Heel Pain and the Functional Anatomy of the Plantar Calcaneal Fat Pad

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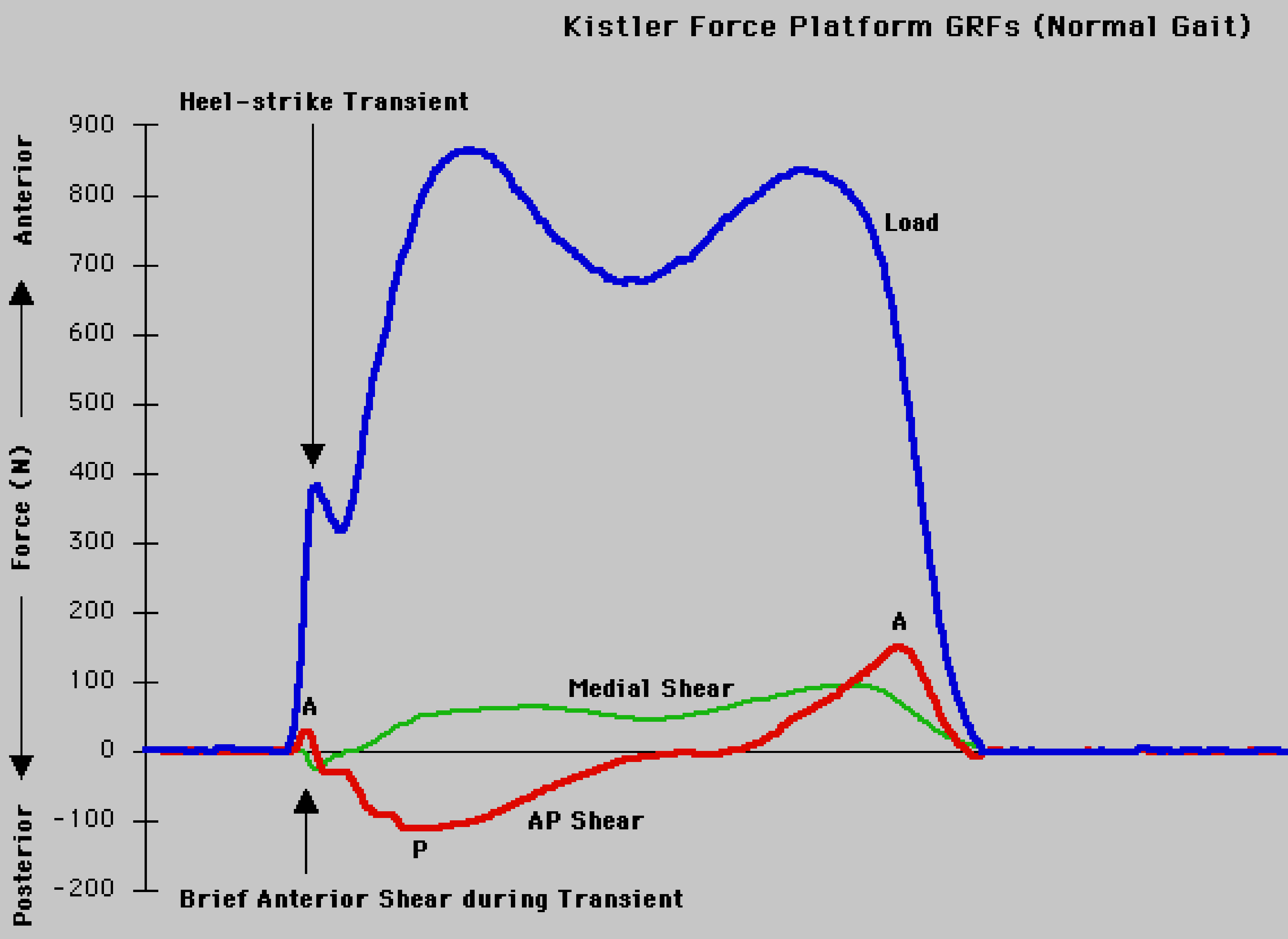
Primary Functions

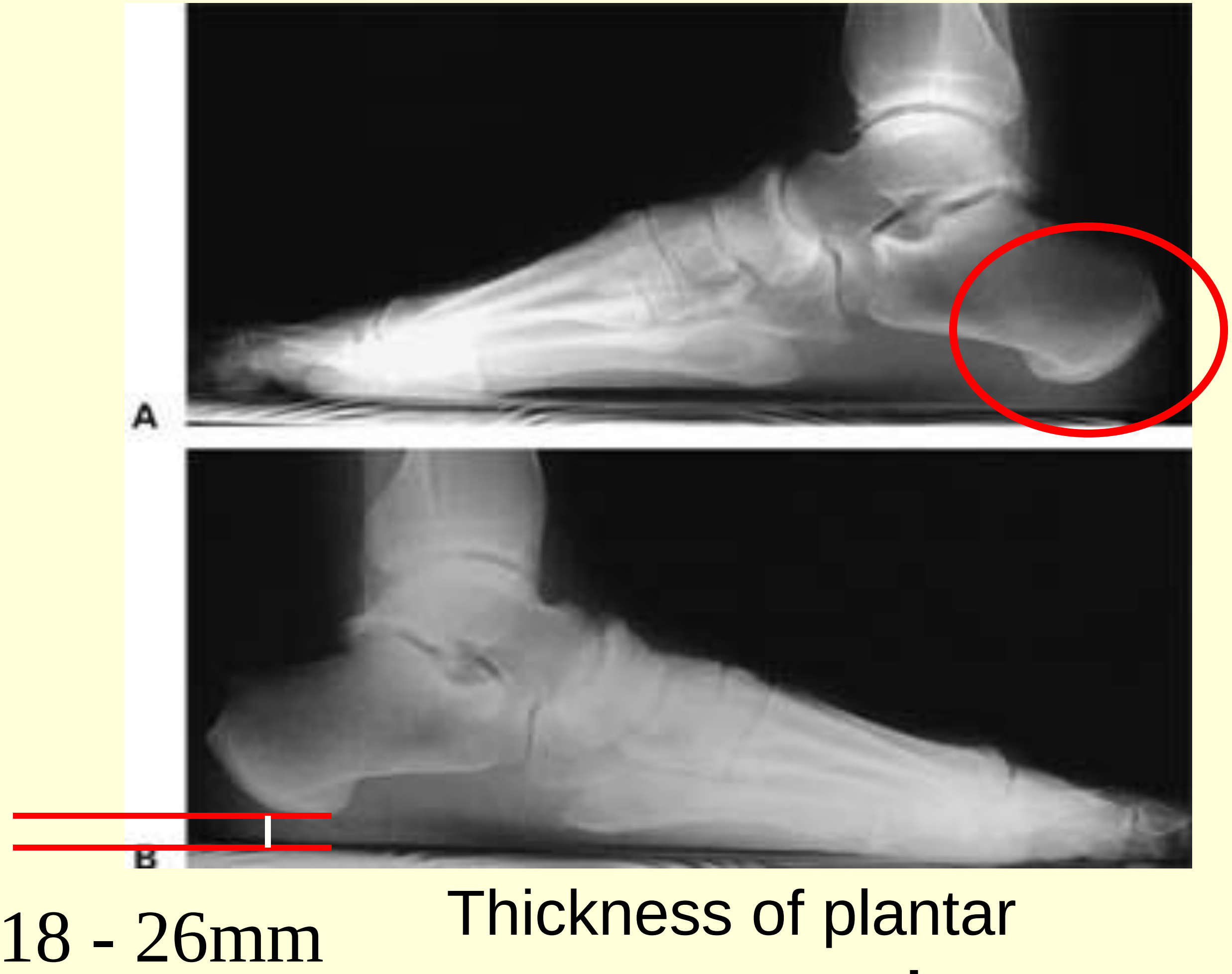
- Absorb shock at heel strike (ability to reduce size of impact force)
- Energy Dissipation
- Load bearing
- 70-100% of body weight in 0.05 secs

(Perry J. (1992) Gait Analysis. Normal and Pathological Function. Slack Incorporated USA, p.84)

- Pursuance of these however produces other important functions
- Venous heel pump/superficial venous drainage
- Grip
- Insulation


Kistler Force Platform GRFs (Normal Gait)
Heel-strike Transient
900
800
700
600
500
400
300
200
100
0
-100
-200
Anterior
Force (N)
Posterior
Load
A
Medial Shear
A
AP Shear
P
Brief Anterior Shear during Transient

Rome et al. 1998
 - stat. significant mean difference in thickness = 8.4mm (95%CI 7.68-9.13mm)



Thickness of plantar heel 'fat pad'

Rome K., Campbell R.S.D., Flint A. A., Haslock I. (1998). Ultrasonic heel pad thickness measurements: a preliminary study. The British Journal Of Radiology, 71 p.1149-1152

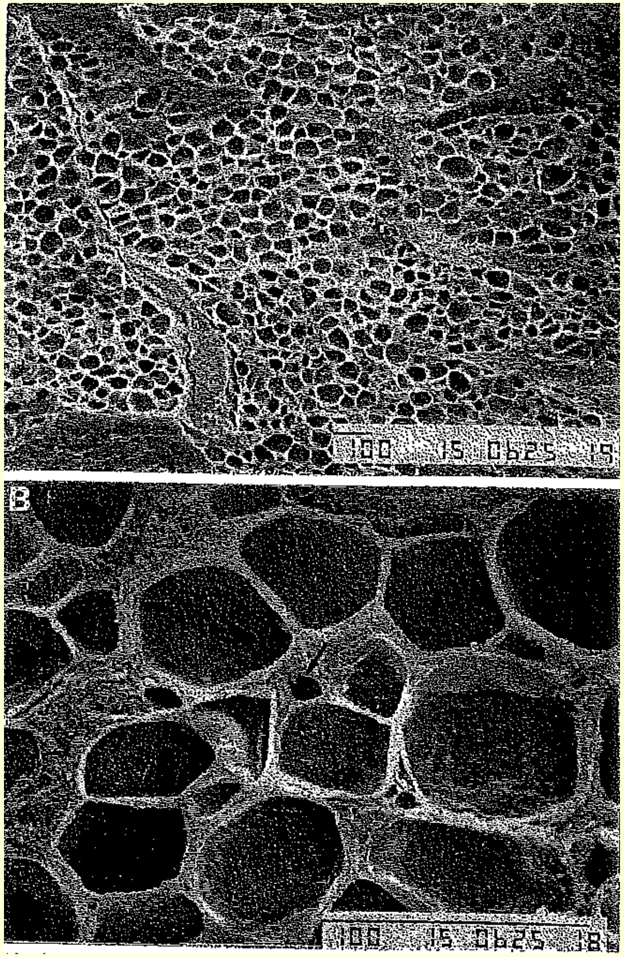
Plantar heel fat pad construction – general features

- Approx. 18mm of thickness inferior to calcaneal tubercles (can hypertrophy to 26mm)
- Loaded surface area of between 9-19 sq. cm
- Contains micro and macro-chambers, superficial to deep
- Reticular arrangement of collagen/elastin septral walls containing lipocyte

Bojsen-Møller,F.,Jørgensen U. (1991) The Plantar Soft Tissues: Functional Anatomy and Clinical Applications. Chapter in Jahss M.H. (1991) Disorders of the Foot and Ankle-Medical and Surgical Management 2nd Ed. W.B.Saunders, Philadelphia.

Plantar heel construction

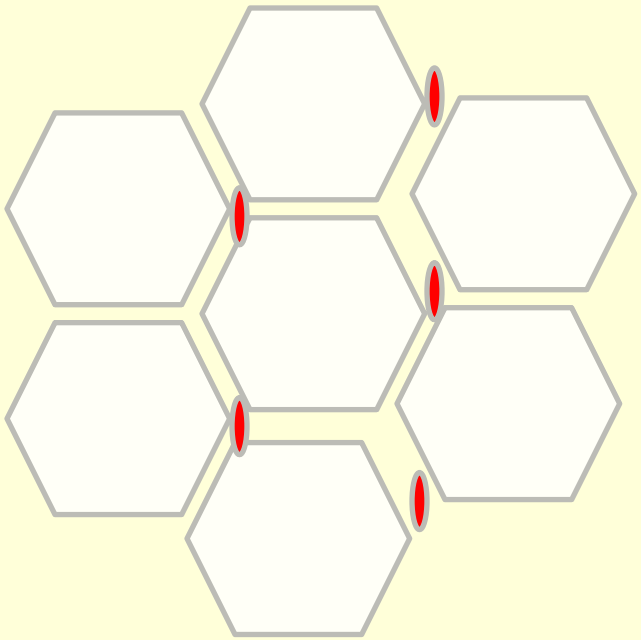
- Micro-chambers
- ≈ 3.5mm thick unloaded and 3.3mm loaded
- Macro-chambers ≈10mm thick unloaded and 5.5mm loaded
- Hsu C.C., Tsai W.C., Wang C.L., Pao S.H., Shau Y.W., Chuan Y.S. (2007) Microchambers and macrochambers in heel pads: are they functionally different? J. Appl. Physiology 102: 2227-2231



Jahss et. al. 1992

Plantar heel construction

- Superficial micro-chambers immediately inferior to the dermis - held together by septral walls of dense irregular collangenous connective tissue
- Superficial layer is highly vascular (contained blanching on pressure)
- Separated from macro-chambers by ligamentous tissue in the shape of a cup, the internal cup



- Vascular supply – 2 posterior branches and calcaneal branch of the peroneal artery and anastomoses of the posterior tibial artery

Plantar heel construction

- Internal cup attached to the calcaneal periosteum via vertical bands of septa forming the macro-chambers which thicken at the point of insertion

  Snow S.W., Bohne W.H. (2006) Observations on the fibrous retinacular of the heel pad. *Foot and Ankle International* 27.(8):p.632-5.)

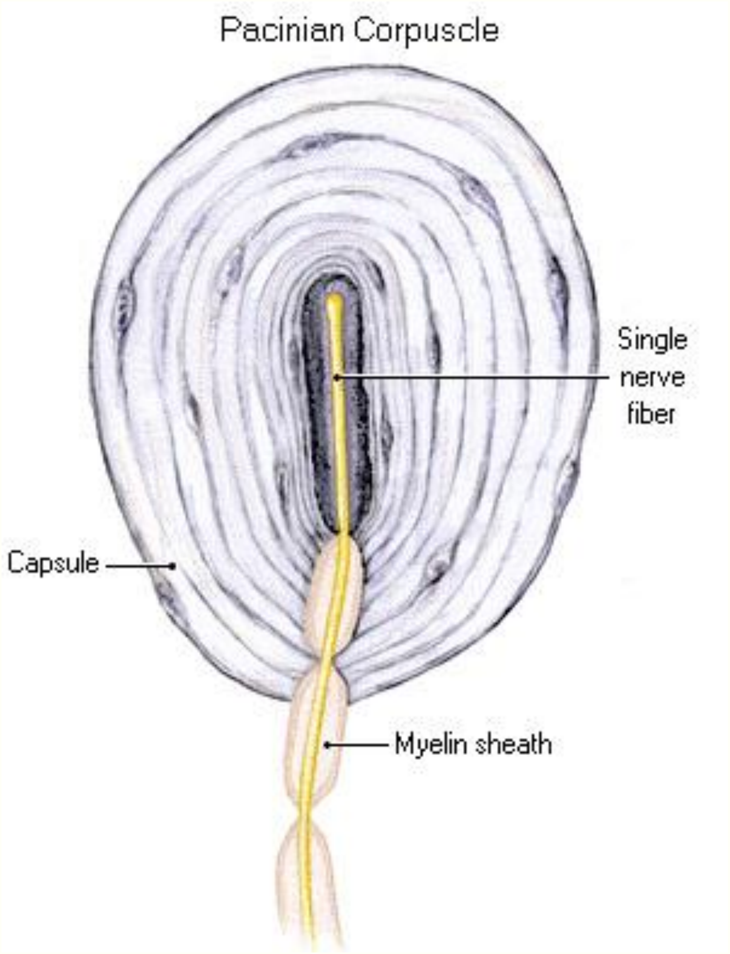
  Macro-chambers septral walls arranged in a reticular 'honeycombed' fashion with no interconnection between the 'units' in a closed cell structure.

Jahss M.H., Michelson J.D., Desai P., Kaye R., Kummer F., Buschman W., Watkins F., Reich S. (1992) Investigations into the Fat Pads of the Sole of the Foot: Anatomy and Histology. Foot and Ankle Vol.13 No.5 p.233-242

Plantar heel construction

- Both macro and micro-chambers contain a combination of different fatty acids with a greater ratio of unsaturated (palmitoleate,oleate, vaccenate and linoleate) to saturated (myristate,palmitate and stearate) in order that viscosity is maintained in temperatures lower than body heat
- Buschmann WR, Hudgins LC, Kummer F, Desai P, Jahss MH. Sep;14(7):389-94. Fatty acid composition of normal and atrophied heel fat pad. Foot Ankle. 1993

Afferent nerve endings/mechanoreceptors



- High concentration of Vater-Pacinian corpuscles in the fat chambers superior to the calcaneus. These corpuscles sense high frequency shocks and tissue displacement
- **Jahss M.H., Michelson J.D., Desai P., Kaye R., Kummer F., Buschman W., Watkins F., Reich S. (1992) Investigations into the Fat Pads of the Sole of the Foot: Anatomy and Histology. Foot and Ankle Vol.13 No.5 p.233-242**

Afferent nerve endings/ mechanoreceptors

- High concentration of Meissner's corpuscles in the heel dermis sensing touch
- Contribute to balance during the stance phase via phasic muscle activation?

Under Compression

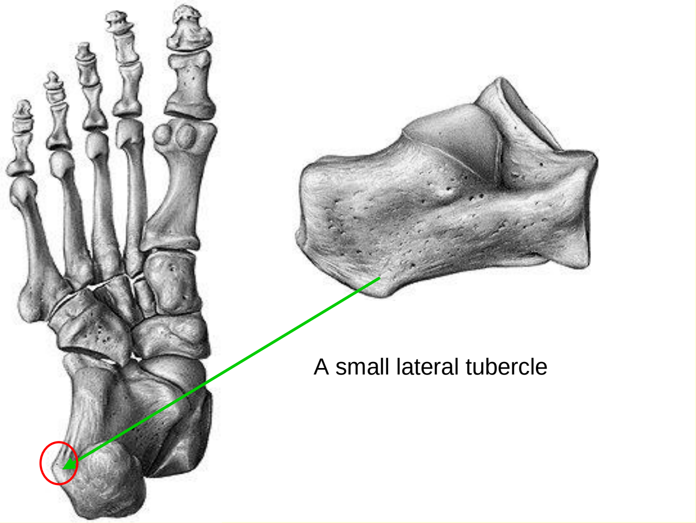
- Perry calculated that the impact load on the medial tuberosity of the calcaneus was approximately 5kg/cm2 with a frequency of 1160 impacts per mile, in a normal walking subject.
- Perry J. Anatomy and Biomechanics of the Hindfoot. Clinics in Orthopaedics 1983;177:9-15

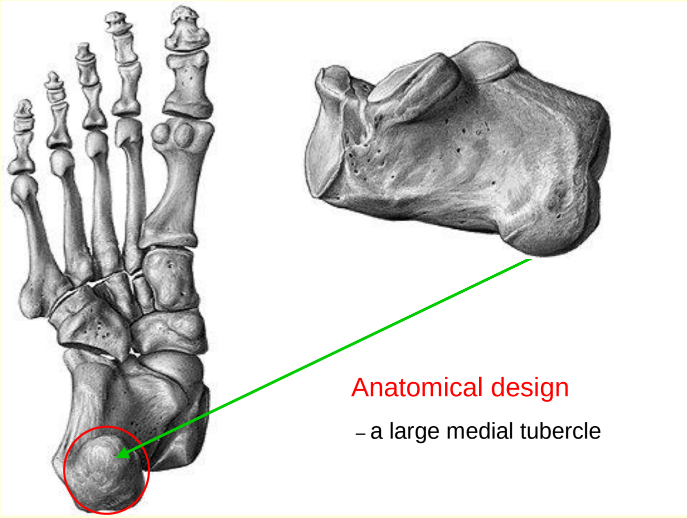
Under Compression

- 1. The chambers expand dissipating collision forces (primarily lateral expansion because the medial calcaneal retinaculum reduces medial expansion)
- Snow S.W., Bohne W.H. (2006) Observations on the fibrous retinacular of the heel pad. *Foot and Ankle International* 27.(8):p.632-5.)
- 2. The calcaneal tubercles ‘sink’ into the chambers further adding to the shock absorption effect
- Rome K. Mechanical properties of the heel pad: current theory and review of the literature. The Foot Vol.8, Issue 4, (1998), pp179-185.

Lateral expansion confinement

- Jorgensen and Bojsen-Moller (1989) compared the ability of traumatised cadaver heel fat pads to non traumatised cadaver heel fat pads (n=10).
- Shock absorbency was reduced by a mean of 24%; confining the heel fat pad increased shock absorbency by 49% in traumatised heels and ~ 30% in non traumatised heels
- Jorgensen U., Bojsen-Moller F. (1989) Shock absorbency of factors in the shoe/heel interaction – with special focus on the role of the heel fat pad. Foot and Ankle 9(6): p.294-9





Under Compression

- The micro chamber layer has a high degree of stiffness in response to loading and the septral walls are composed of predominately elastic fibres
- The macro chambers (approximately equal amounts of elastic and collagenous fibres) respond with a proportionately larger degree of deformation and corresponds with overall heel pad stiffness

Hsu C.C., Tsai W.C., Wang C.L., Pao S.H., Shau Y.W., Chuan Y.S. (2007) Microchambers and macrochambers in heel pads: are they functionally different? J. Appl. Physiology 102: 2227-2231

Heel Pad Paradox

- Non traumatised pad – efficient ‘damper’
- Large difference in energy dissipation between *in vivo* (~ 95%) samples and *in vitro* (~30%) samples and a pronounced hysteresis only in the *in vivo* samples
- (Aerts, Ker, De Clercq et al. 1995) – explained this paradox noting the presence of the whole lower limb *in vivo*

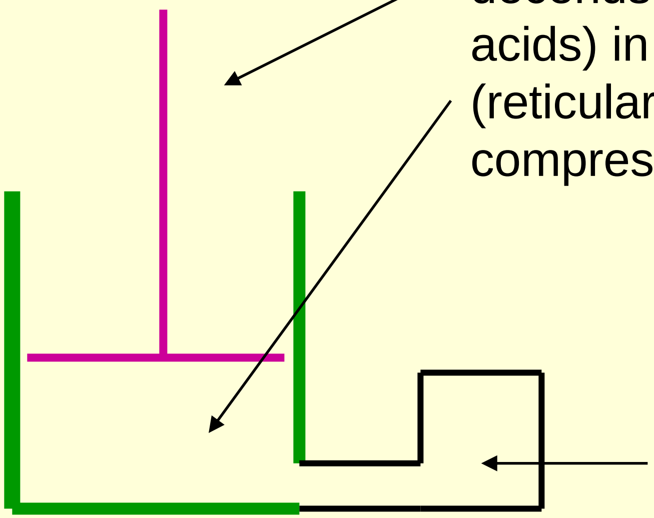
Aerts P., Ker R.F., DeClercq D., Ilsley D.W., Alexander R. McN. (1995) The Mechanical Properties Of The Human Heel Pad: A Paradox Explained. Journal of Biomechanics 28(11) p. 1299-1308

Venous damping

- The combined stroke volume emitted from plantar sole and heel compression is ≈ 20-30ml.
- Gardner A.M.R., Fox R.H. (1992) The venous footpump: influence on tissue perfusion and prevention of venous thrombosis. Annals of Rheumatic Diseases, Vol 51 p.1173-1178
- Impact energy is used for antigravity propulsion of this venous blood contributing to a shock dampening effect.
- Weijers et al. (2005) confirmed this damping effect recently in further research
- Weijers R.E., Kessels A.G.H., Kemerink J.(2005) The damping properties of the venous plexus of the heel region of the foot during simulated heel strike. *Journal of Biomechanics.* Vol.38 Issue12 p.2423-2430

Mechanical Dashpot

(Adapted from Bojsen-Moller and Jorgenson 1991)



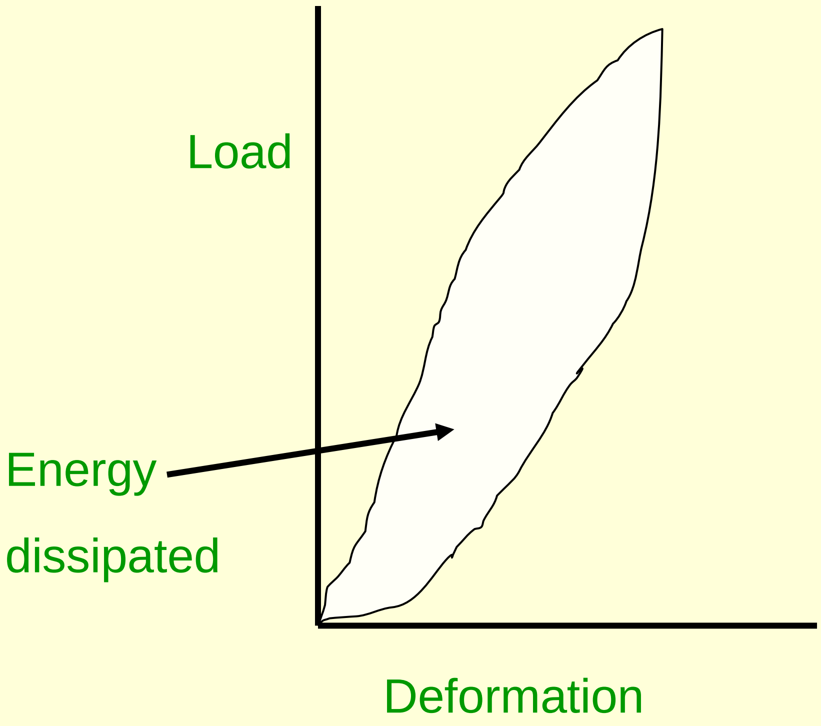
As the ‘piston’ (calcaneus) decends the fluid (fatty acids) in the cylinder (reticular septral cells) is compressed

Lateral expansion chamber

This compression forces venous blood transversely into the superficial medial and lateral marginal veins and thereon to the large and small saphenous veins

Hysteresis - Damping

- Energy dissipated during the impact of the calcaneus within the fat pad is then probably due in part to the propulsion of venous blood from the heel fat pad.
- Level of hysteresis prevents ‘bounce’ and allows grip



Diabetes and the heel pad

- Collagen septa in the heel fat pad is thought to thicken in the diabetic patient
- The micro and macro chambers are also believed to decrease in size
- The consequence of these factors is impaired fat pad function i.e. reduced compressibility

Tong J., Lim C.S., Goh O.L. (2002) Technique to study the biomechanical properties of the human calcaneal fat pad. The Foot. Vol.13. Issue 2: p.83-91