A person is rappelling down a red rock cliff face. The cliff has distinct horizontal layers of red and orange rock. The sky is bright blue with scattered white clouds. The person is wearing a harness and a helmet, and is positioned in the center of the frame, slightly to the right.

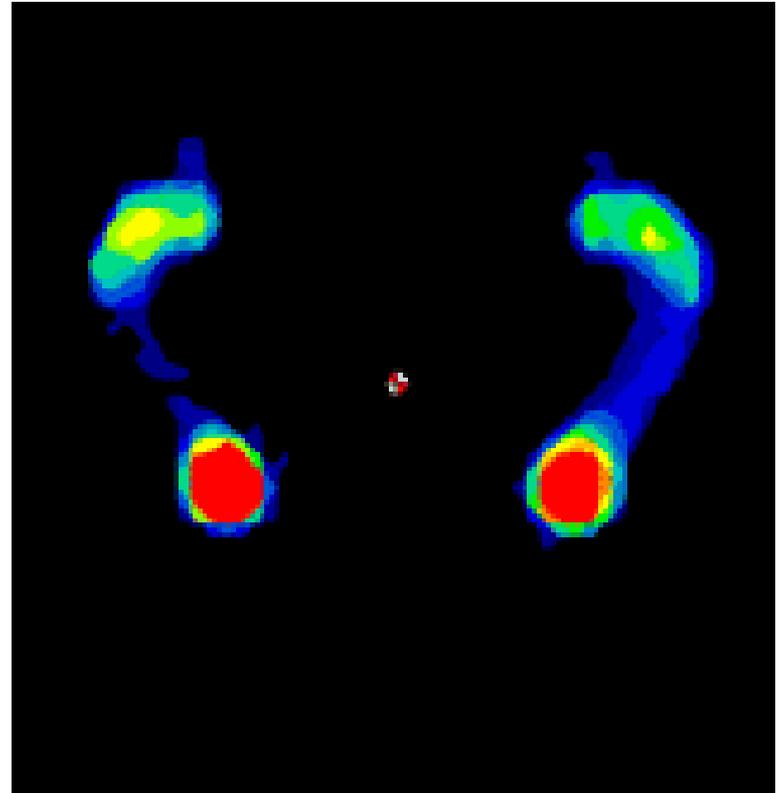
Biomechanical Considerations of the Diabetic Foot

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What do we know about the diabetic foot?

- Diabetic neuropathy changes the foot structure
- Affects foot function
- Abnormal mechanical loading of the foot
- Diabetic foot ulceration



What is different about gait in the diabetic and neuropathic patient?

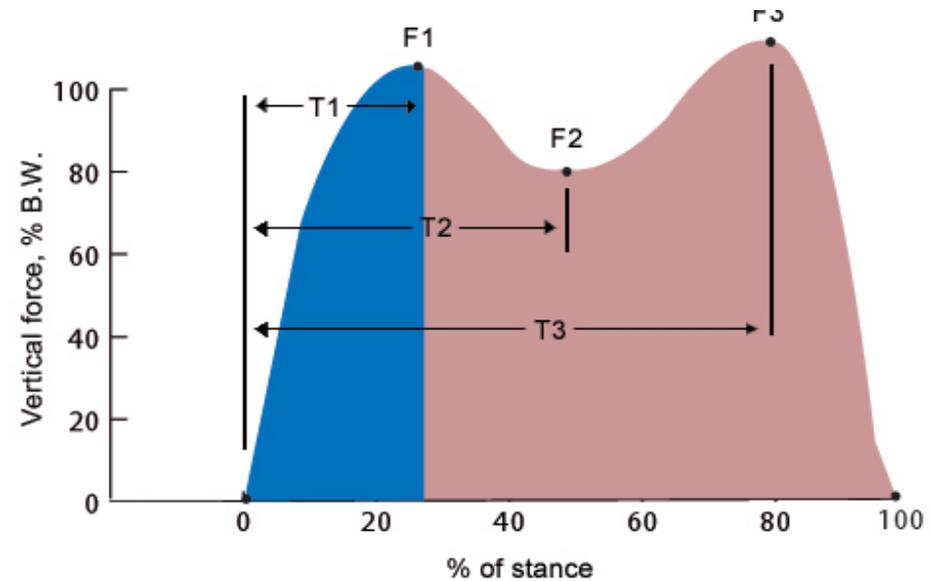
Diabetics with neuropathy

- Smaller stride length
- Slower walking speed
- Spend less time in single support



What is different about gait in the diabetic and neuropathic patient?

- Peak vertical force is greater, especially in diabetics with neuropathy
- With neuropathy, timing is different so that the peak vertical force occurs at heel strike instead of toe-off
- Force - pressure



Vertical Load

What Causes Abnormal Foot Pressures?

1. Bony prominences
2. Plantar tissue stiffness or flexibility
3. Plantar tissue thickness
4. Prominent metatarsal heads
5. Increased hardness (resistance to pressure) of the skin
6. Charcot arthropathy
7. Callus
8. Limited joint mobility (ankle, STJ & 1st MTP)
9. Thickness of the Achilles tendon
10. Thickness of the plantar fascia

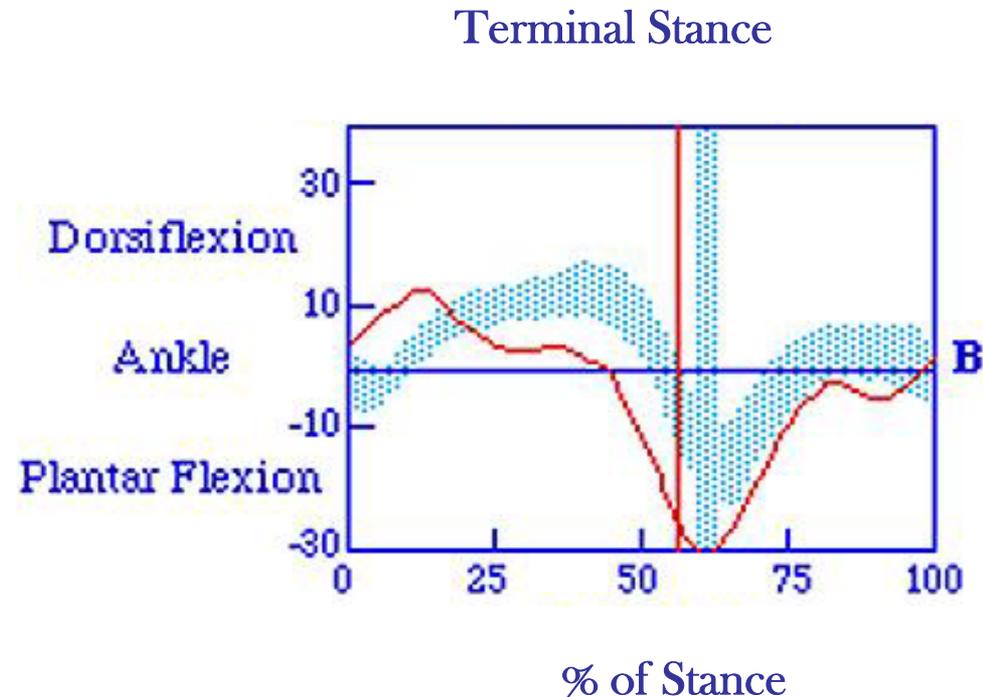
What is the role of joint stiffness in abnormal forefoot pressures?

- Joint stiffness is a function of joint moment and motion.
 - Joint is stiffer if it has less motion
 - Joint is stiffer if it has a greater moment or torque



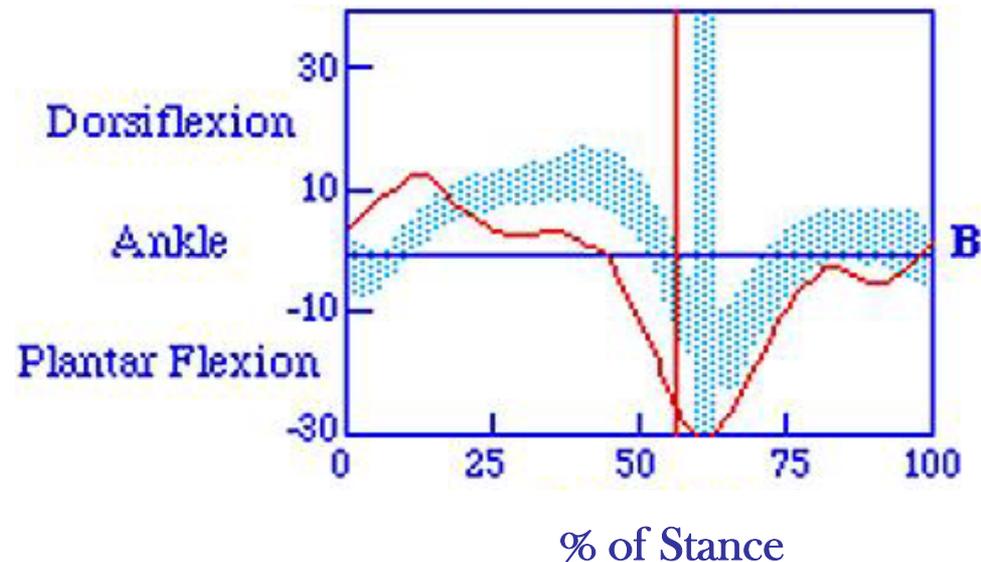
What is the role of joint stiffness in abnormal forefoot pressures?

Is there a difference in joint stiffness between diabetic patients with and without neuropathy?



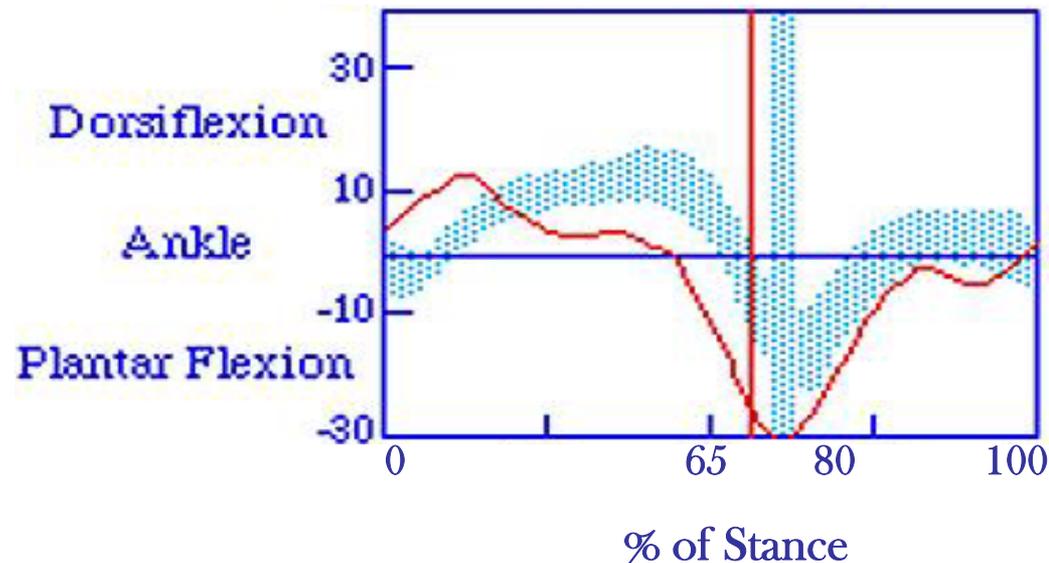
Ankle Joint Stiffness in Diabetics

- Less ankle stiffness
- Timing - peak dorsiflexion occurred earlier at 60-70% of stance
- Large increase in stiffness in the transition period between dorsiflexion and plantarflexion



Ankle Joint Stiffness in Neuropathic Patients

- Higher ankle stiffness
- Peak dorsiflexion occurred later at 65-80% of stance
- Consistent increase in stiffness toward dorsiflexion



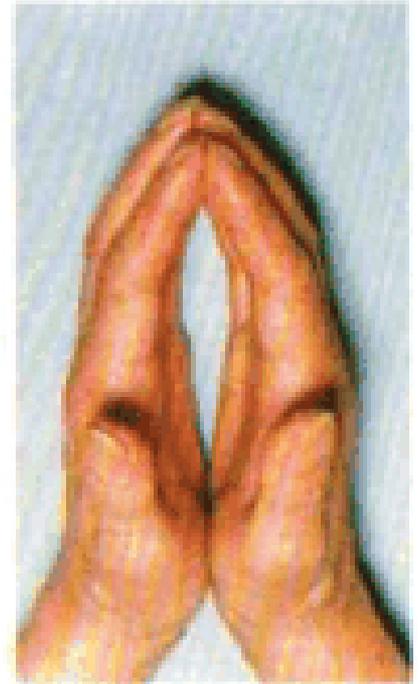
How does stiffness correlate to increased plantar pressures?

- Muscle strength may not be a contributing factor
- Timing to peak ankle dorsiflexion may be



What is the role of limited joint mobility in causing high plantar forefoot pressures?

- Progressive stiffening of the collagen containing tissues
- Loss of joint mobility
- Lead to a fixed flexion deformity
- Predisposes to foot ulceration

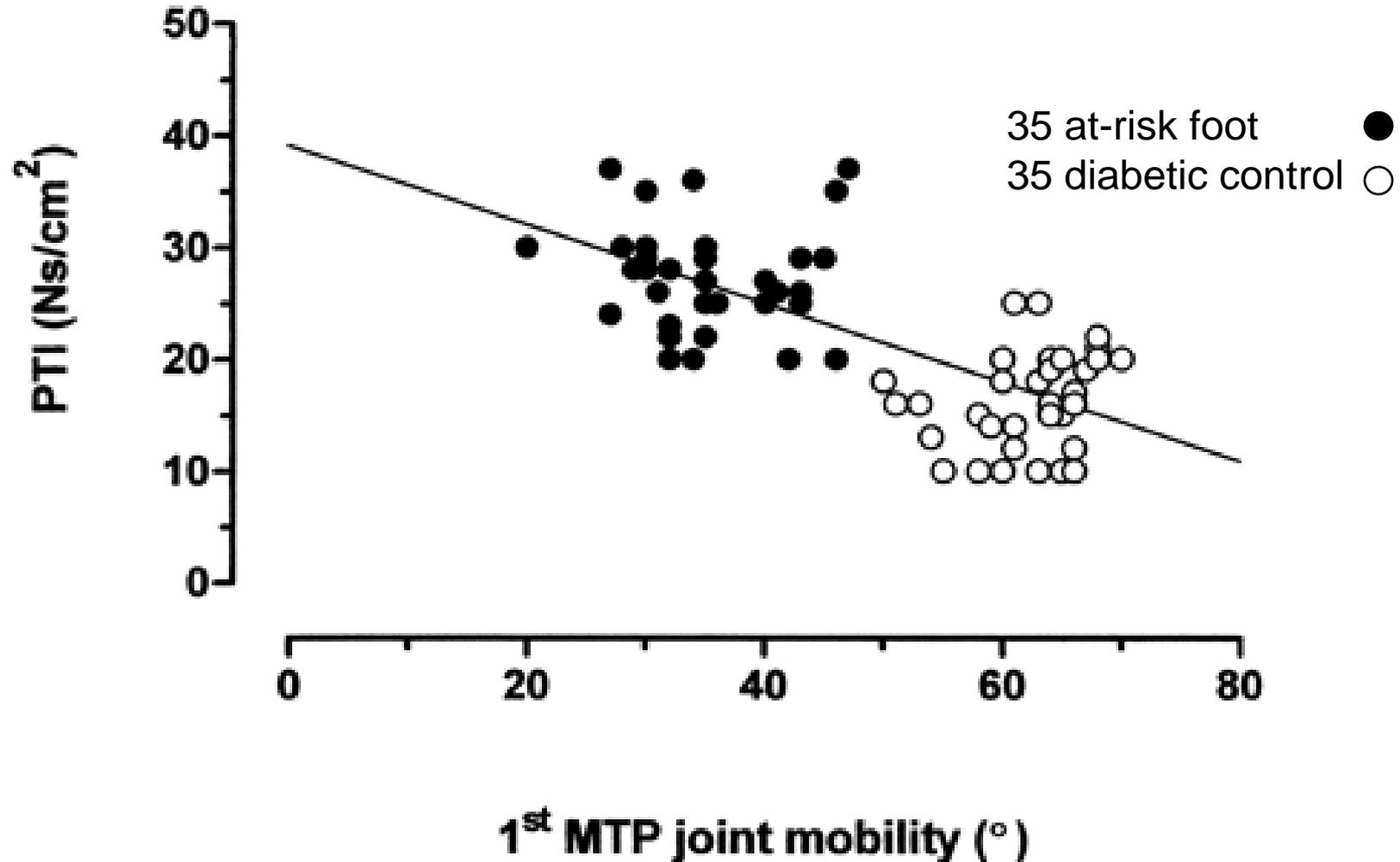


Prayer sign

Limited Joint Mobility

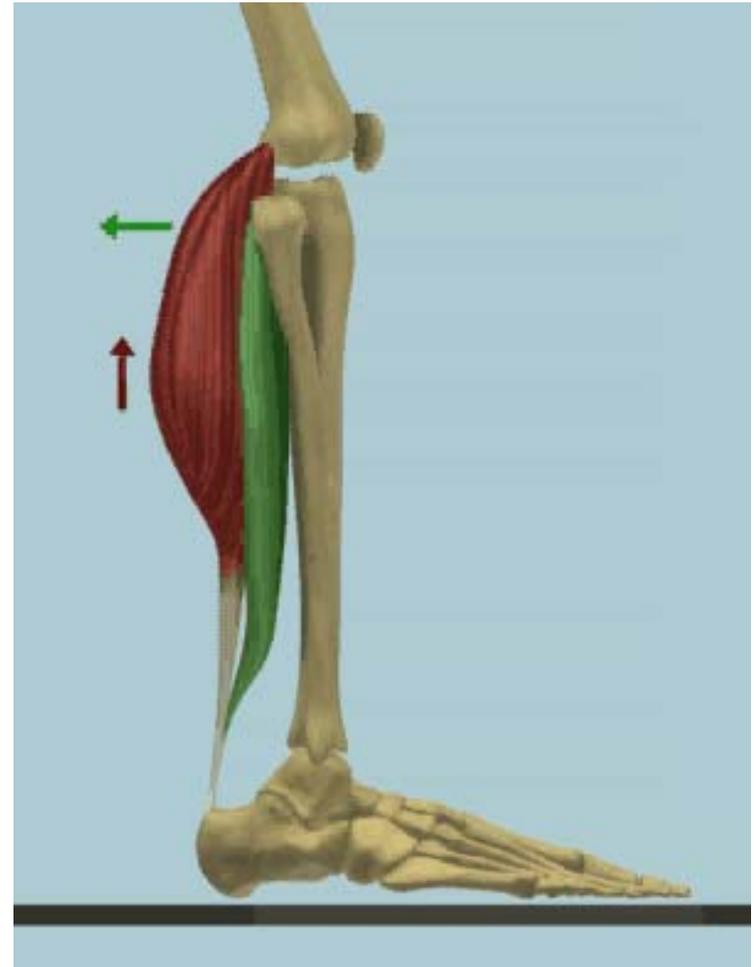
	35 Diabetics with Neuropathy (at-risk)	35 Diabetic	35 Non- Diabetic
Ankle joint mobility	17.9 ± 0.7	28.4 ± 0.8	31.0 ± 1.6
1st MTP joint mobility	35.3 ± 1.1	62.0 ± 0.8	59.4 ± 1.0
Pressure time integrals (N · s/cm ²) P<0.0001	27.4 ± 0.8	16.1 ± 0.7	16.4 ± 0.6

Correlation of the passive first MTP joint mobility and PTI



Are there other causes for increased forefoot pressures in diabetic patients?

- Limited joint mobility at the ankle
- Limited joint mobility at the MTP
- Increased thickness of the Achilles tendon
 - Armstrong et al., *JBJS*, 1999
 - Hastings et al., *J Orthop Sports Phys Ther*, 2000



What is the role of the plantar fascia in abnormal forefoot pressures?

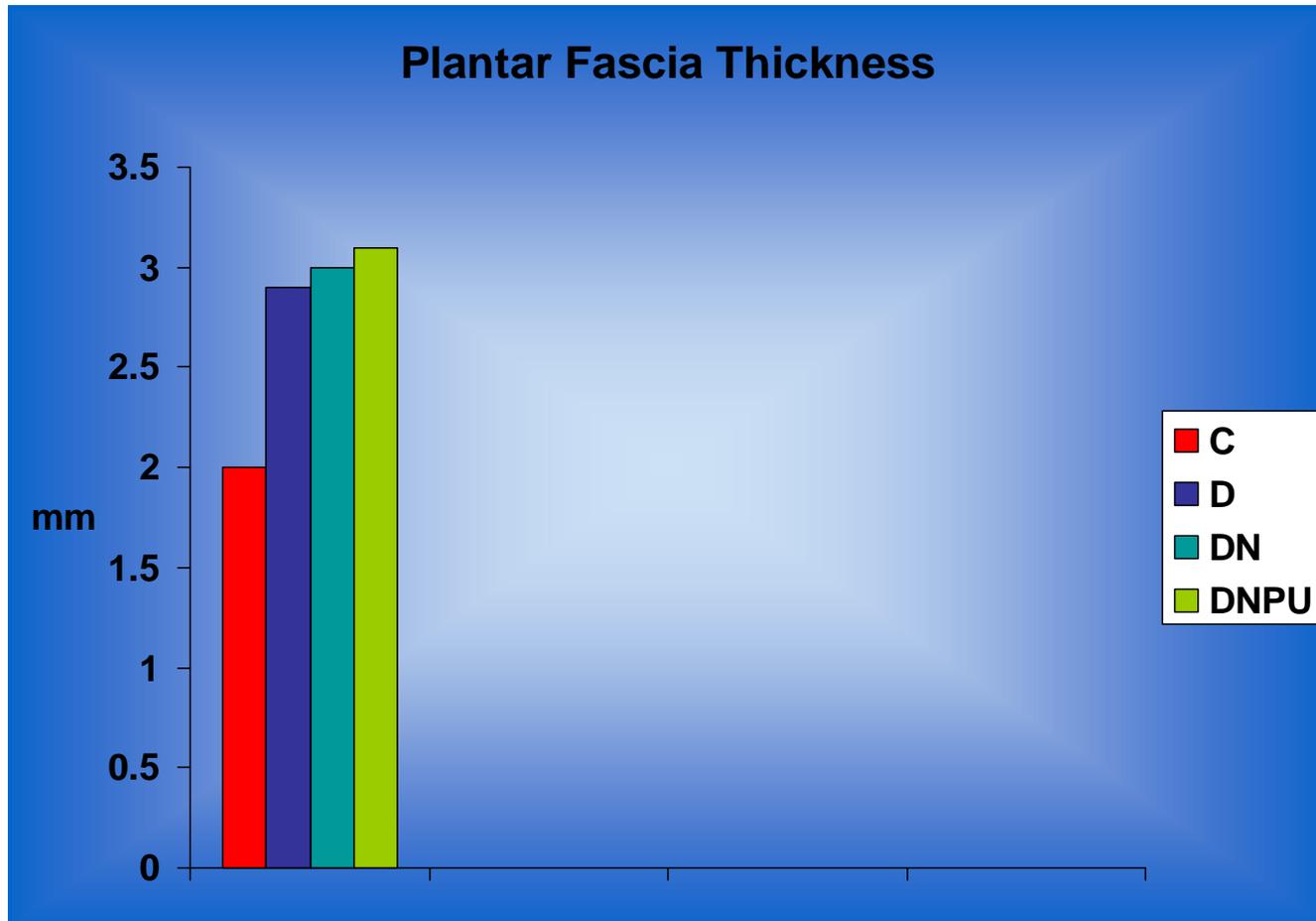
Relationships among

- Thickness of plantar fascia
- Mobility of the metatarso-phalangeal joint
- Forces expressed under the metatarsal heads.

61 diabetic patients

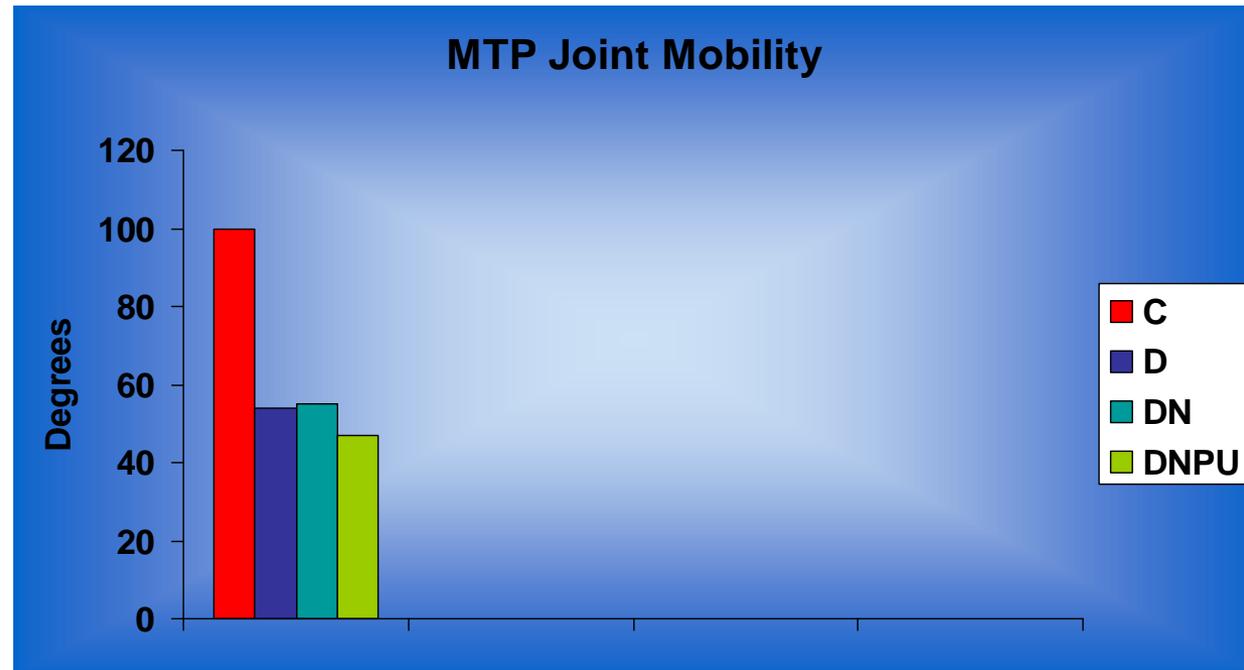
- 21 without diabetes (C)
- 27 diabetics without neuropathy (D)
- 19 diabetics with neuropathy (DN)
- 15 diabetics with neuropathy & previous ulceration (DNPU)

Diabetic patients presented with increased thickness of plantar fascia



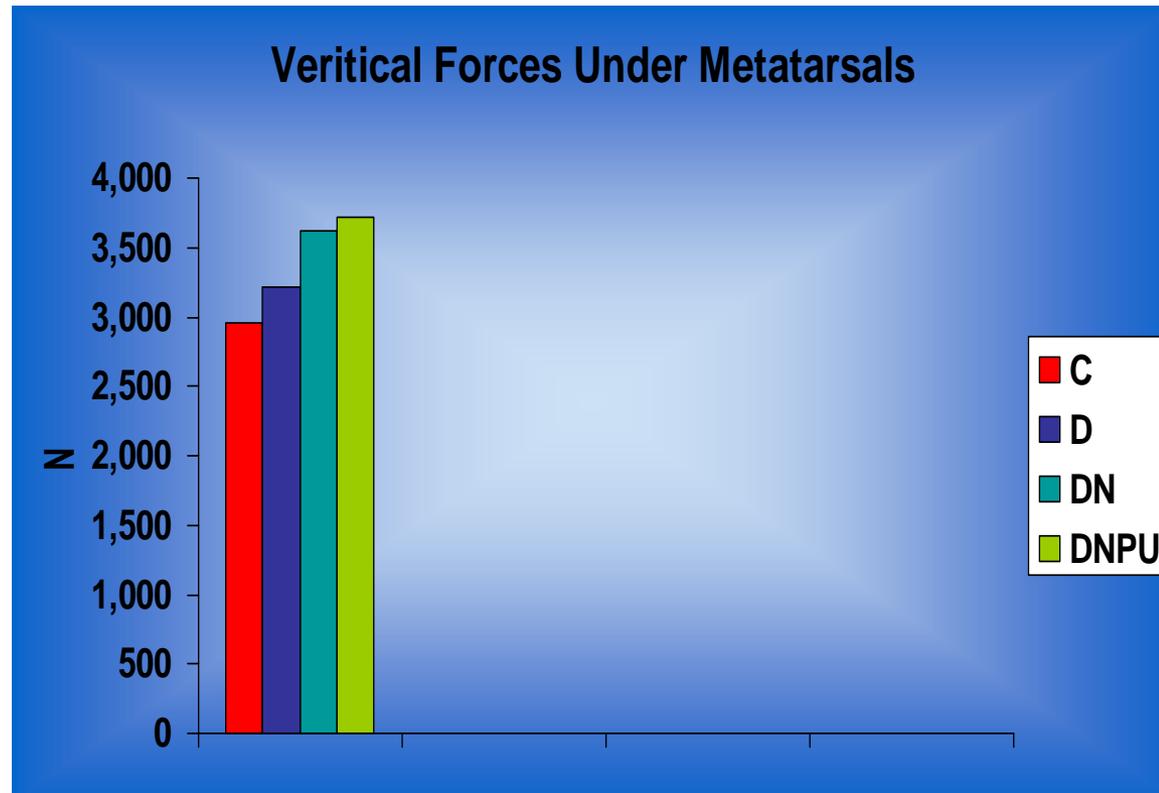
MTP range of motion

- Diabetics had significantly reduced MTP range of motion
- The thicker the plantar fascia the less range of motion noted at the MTP



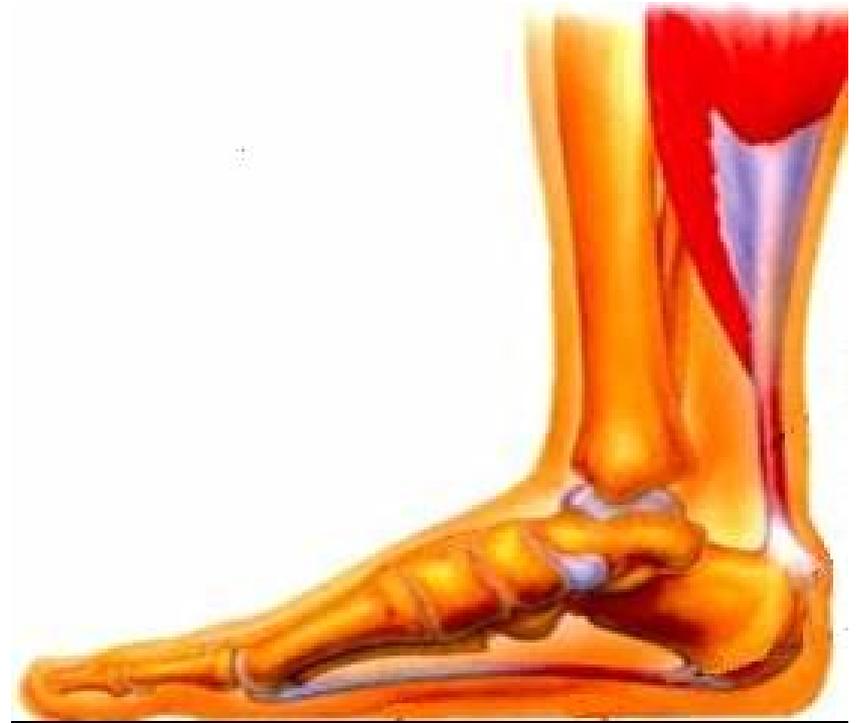
Vertical forces under metatarsal heads

Direct correlation between thickness of the plantar fascia and increased vertical forces under the metatarsal heads.



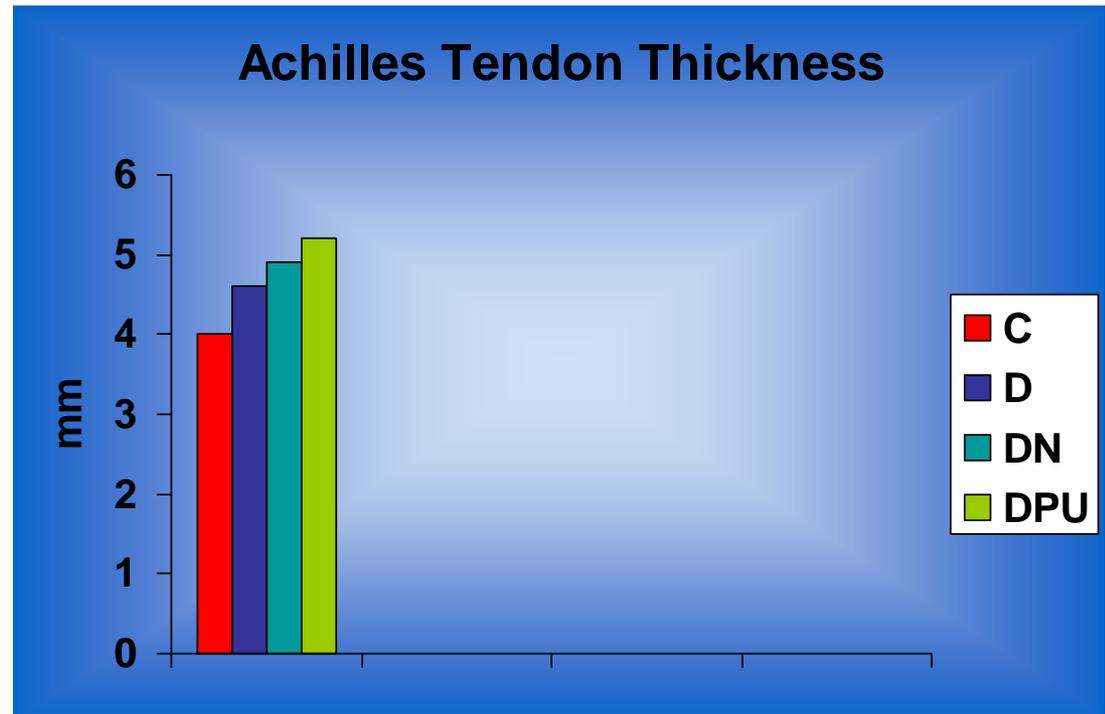
Taking it one step further

- Using data from the previous study
- Does increased thickness in the plantar fascia alter the windlass mechanism?



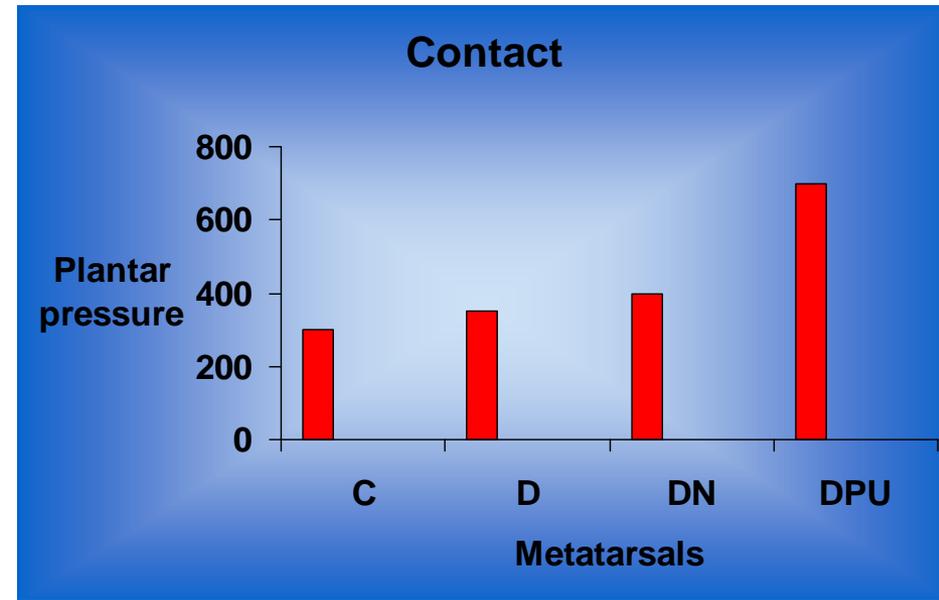
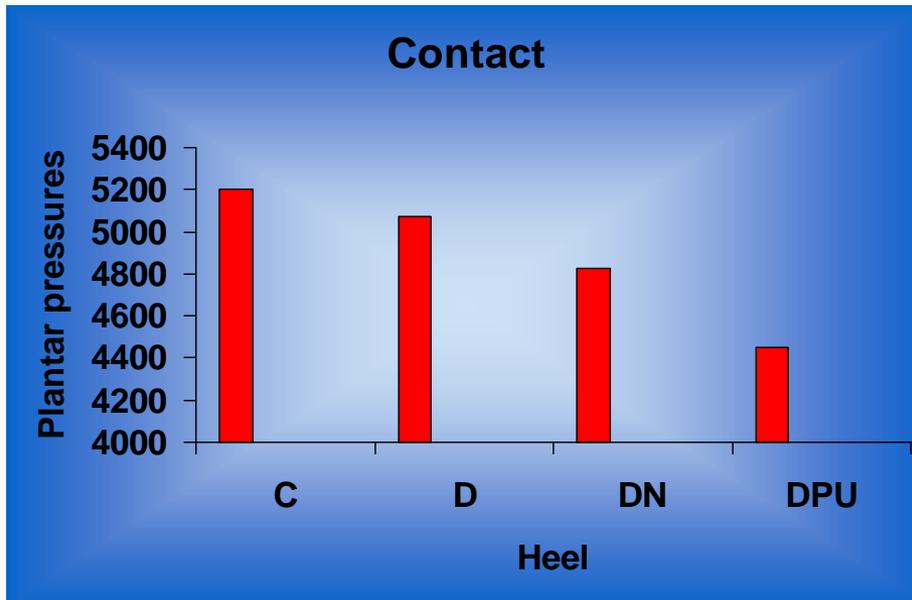
Taking it one step further.

- Diabetic patients presented with increased thickness of the Achilles tendon
- Inverse correlation between the PF & AT with DNPU



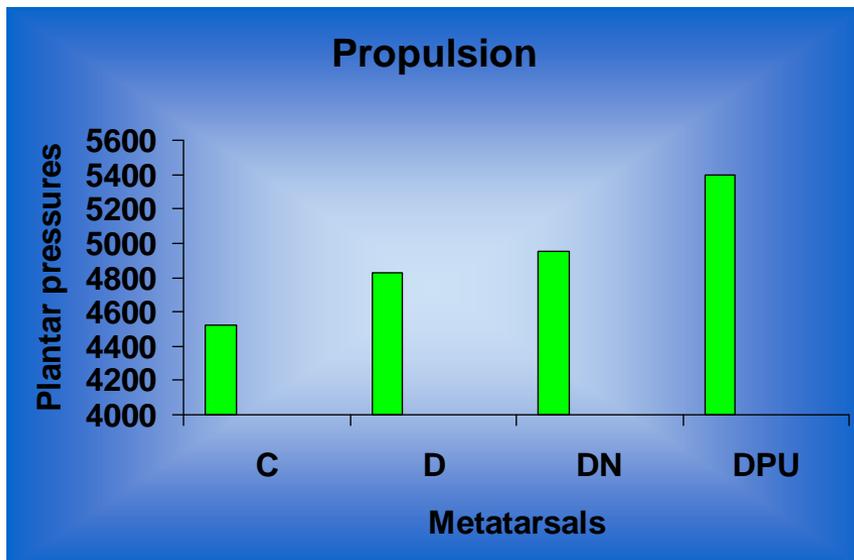
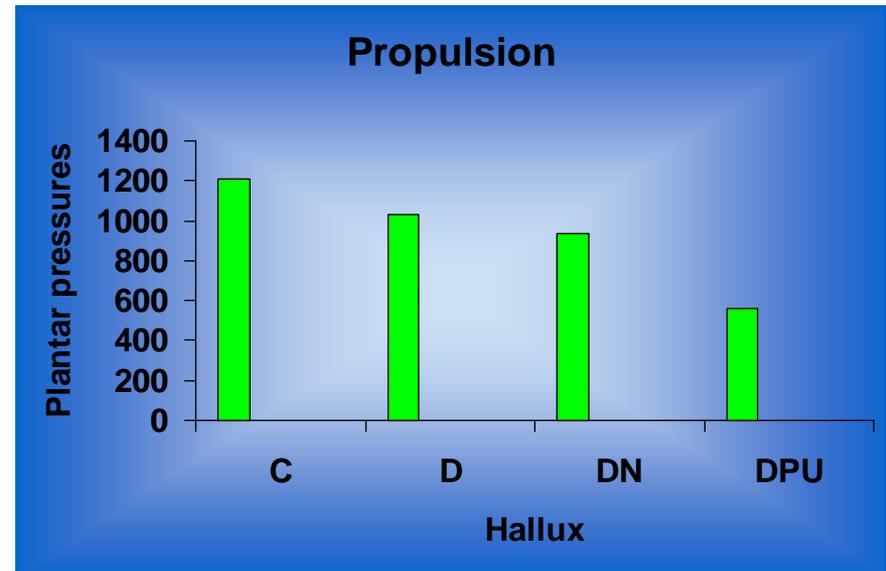
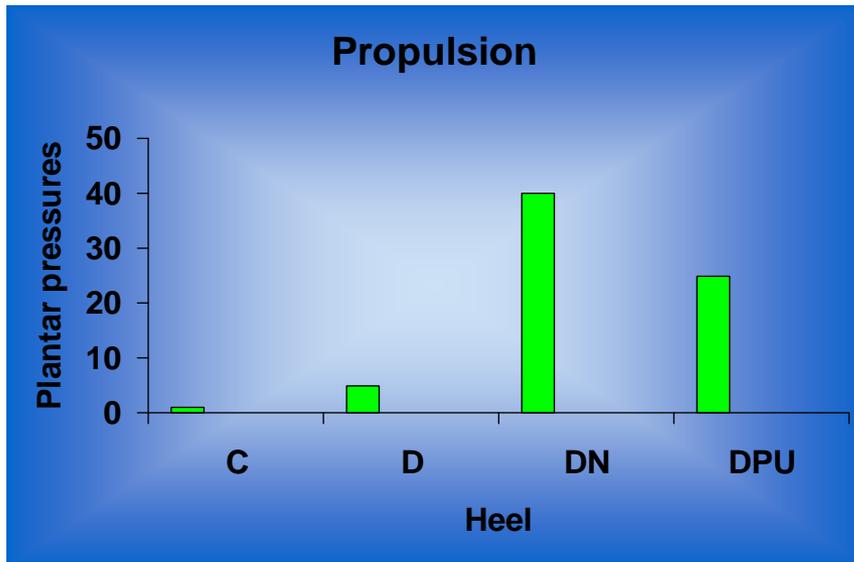
Diabetic patients had increased thickness of the Achilles tendon

Vertical Ground Reactive Forces



DN & DPU patients had lower heel and higher metatarsal integrals during landing

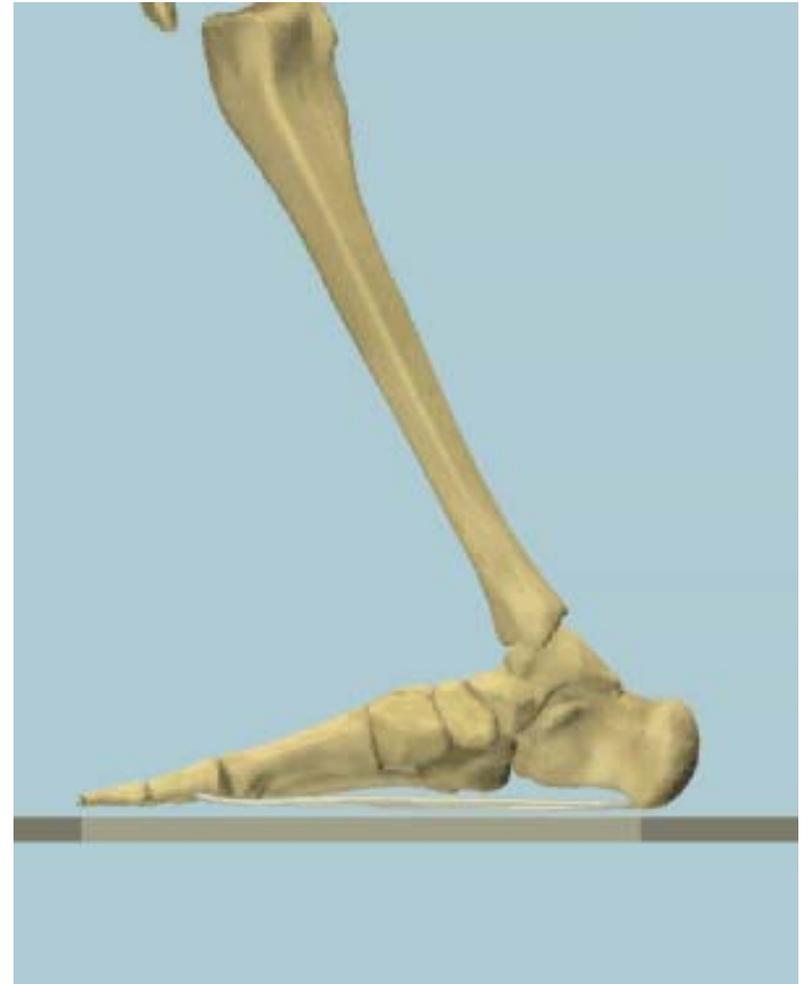
Vertical Ground Reactive Forces



Result: an early and prolonged loading of the metatarsal area

Altered onset of the windlass mechanism

- The Windlass should engage during propulsion.
- If the plantar fascia is abnormally thickened, the Windlass will engage early
- Foot becomes locked in a rigid configuration



What does this mean for treatment options?

- 17 diabetic subjects with high plantar pressures.
- Effects of:
 - Orthoses
 - Cushioning
 - Combination



Results

Patients were evaluated twice

- 3-mm flat PPT cushioning – 20% reduction
- Custom-made orthoses – 15% reduction
- PPT + Custom –made orthoses – 27% reduction
- Results were variable and in some cases reductions of up to 63% were achieved.

Most interesting

- Diabetics who had been using orthoses for 12 months had a significant reduction in peak plantar pressure when reassessed without orthoses.
- Those that had used orthoses walked slightly faster than in the initial examination, while those who had not used orthoses walked slower.

Questions to ponder

- Diabetics walk slower
- Timing is different in neuropathic patients
- Timing to peak dorsiflexion is different
- Early loading of the metatarsals
- Early engagement of the plantar fascia



Questions to ponder

1. Were plantar pressures reduced because the orthosis had an effect on timing?
2. If this is so, should we be using functional orthosis in the diabetic patient?



Thank you