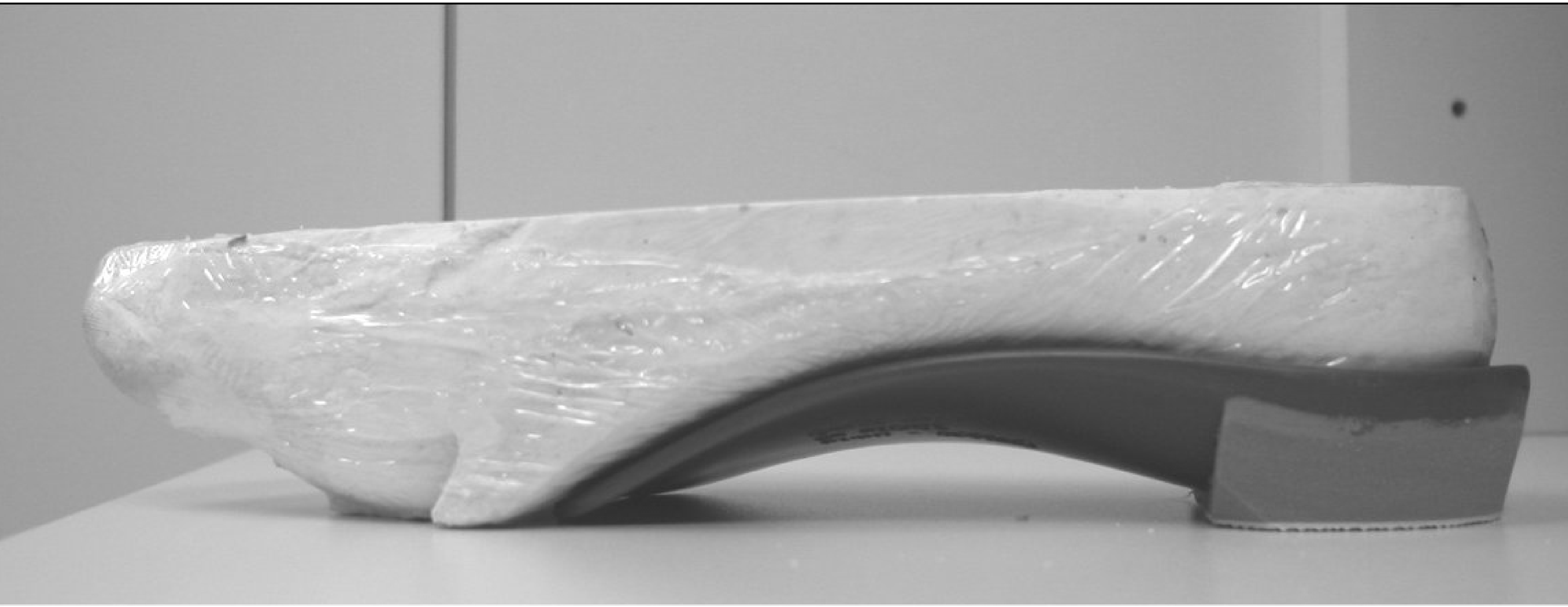
- Pt. seated, feet hang in air
- Feet plantarflexed
- “Bring soles together”

Abboud: J, Kupcha P: Supination Lag as an Indication of Posterior Tibial Tendon Dysfunction. Foot Ankle 19:570, 1998

Proprioception and Joint Position

Proprioception appears to be compromised in a joint which is positioned at end range of motion

Glencross D, Thornton E: Position sense following joint injury. J Sports Med Phys Fitness 21:23, 1981.



Effects of Foot Orthoses on Patients with Chronic Ankle Instability

Douglas H. Richie, Jr., DPM*

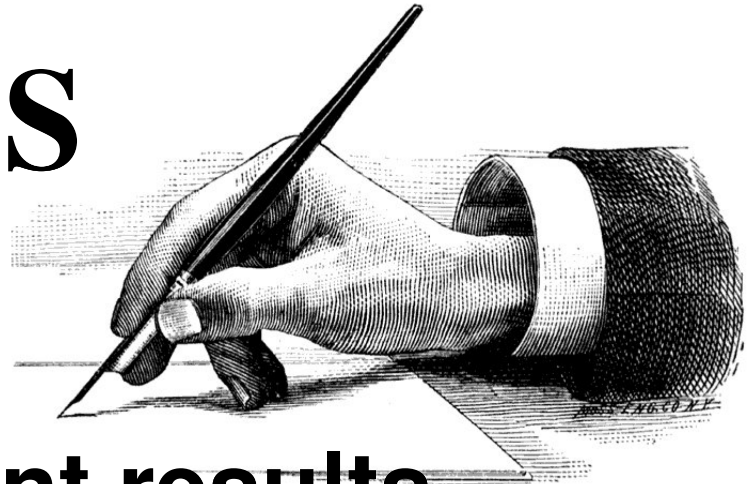
Chronic instability of the ankle can be the result of mechanical and functional deficits. An acute ankle sprain can cause mechanical and functional instability, which may or may not respond to standard rehabilitation programs. Chronic instability results when there is persistent joint laxity of the ankle or when one or more components of neuromuscular control of the ankle are compromised. A loss of balance or postural control seems to be the most consistent finding among athletes with chronic instability of the ankle. Recent research in patients with acute and chronic ankle instability has revealed positive effects of foot orthoses on postural control. This article reviews the current research relevant to the use of foot orthoses in patients with chronic ankle instability and clarifies the suggested benefits and the shortcomings of these investigations. (J Am Podiatr Med Assoc 97(1): 19-30, 2007)

AFO's and TPD

- 49 pts: 40 feet AFO, 13 feet UCBL
- 37 female, 12 male Avg. age 66 yrs.
- Mean follow up: 20.3 months
- Period of use: 14.9 months
- Daily use: 12.3 hrs.

Chao W, Wapner KL, Lee TH, et al. Nonoperative management of posterior tibial tendon dysfunction. Foot Ankle 17: 736, 1996

RESULTS



- 49 pts.
- 67% good to excellent results (functional scoring)
- Five patients underwent surgery
- 33% had discontinued use of AFO and remained Asx

Chao W, Wapner KL, Lee TH, et al. Nonoperative management of posterior tibial tendon dysfunction. Foot Ankle 17: 736, 1996

Studies of AFO Treatment of Adult Acquired Flatfoot

Chao W, Wapner KL, Lee Th, Adams J, Hecht PJ. Nonoperative management of posterior tibial tendon dysfunction. Foot Ankle Int. 17(12): 736-41, 1996.

Augustin JF, Lin SS, Berberian WS, Johnson JE. Nonoperative treatment of adult acquired flatfoot with the Arizona Brace. Foot Ankle Clin. 8 (3): 491-502, 2003.

Alvarez GR, Marini A, Schmitt C, Satlzman CL. Stage I and II posterior tibial tendon dysfunction treated by a structured nonoperative management protocol: an orthosis and exercise program. Foot Ankle Int. 27 (1): 2-8, 2006.

Lin JL, Balbas J, Richardson EG. Results of non-surgical treatment of stage II posterior tibial tendon dysfunction: a 7- to - 10 year follow up. Foot Ankle Int 29 (8): 781-786, 2008

Krause F, Bosshard A, Lehmann O, Weber M. Shell brace for stage II posterior tibial tendon insufficiency. Foot Ankle Int 29 (11): 1095-1100, 2008.

SUMMARY OF STUDIES OF AFO BRACING FOR PTTD

Patients able to discontinue brace:

Chao	**12 %**
Lin	**67 %**
Alvarez	**80%**

Augustin AOFAS scores: 37.7 increased to 70.7

Lin AOFAS scores: 42.6 increased to 78.4

Dynamical Influence of a Richie Brace Intervention: A Case Study

Christopher L. MacLean, Ph.D. (Candidate)

Paris Orthotics Lab Division

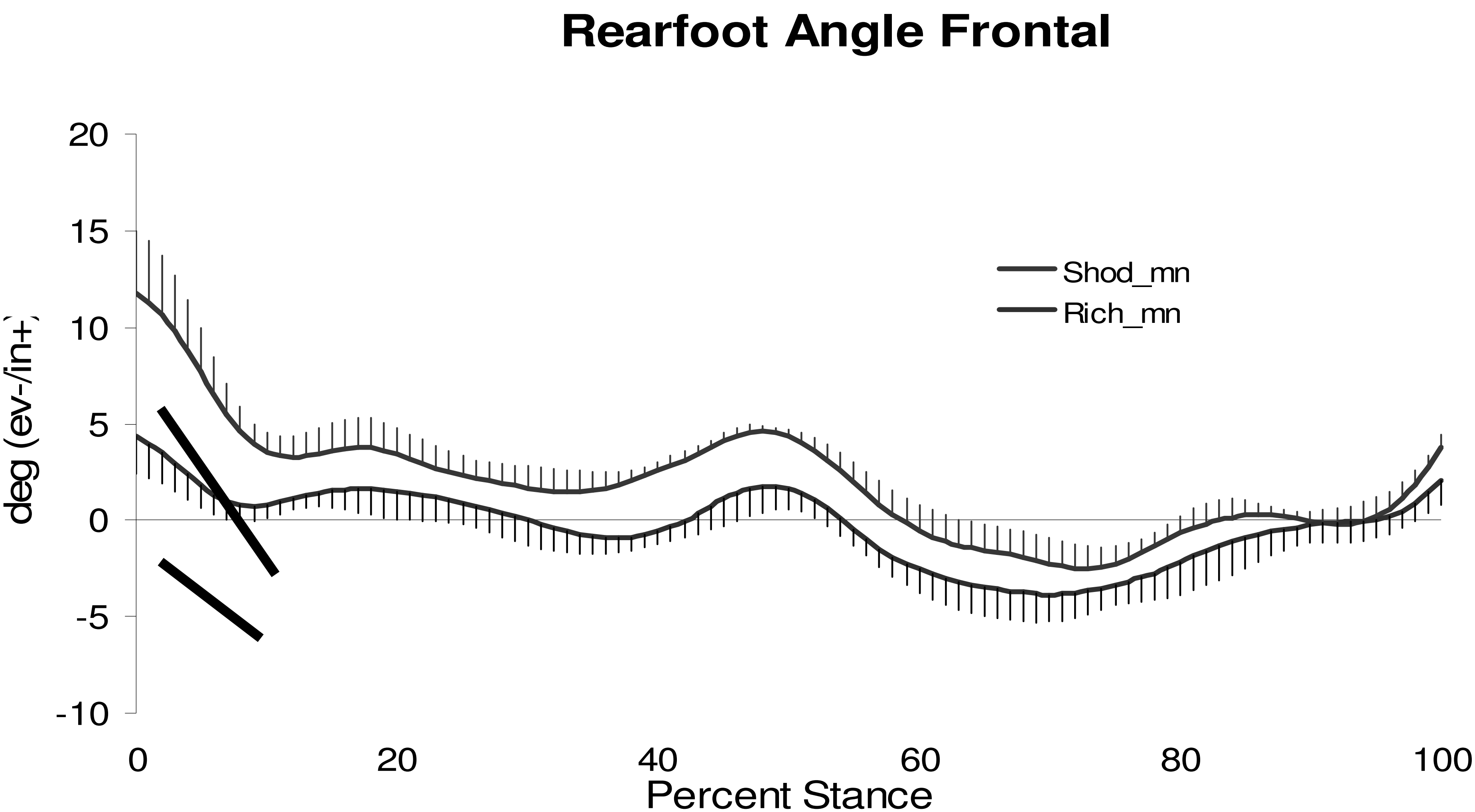
Vancouver, British Columbia

Canada

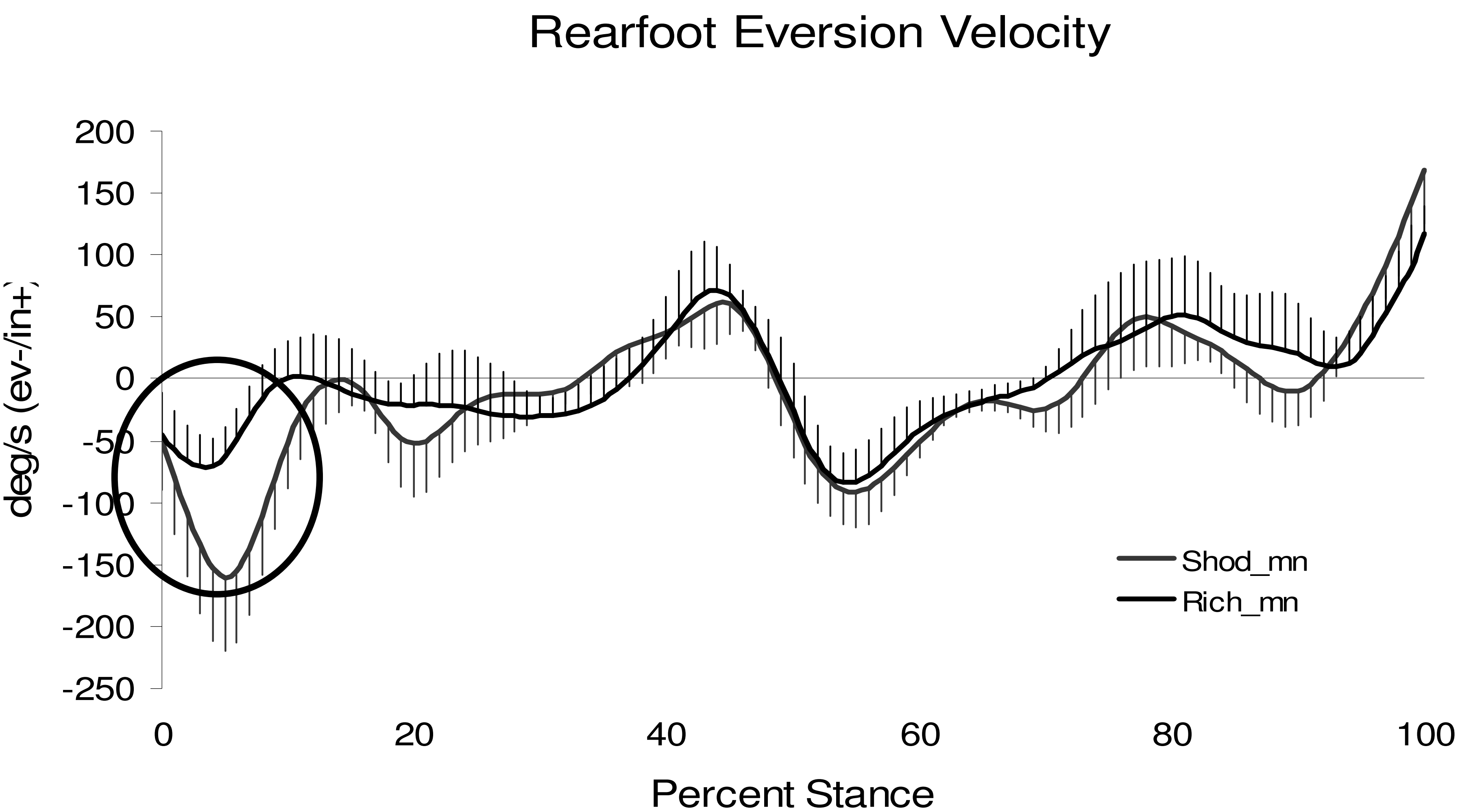
Case Description

- 58-year old male,
- 82kg (180lbs) and 5’10”,
- Diagnosed with severe B/L PTTD by a DPM in Boston,
- Compared 4 conditions:
  - Shod,
  - Shod + Root Functional,
  - Shod + PTTD device, and
  - Shod + Richie Brace.

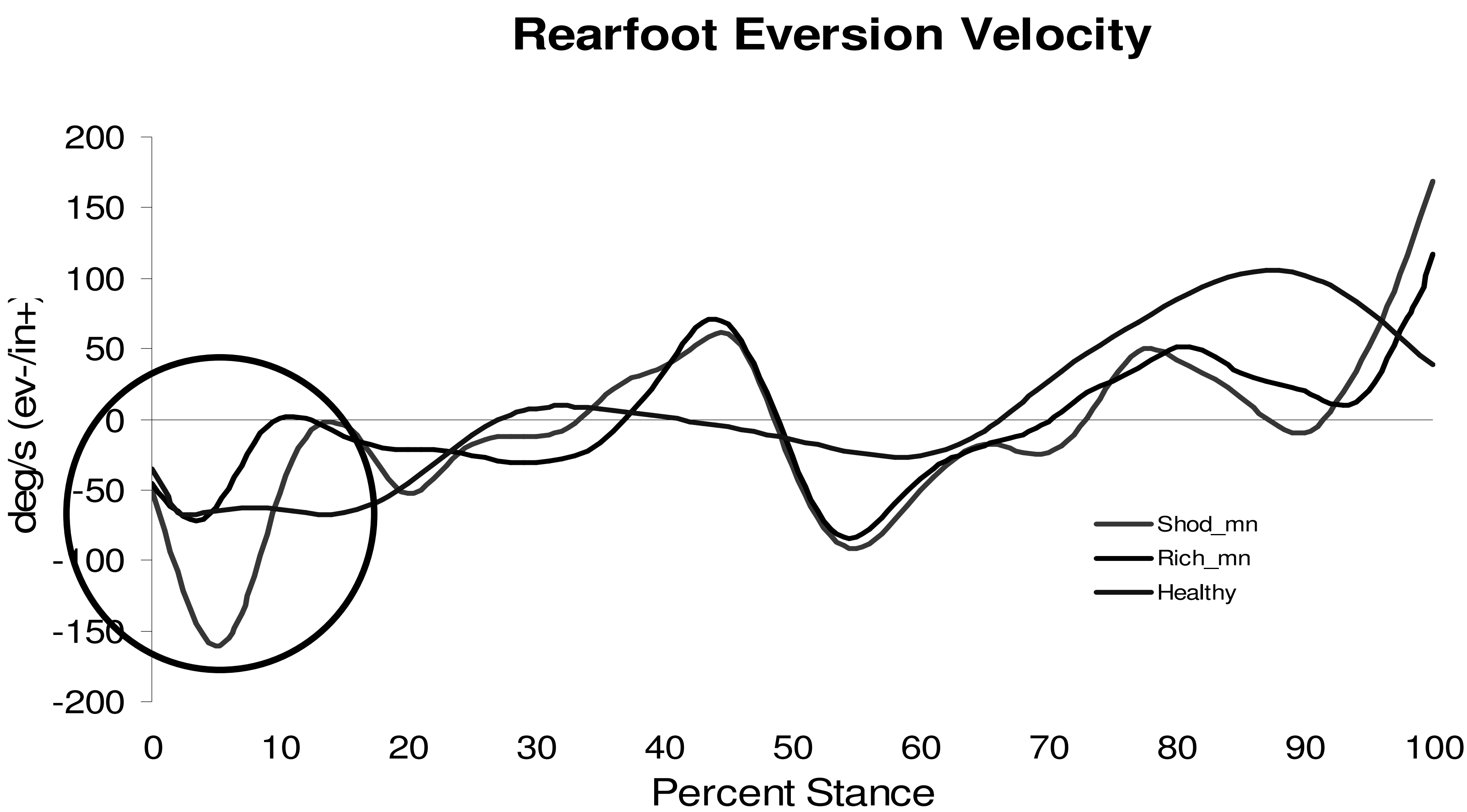
Rearfoot Analysis



Rearfoot Angle Frontal
20
15
10
5
0
-5
-10
deg (ev-/in+)
0
20
40
60
80
100
Percent Stance
Shod_mn
Rich_mn

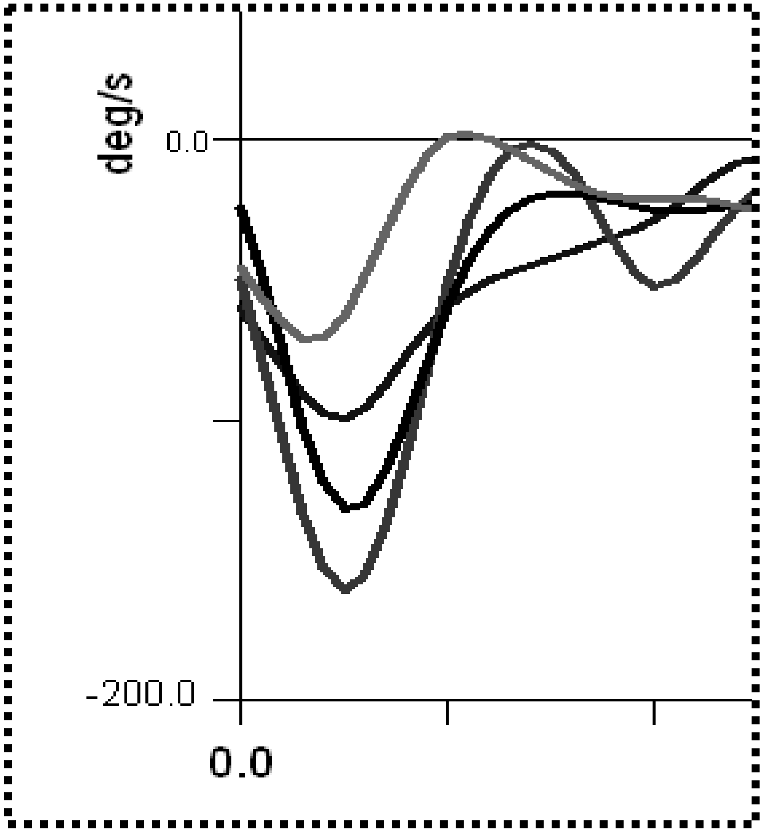


Rearfoot Eversion Velocity
200
150
100
50
0
-50
-100
-150
-200
-250
deg/s (ev-/in+)
0
20
40
60
80
100
Percent Stance
Shod_mn
Rich_mn


Rearfoot Eversion Velocity
200
150
100
50
0
-50
-100
-150
-200
deg/s (ev-/in+)
0
10
20
30
40
50
60
70
80
90
100
Percent Stance
Shod_mn
Rich_mn
Healthy

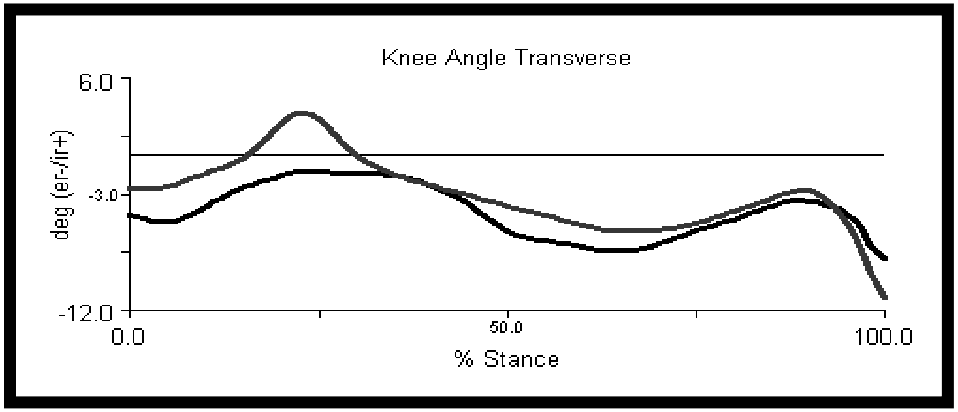
Rearfoot Eversion Velocity

------	SHOD
-----	ROOT
-----	PTTD
-----	RICH

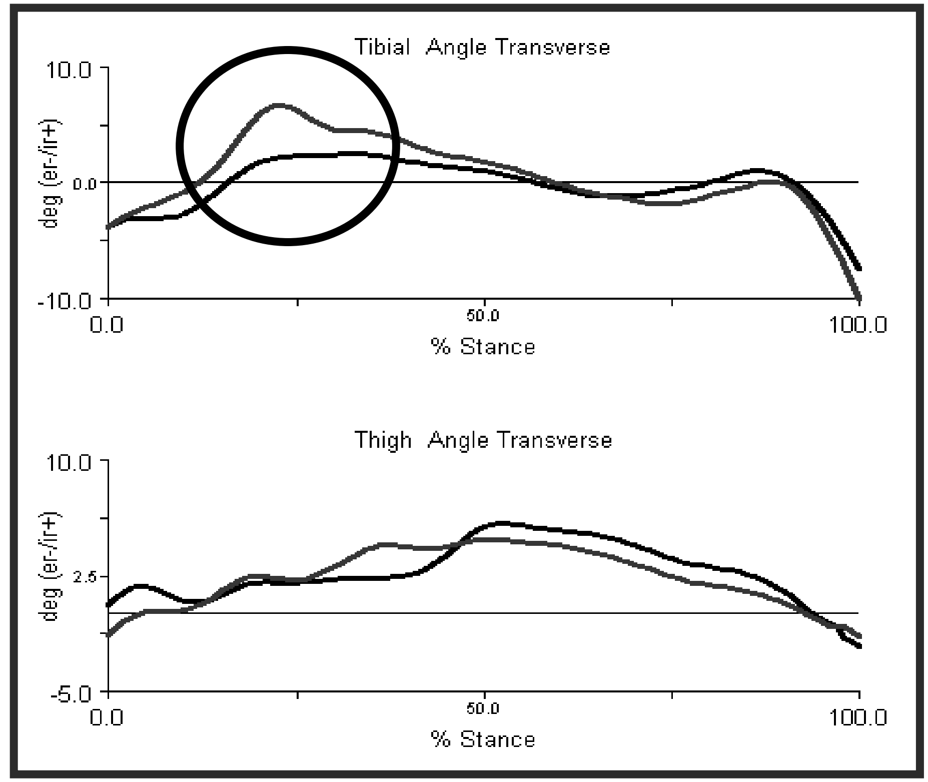


Knee Analysis

Knee Angle Transverse



Knee IR angle reduced during loading response.



Tibial internal rotation (IR) reduced.

Thigh internal rotation unchanged.

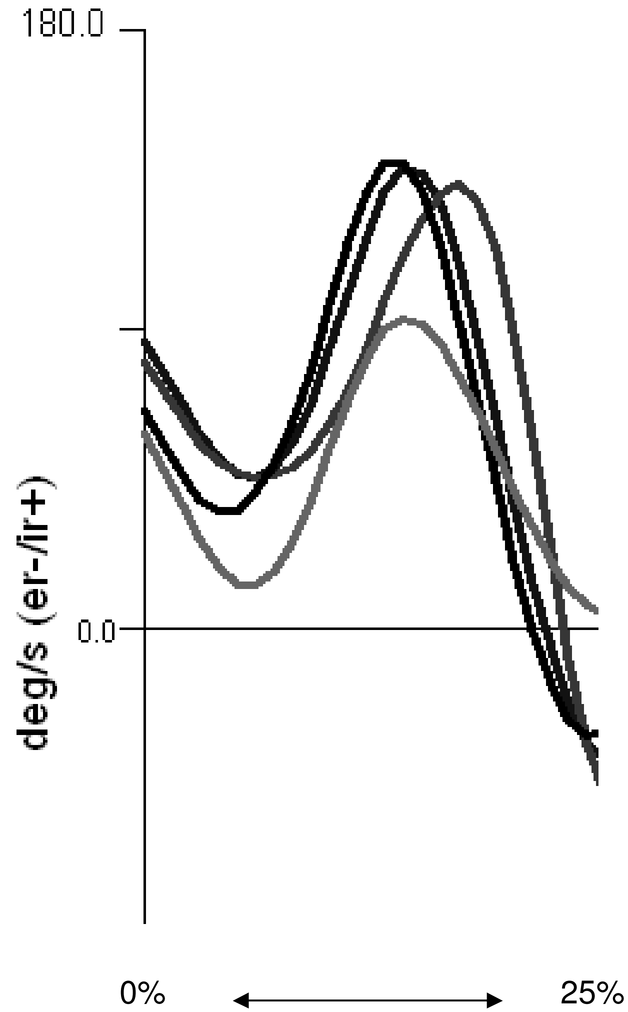
Tibial Velocity Transverse

------ SHOD

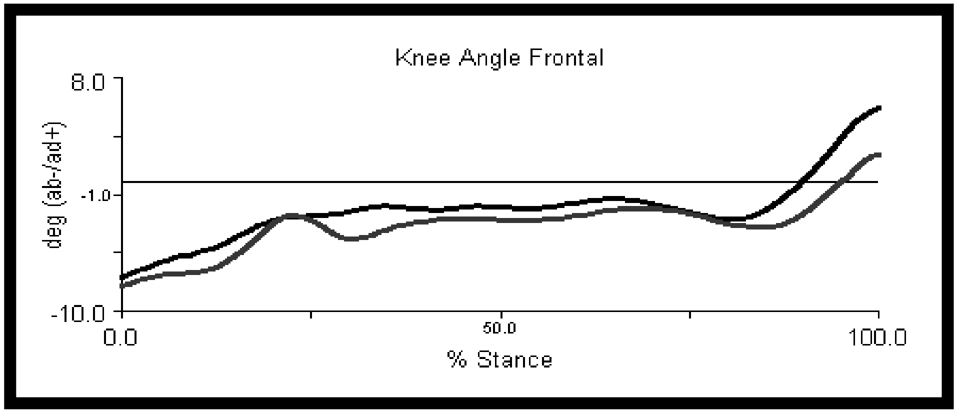
----- ROOT

----- PTTD

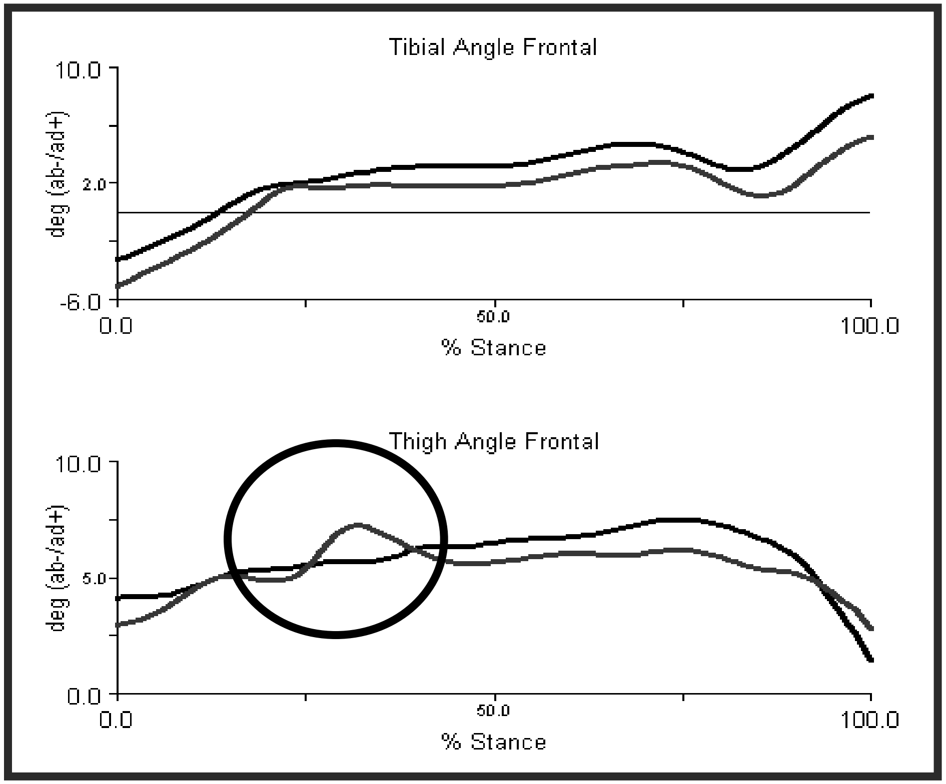
----- RICH



Knee Angle Frontal



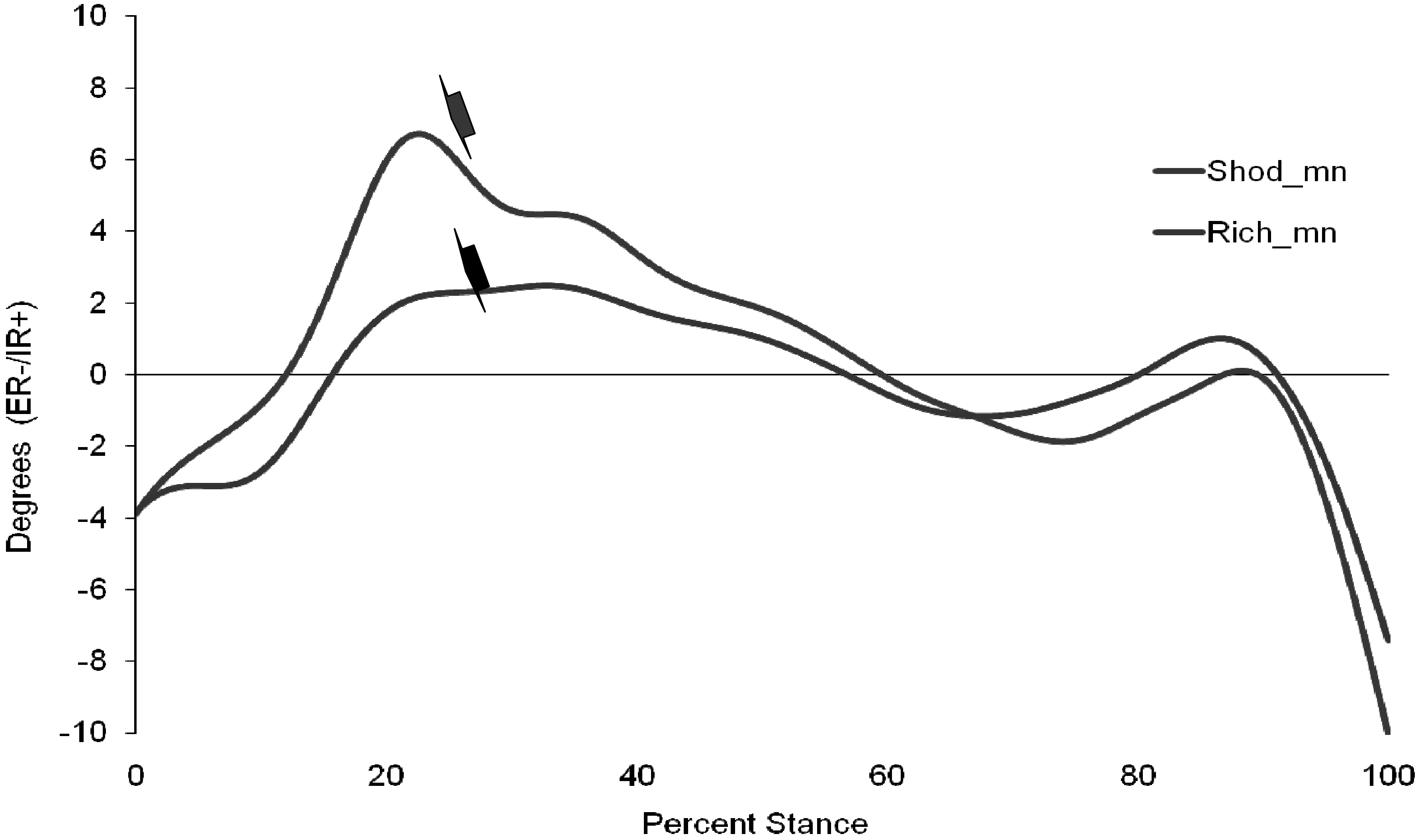
Knee abduction (valgus) angle reduced slightly (1-2°) throughout.



Tibial adduction increased.

Thigh adduction increased slightly (more fluid motion).

Tibial Angle: Transverse Plane



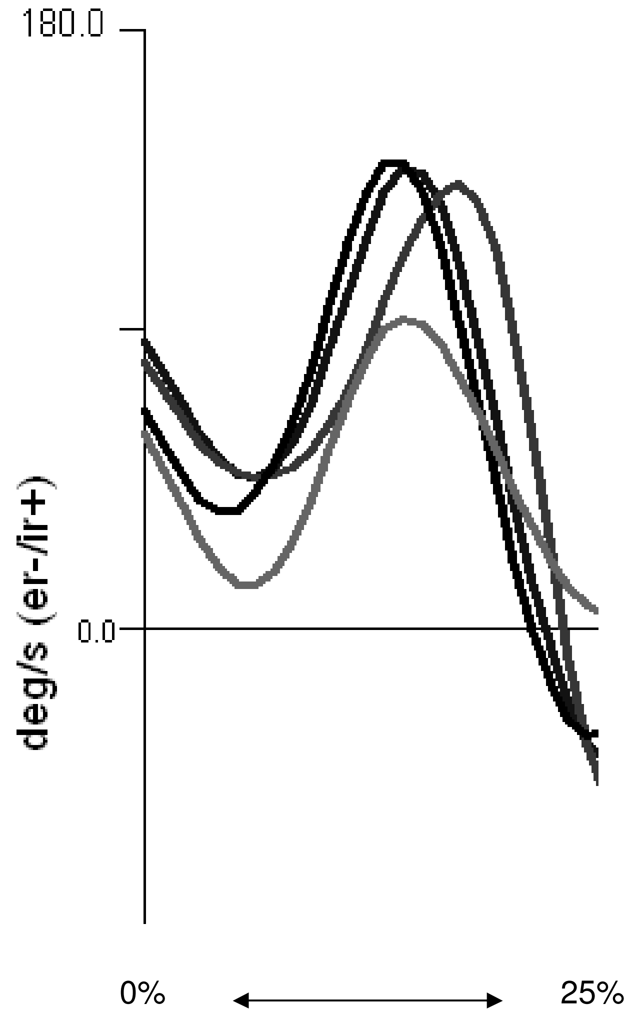
Tibial Velocity Transverse

------ SHOD

----- ROOT

----- PTTD

----- RICH



Take Home Message

- In the case subject:

1. At the ankle, the subject exhibited:
    - ↓s in rearfoot eversion (pronation) velocity, excursion, moment and impulse.
    - Small ↑s in rearfoot eversion angle throughout stance.

Take Home Message

- In the case subject (cont'd):

2. At the knee, the subject exhibited:
    - ↓s in knee internal rotation,
    - ↓s tibial internal rotation angle and velocity, and
    - ↓s in knee abduction (valgus) of 1-2° which may be clinically significant.

Take Home Message

- In the case subject (cont'd):

3. Sagittal plane dynamics were not influenced in this subject:
    - Terminal phase ankle plantar flexion unchanged, and
    - Terminal phase rearfoot adduction unchanged (Rattanaprasert et al., 1999).

Ankle Flexion-Extension

	Moment Arm	Excursion
TA	High	High
FDL	High	High
TP	Low	Low

Hintermann, 1994

Vascularity

Frey, JBJS 72A: 884, 1990

<u>**TP Tendon**</u>

- **No mesotendon distally**
- **blood supply : PT & DP art.**
- **Hypovascular zone begins 40mm prox. to navicular, extends 14mm prox.**

Tendon of Tibialis Posterior

1. Zone of hypovascularity
   from tip of malleolus:
   14 mm prox $\longrightarrow$ 10 mm distal

2. Abrupt change of direction

3. 1st Pulley: Malleolar groove
   2nd Pulley: Navicular

Bracing the Adult Acquired Flatfoot

RECENT INSIGHTS

- Not solely due to TPD
- Pre-existing flatfoot
- Tibia is dominant lever

Two Lever Theory

"The ankle connects two unequal levers, the leg and the foot. The longer lever contains only a pair of bones, the tibia and fibula. The more massive tibia conveys most of the body weight directly on the talus and acts as a solid lever in ankle injuries. The foot, on the other hand, is composed of numerous small bones intercepted by joints, which weaken it as a lever."

Kelikian, 1985

Subtalar Stability
Role of Ligaments

- CFL, Ant & Post ITCL and Post Talo Calc Lig all contribute to stability in all positions
- Ant & Post ITCL most important

Stephens MM, Sammarco GJ: The stabalizing role of the lateral ligament complex around the ankle and subtalar joints. Foot and Ankle 13(3) 130-136, 1992.