Biomechanics of Foot Orthoses and Therapeutic Shoes

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General Overview

Foot Function

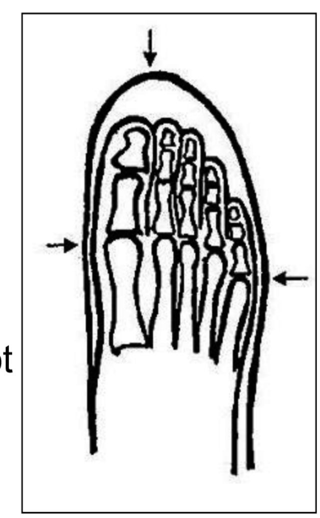
- ✓ Stable base of support
- ✓ Instantaneous adaptability to uneven terrain
- ✓ Shock attenuation
- ✓ Propulsion as a rigid lever
- ✓ Optimize the use of muscle energy

Goals of the Footwear

Flexibility
+
Stability
+
Motion Control

Allowance for Footwear

- ✓ Free movement of the toes
- ✓ Good fit
  - adequate length
  - adequate width
  - quarters of adequate height
  - shape to grip the heel
- ✓ Good contact with the surface of the foot
- ✓ Cradle the foot
- ✓ Absorb humidity
- ✓ Limit any increase in foot temperature
- ✓ Low weight



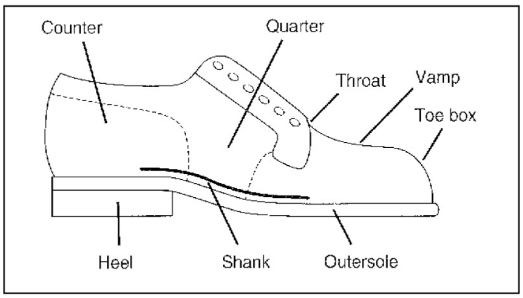
Foot Orthoses

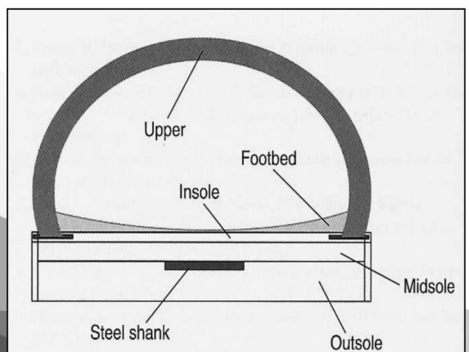
- **Goal of the orthoses application**
  - **functional (corrective)**: designed to maintain normal subtalar and midtarsal biomechanics
  - **accommodative**: used when deviation of the subtalar and midtarsal joints is rigid or when a local relief is required for a painful area
- **Method of fabrication**
  - molded, nonmolded
- **Physical properties of materials**
  - soft / flexible, semirigid, rigid

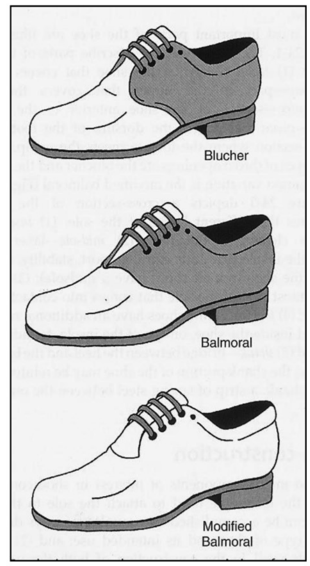
Physical Properties of Orthoses Material

- **Soft / flexible**
  - low-temperature polyethylene foams
    : Plastazote, Pelite, Aliplast
  - Others
    : ethylene vinyl acetate(EVA), Poron, PPT
- **Semirigid**
  - graphite laminates
  - polypropylene
  - polyethylene
- **Rigid**
  - acrylic plastics
  - acrylic plastic and carbon fiber-mesh composite

Footwear Components

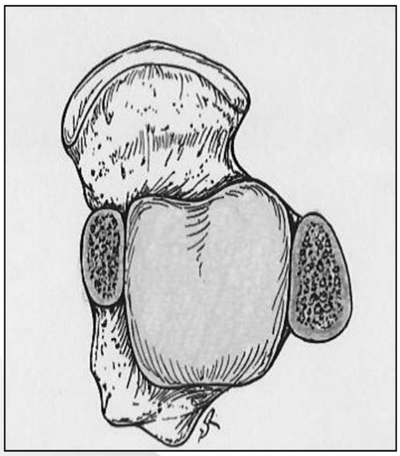


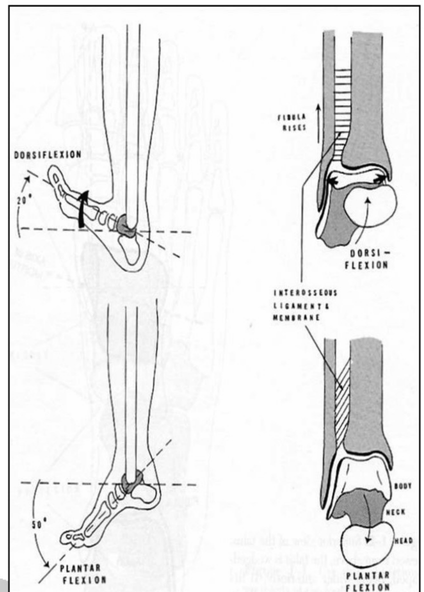




Ankle Joint

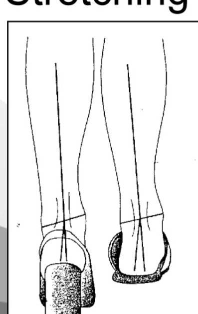
Ankle Joint

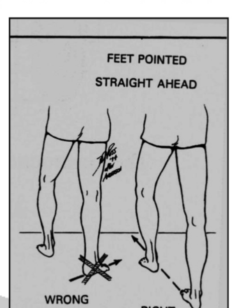


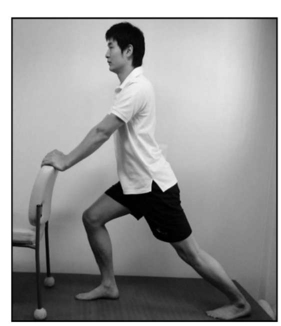


Calf Muscles Tightness

- ✓ Tight calf muscles increase the compensation of the STJ, causing more pronation
- ✓ They also cause more tension on the plantar aspect of the feet as they attach
- ✓ Stretching is necessary to increase the ROM







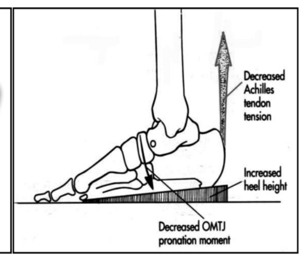
Heel Lifts

✓ Mechanism

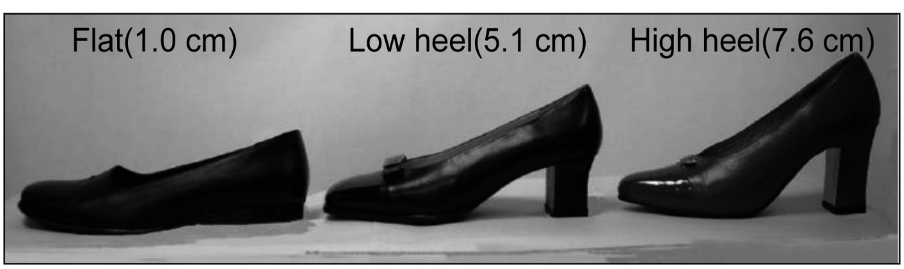
- reduce compensatory pronation of STJ from heel rise through push-off
- shorten lever arm leads to less tension on plantar fasciae
- less tension to the arch by keeping in supinated position of the subtalar and midtarsal joint

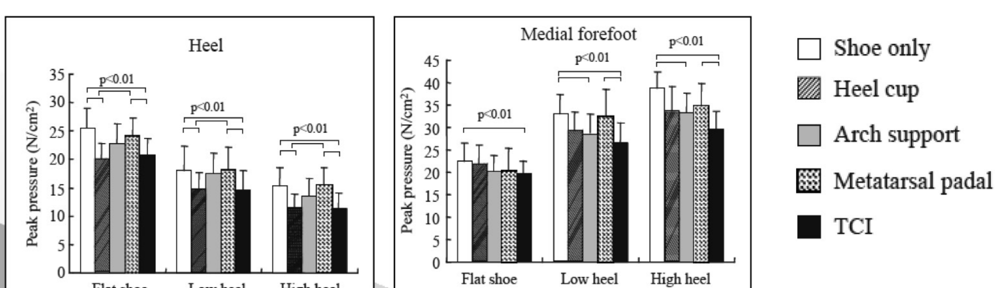
✓ Indications

- tightness of triceps surae or Achilles tendon
- forefoot equinus
- plantar fasciitis
- heel pad atrophy
- bursitis under a heel spur
- limb length discrepancy



Heel Height





Lee YH & Hong WH, 2005

Standard heel height: 3/4-inch

Heel Height

- ✓ Significant changes in either lower back or lower limb EMG muscle activity with increasing heel height

  Lee et al, 1990; Stefanyshyn et al, 2000; Lee et al, 2001; Li et al, 2007

- ✓ Peroneus longus and lateral gastrocnemius are more fatigable in habitual wearers of high-heeled shoes

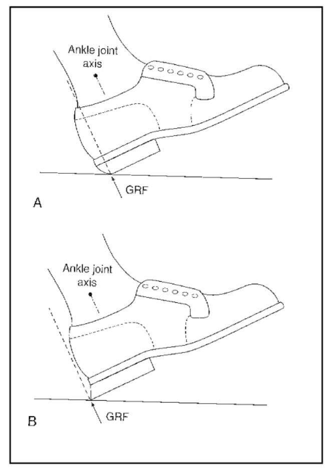
  Gefen et al, 2002

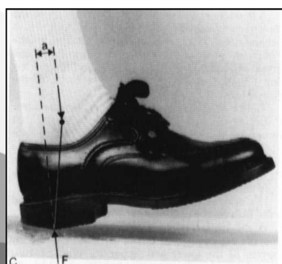
Soft Heels/SACH

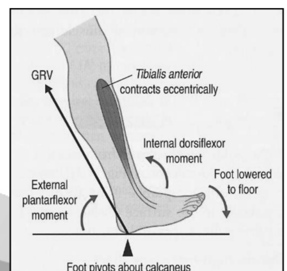
- ✓ Simulate ankle plantar flexion
- ✓ Reduce stress on ankle dorsiflexors
- ✓ Decrease flexion momentum at the knee
- ✓ Provide a maximum amount of shock absorption under the heel
- ✓ Anterior shin splints, patellofemoral syndrome, ankle fusion, prosthetic feet, solid AFO, ankle pain aggravated by movement such as arthritis

Beveled Heel

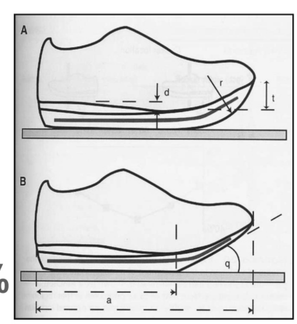
- ✓ Delay heel strike
- ✓ Decrease lever arm of ankle plantar flexion reducing the stress on ankle dorsiflexors
  - similar to being barefoot
- ✓ Simpler than SACH
- ✓ Similar to soft heel/SACH







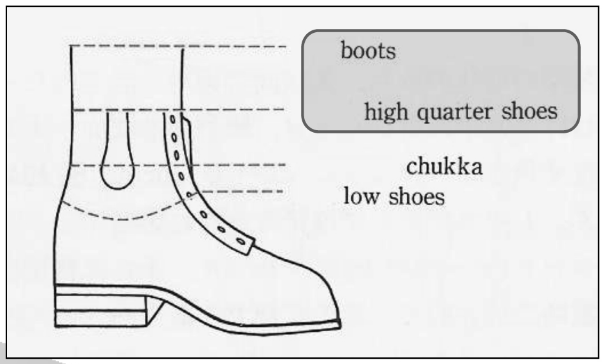
Rocker Sole



- ✓ Walk with minimum motion of the joints of the foot
  - no extension of the MTP joints is required during the phase of forefoot weight bearing
- ✓ Reduce **forefoot pressures** by up to **50%** compared to walking in flexible shoes
- ✓ Increase in loading time in the hindfoot and midfoot
- ✓ **May decrease the magnitude of force required from the Achilles tendon to plantarflex the ankle**
- ✓ Require caution for patients with impaired balance
  - diabetic neuropathy, elderly
- ✓ Hallux rigidus, metatarsalgia, forefoot plantar ulceration, **Achilles tendinitis**

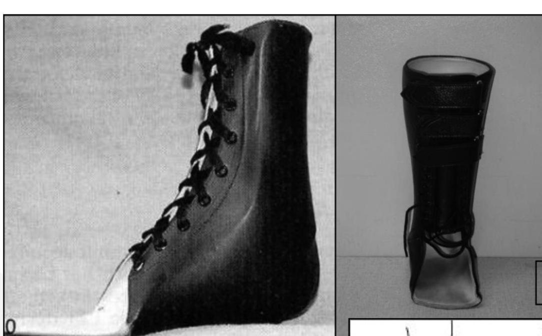
Shoe Height

- ✓ Boots
- ✓ High-quarter shoes
  - prevents piston action during walking and back-and-forth sliding of the foot
  - provides medial-lateral stability at the ankle and subtalar joints
- ✓ Chukka
- ✓ Low(-quarter) shoes
  - oxford
  - do not restrict ankle or subtalar motion

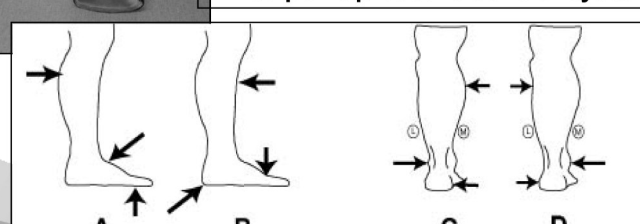


Ankle Foot Orthosis

- ✓ Arizona AFO

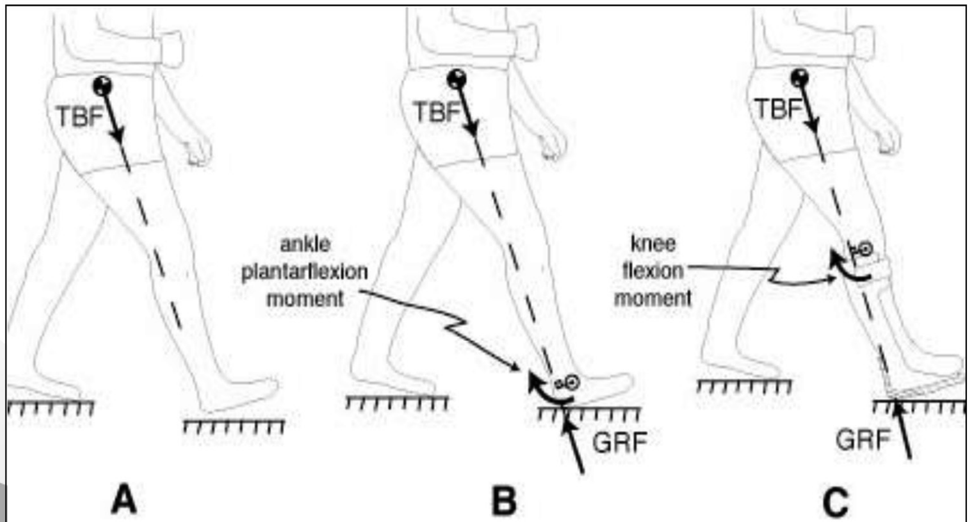


Three point pressure control system



- ✓ Baldwin brace

AFO – Sagittal Plane Control



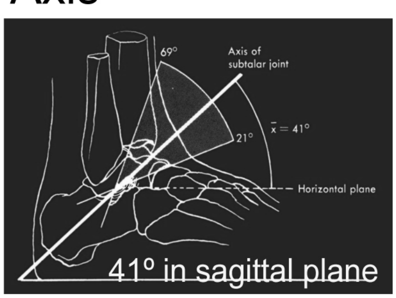
Orthosis for Ankle Sprain

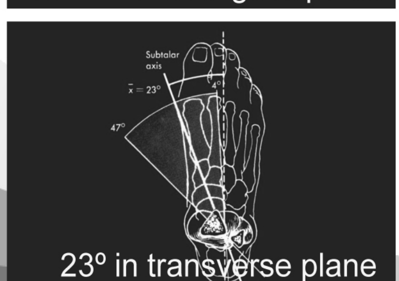
✓ Air cast ankle brace

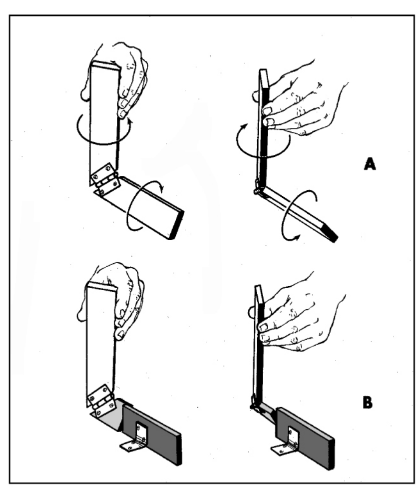
Subtalar Joint

Subtalar Joint

✓ Axis







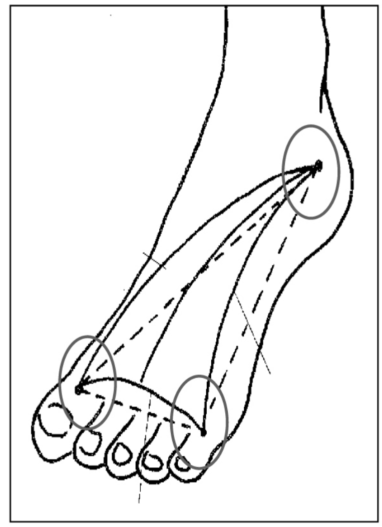
Subtalar Joint

- ✓ Triplanar motion
- ✓ Pronation
  - Eversion + Abduction + Dorsiflexion
- ✓ Supination
  - Inversion + Adduction + Plantarflexion

Pronation vs. Supination

- ✓ Pronation
  - Cushioning mechanism
  - Absorb shock
  - Unstable
- ✓ Supination
  - Really supported
  - Stable platform

Tripod Effect



Insole Modifications

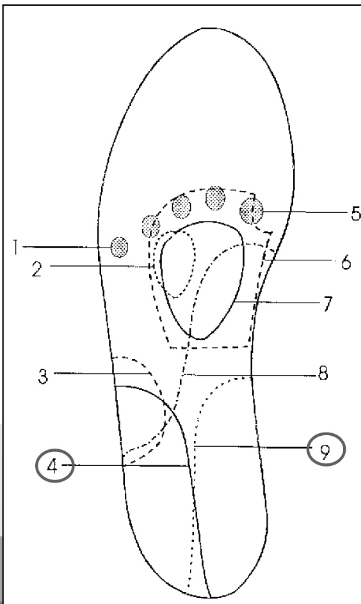


FIGURE 2. Placement of various pads and wedges on the ⅛" Plastazote.
1. 5th metatarsal head (localized by lipstick technique)
2. Neuroma pad
3. Cuboid pad
4. Lateral heel wedge
5. 1st metatarsal head (localized by lipstick technique)
6. Sesamoid relief
7. Metatarsal pad
8. Barton wedge
9. Medial heel wedge

Medial Heel Wedge

✓ Mechanism
- used to control hyperpronation and decrease excursion of tendons on the medial side of the ankle

✓ Indications
- flexible valgus of the calcaneus (flat foot)
- sinus tarsi pain

Muscle Activity in Flat-arched Foot Patients

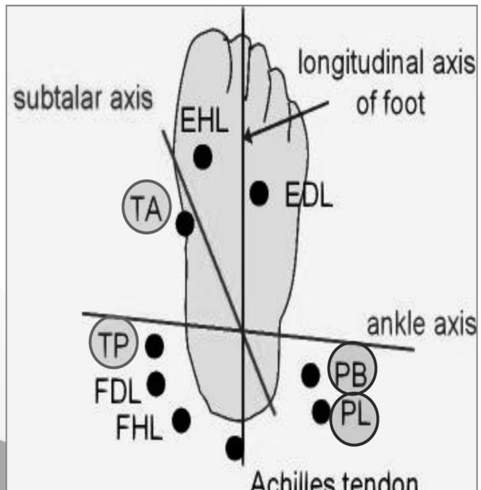
✓ Increased activity of tibialis posterior, tibialis anterior, toe flexors, calf muscles in excessive pronation

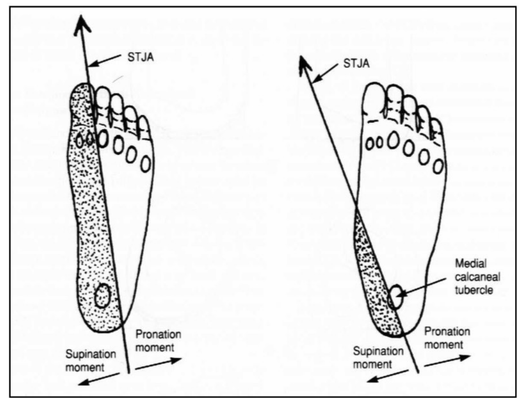
✓ Peak EMG amplitude (compared to barefoot)

	Bracing	Taping
Tiabialis posterior	-22.0%	-33.1%
Peroneus longus	-34.0%	-29.4%
Tibialis anterior	-18.7%	-13.1%

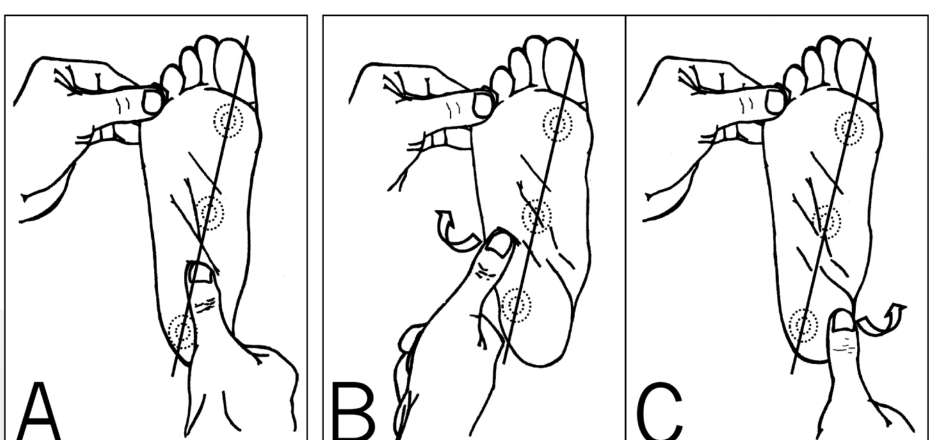
Franettovich MM et al. J Sci Med Sport 2012

Invertor Vs. Evertor





Kirby's Method of STJ Axis Estimation



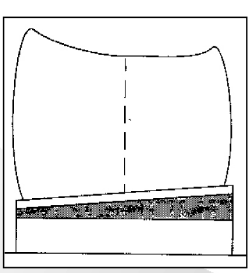
No subtalar rotation | Subtalar pronation | Subtalar supination

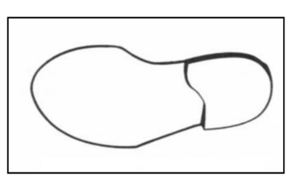
Lateral Heel Wedge

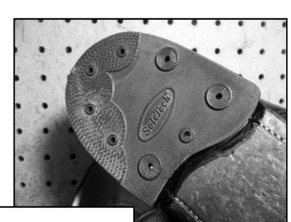
- ✓ Mechanism
  - elevation of the lateral heel decreases the medial drive on floor contact at heel strike, tipping the calcaneus into valgus
- ✓ Indications
  - used when flexible varus of the calcaneus is present
  - lateral ankle sprain
  - cavus foot

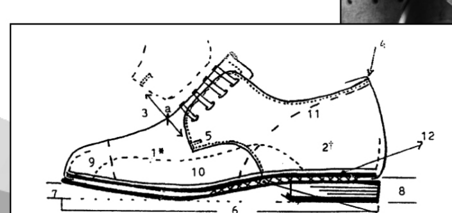
Therapeutic Shoes Modification

- ✓ Long rigid medial counter
- ✓ Thomas heel
- ✓ Reverse Thomas heel







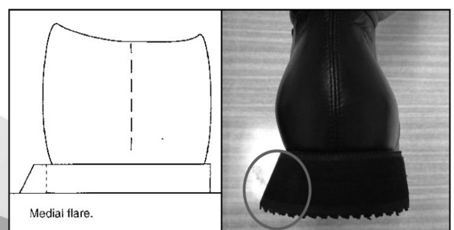


Flares

- ✓ ¼-inch-wide medial or lateral extensions or the sole or heel
- ✓ Acts as an outrigger
- ✓ Provides a wider base of support for the foot
- ✓ Partial foot amputation

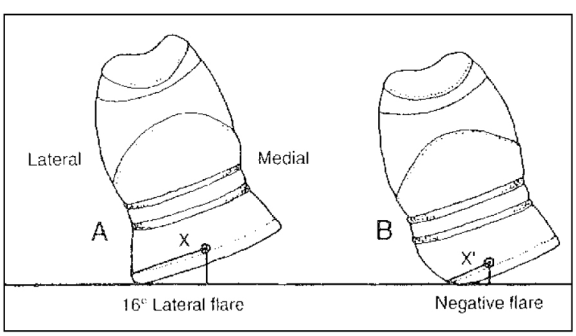
  Fixed varus or valgus ankle deformity

  Unstable foot or ankle

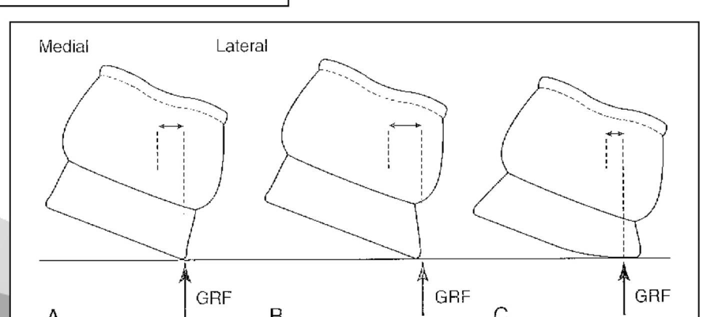


Flare

Lateral Flare vs. Pronation

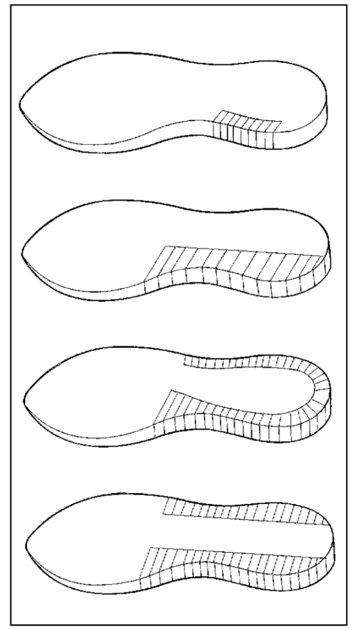


Nigg BM & Norlock M, 1987

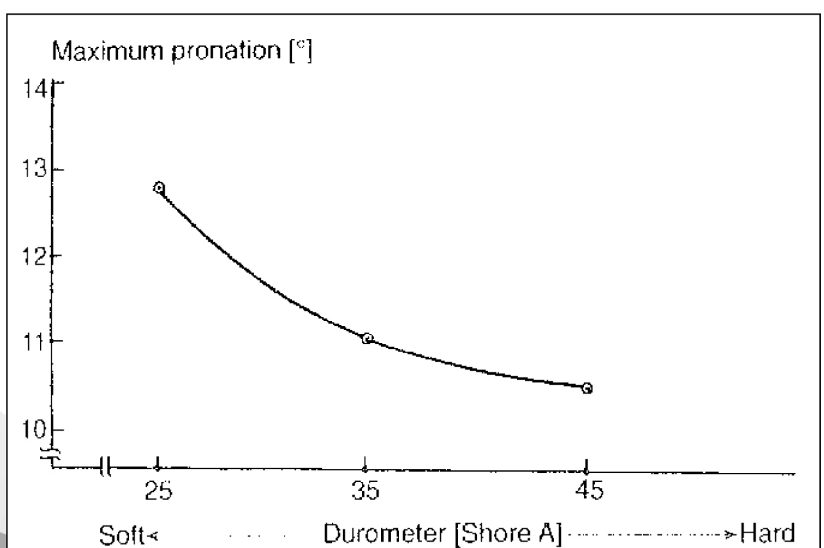


Midsole

- ✓ Provides the structural integrity of athletic shoes
- ✓ Deteriorate after several months, even if not used
- ✓ Shock-absorbing capability in running shoes
  - deteriorate to 70% after 500 miles
- ✓ Made of EVA (ethyl vinyl acetate), polyurethane, or a combination with air cells



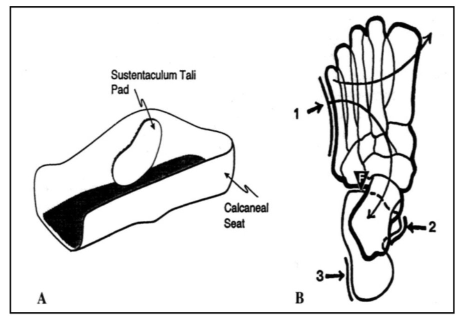
Midsole Density vs. Maximum Pronation



Frederick EC, 1989

University of California at Berkeley Laboratory (UCBL)

- ✓ 3 point system
  1. high lateral wall of 5th MT shaft (1/2 or 2/3)
  2. sustentaculum tali
  3. lateral wall of hindfoot

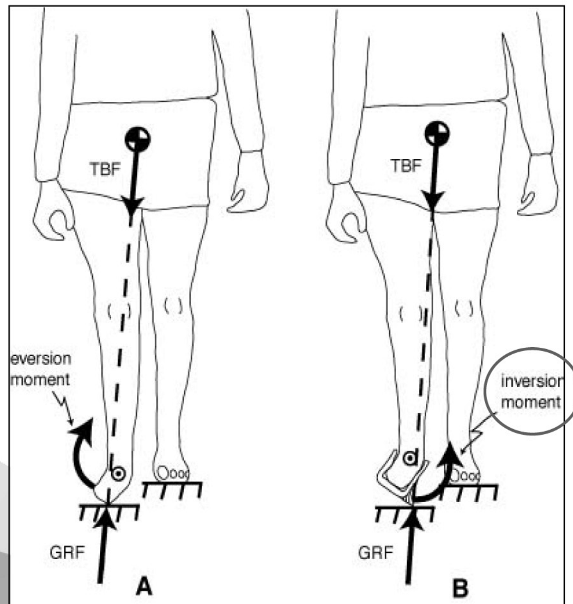


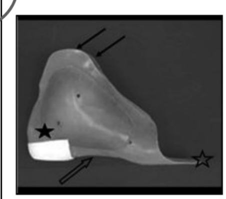
- ✓ Designed to correct the flexible hindfoot and hold it in a neutral position
- ✓ Limits motion in the subtalar joint and helps prevent subfibular impingement

University of California at Berkeley Laboratory (UCBL) Supramalleolar Orthosis (SMO)




Valgus Deformity Control
- SMO with a Medial Butress -

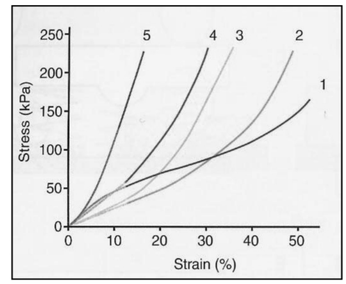




Hindfoot(Heel)

Insole

- Initially relatively stiff to small stresses
  → less stiff in response to midrange stresses
  → compaction of the material
  → very stiff(little strain)
- Many soft materials (particularly thin insoles) are used beyond 50% compression
- Brodsky et al. (1988)
  - repeated shear and compression after 10,000 cycles
    → loss of thickness
      : 0(PPT), 50%(Plastazote #1)

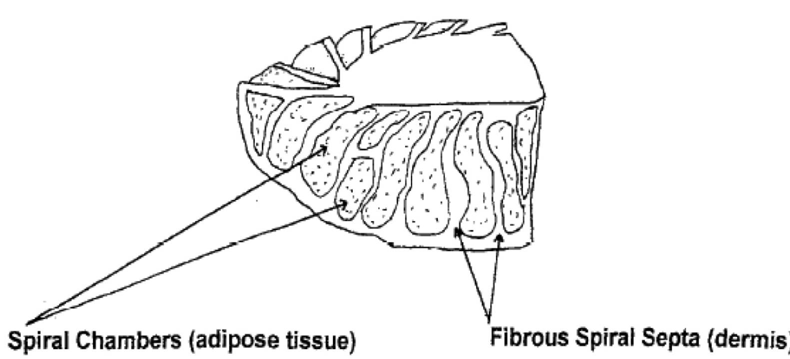


1. Poron (PPT)
2. Spenco
3. Plastazote #1
4. Plastazote #2
5. Soft Pelite

Insole replacement at regular intervals!

Heel Pad

✓ Structure of heel pad-lateral view



Rome K. The Foot 1998

Heel Cup

✓ Mechanism
- cushioning & heel elevation
- preventing heel fat pad from spreading

✓ Indications
- heel pad atrophy
- plantar fasciitis

Heel Cup Effects

✓ The difference in heel pad thickness during standing

	n	Increase in heel pad thickness, mean (mm)	95 % confidence interval	P-value
Bare foot vs Shoe only	45	2.19	1.69–2.69	<0.001
Bare foot vs Shoe with cup*	15	3.57	2.56–4.29	<0.001
Shoe only vs Shoe with cup*	15	1.53	0.63–2.23	= 0.002

*Treatment group only.

Perhamre S et al. Scand J Med Sci Sports 2011

Heel Cup Effects

✓ Peak pressure during standing and running

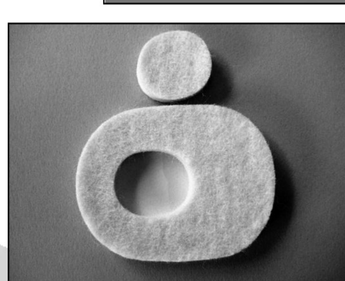
	Peak pressure, mean (mmHg)			
	n	Shoe only	Shoe with cup	Difference (%)
Standing on heel	10	1407	1056	−25
Running	9	1412	1109	−21

Perhamre S et al. Scand J Med Sci Sports 2011

Pad for Calcaneal Spur

✓ Horseshoe heel pad

✓ Aperture pad



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