Intrinsic muscles of the foot

Anatomy, dysfunction and rehabilitation

Function of intrinsic foot muscles

- Give dynamic control to the foot
- Regulate the rate of pronation
- Stabilize the arches of the foot

Function of intrinsic foot muscles

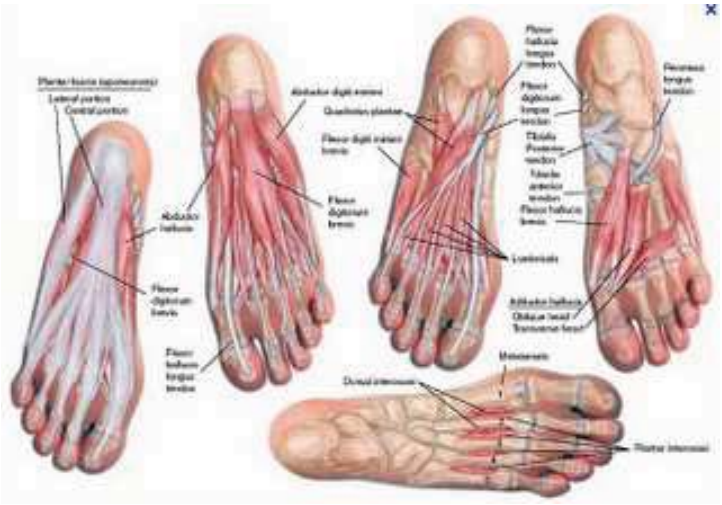
Dysfunction implicated in:

- Hammer and claw toe deformity (Myerson & Shereff, 1989)
- Hallux valgus (Arinci et al., 2003)
- Plantar fasciitis (Allen & Gross, 2003); Chang et al., 2012)

Anatomy

Intrinsic foot muscles

Quiz

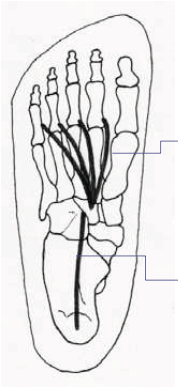


1st layer (most superficial)

- Abductor hallucis
- Flexor digitorum brevis
- Abductor digiti minimi

Abductor hallucis

- Palpable muscle in medial arch
- Abduction and plantar flexion of the hallux
- Eccentrically resists pronation
- Concentrically helps to invert the sub-talar joint

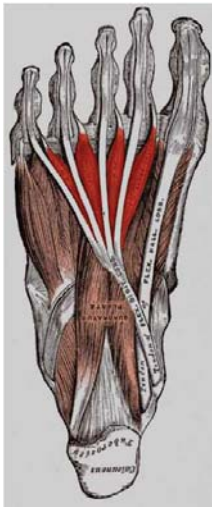


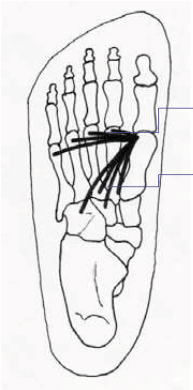
2nd layer

Lumbricals

Quadratus Plantae

Lumbricals

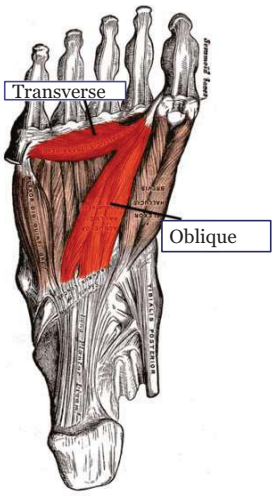




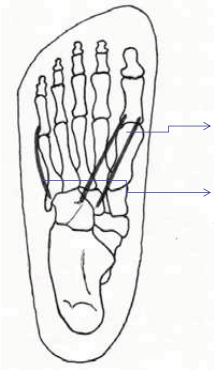
3rd layer

Adductor hallucis transverse

Adductor hallucis oblique

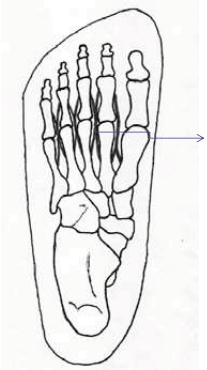


Adductor hallucis



3rd layer

- Flexor hallucis brevis
- Flexor digiti minimi



4th layer

- Plantar and dorsal interossei

Plantar and dorsal interossei

Plantar interossei	Dorsal interossei

Most amazing foot-nerd website ever

- http://www.beyondthepalecreative.com/images/2D/Kaplan_C_flash_interactive.swf

Anatomy

Mann & Inman, 1964

- Abductor hallucis passes under and is perpendicular to the oblique midtarsal joint axis
- AbdH contributes to stabilization and supination of the midtarsal joint against the pronating force of ground reaction during propulsion

Anatomy

Reeser et al. (1983)

- Flexor digitorum longus tendon enters the foot from the medial side and pulls the toes medially
- Quadratus plantae allows the toes to flex in the sagittal plane by redirecting the pull of the flexor digitorum longus

Anatomy

Kura et al. 1997

- Abductor hallucis and adductor hallucis oblique have greatest cross-sectional area
- Generate propulsion forces and stabilize the hallux and MTP joint
- AbdH stabilizes MLA
- AdH stabilizes MTA

Anatomy

Chang et al. (2012)

- The foot intrinsics are larger than some muscles of the leg.
- Total PIFM volume (113.3 cm^3) is larger than the flexor hallucis longus (74.0 cm^3) and the flexor digitorum longus (18.7 cm^3)
- Total PIFM similar size to TP muscle volume (104.2 cm^3)

data via Fukunaga et al. (1992)

Measuring intrinsic muscles

Force and activity

Caveat

- Intrinsic muscles are small and buried in the soft tissue of the foot so it is very difficult to isolate them to test their individual function
- Studies that measure intrinsic muscle function have difficulty distinguishing their effect from the action of the extrinsic muscles such as tibialis posterior and flexor digitorum longus

Measuring intrinsic muscles

- Hand held dynamometer most accurate method of measuring intrinsic muscle **strength**
- Cannot completely exclude contribution from extrinsic muscles

Measuring intrinsic muscles

- EMG measures muscle **activity**
- **Surface EMG** - signal is a combination of all the muscle fibre action potentials occurring in the muscles underlying the skin electrodes
- **Intramuscular EMG** - needle electrodes placed directly in the muscle
- Measures function of the intrinsic muscles during a particular task

Measuring intrinsic muscles

Soysa et al. (2012)

"An EMG study with intra-muscular electrodes inserted using real time ultrasound imaging into both intrinsic and extrinsic muscles during dynamometry testing may provide valuable insight into muscle activation patterns of both intrinsic and extrinsic muscles during toe flexor testing."

Function of intrinsic foot muscles

How they influence foot mechanics and how their dysfunction can lead to painful foot syndromes

Function of intrinsic foot muscles

Wong (2007)

- Cadaveric study of AbdH muscle
- AbdH contraction causes:
  - flexion and supination of the first metatarsal
  - inversion of the calcaneus
  - external rotation of the tibia

Function of intrinsic foot muscles

Basmajian & Bentzon (1954)

- Wire electrode EMG during quiet standing
- AbdH, ADM, FDB (as well as TP, Gastroc, PL)
- In most subjects tested intrinsic muscles were inactive during standing

Function of intrinsic foot muscles

Mann & Inman, 1964

- Intra-muscular EMG (wire) collected n=8 (12)
- AbdH, FDB, FHB activated at 30-40% of gait cycle (prior to push-off)
- In pronated feet:
  - AbdH at 0% of cycle
  - FDB at 26% of cycle
  - FHB at 14% of cycle
- Intrinsics active during period of greatest subtalar rotation

Function of intrinsic foot muscles

Mann & Inman (1964)

*****When a person is standing quietly, there is no activity in the intrinsic muscles (except for short bursts of activity, which presumably are evidence of postural adjustments). This electrical silence supports the concept that muscle activity is not necessary to maintain the arch of the loaded foot when it is at rest.*****

Function of intrinsic foot muscles

Fiolkowski et al. (2003)

- EMG testing of AbdH muscle before and after tibial nerve block
- ST neutral –subjects plantarflexed big toe and hold (MVIC)
- Avg EMG activity dropped 27% after block

Function of intrinsic foot muscles

Fiolkowski et al. (2003)

- Navicular drop from ST neutral to relaxed stance measured before and after nerve block
- Avg navicular drop increased 3mm after block
- Concluded that intrinsic muscles have a role in supporting the medial longitudinal arch during relaxed standing

Function of intrinsic foot muscles

Headlee et al. (2008)

- Worked foot muscles to fatigue
- Navicular drop measured pre- and post-fatigue
- Avg change of 1.8 ± 1.3 mm in ND

Function of intrinsic foot muscles

Kelly et al. (2012)

- Ultrasound guided intra-muscular EMG activity from abductor hallucis, flexor digitorum brevis and quadratus plantae
- COP and COPV measured on forceplate
- Intrinsics recruited with **medial** shift of COP
- Conclusion: intrinsics function in balance control

Function of intrinsic foot muscles

Kelly et al. (2012)

- Confirmation that intrinsic muscles function during quiet stance (double stance)
- AbdH most active muscle

Function of intrinsic foot muscles

Goldmann & Bruggemann (2012)

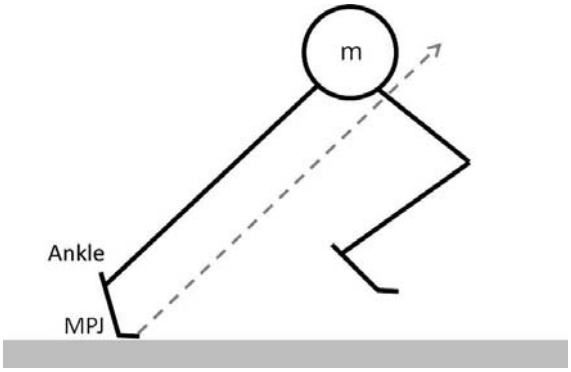
- Measured toe flexor strength at various joint angles (ankle and MTP)
- Toe flexor muscles produce greatest force at:
  - 0–10 ankle joint dorsiflexion
  - 25–45 MTP joint dorsiflexion

Function of intrinsic foot muscles

Goldmann & Bruggemann (2012)

- Body leans forward in running
- Ground reaction force vector points forward
- Strong toe flexors (including the intrinsics) important to transfer force to toes to counteract vertical GRF causing the ankle to dorsiflex
- Intrinsic muscles help control posture

Function of intrinsic foot muscles



Dysfunction of intrinsic foot muscles

Mickle et al. (2009)

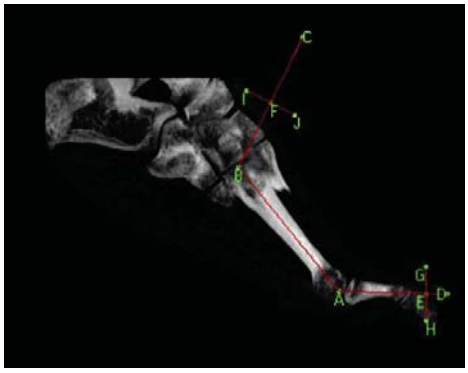
- Measured toe flexor strength on pressure mat
- Assessed for hallux valgus or lesser toe deformities
- Questionnaire at 1 year follow-up re: # of falls
- Reduced toe flexor strength and the presence of toe deformities increases the risk of falls in elderly
- Hallux strength and lesser toe deformities were independent predictors of falls

Dysfunction of intrinsic foot muscles

Kwon et al. (2009)

- Tested strength of toe flexors and extensors with digital dynamometer
- MTP joint angles with CT scan
- Extensor/flexor toe strength ratio was 2.3–3.0 times higher in the hammer toe group
- High correlation between ratio and MTP joint angle

Dysfunction of intrinsic foot muscles



Dysfunction of intrinsic foot muscles

Garth & Miller (1989); Myerson & Shereff (1989)

- Hallux valgus causes the axis of the intrinsic toe flexors to change, making them less biomechanically efficient

Dysfunction of intrinsic foot muscles

Adductor hallucis

Abductor hallucis

Dysfunction of intrinsic foot muscles

Wong (2007)

- Subluxation of the tibial sesamoid reduces the mechanical advantage of the abductor hallucis
- There may be muscle inhibition due to pain at the sesamoid-metatarsal articulation
- Narrow toed shoes may prevent the abductor hallucis from functioning optimally

Dysfunction of intrinsic foot muscles

Allen & Gross (2003)

- Subjects with unilateral plantar fasciitis had significantly weaker toe flexors than subjects in the control group
- Toe flexors for the involved feet were significantly weaker than the uninvolved feet

Dysfunction of intrinsic foot muscles

Chang et al. (2012)

- MRI of intrinsic foot muscles (and TP muscle)
- Comparison of muscle volume between foot with plantar fasciitis and healthy foot
- Foot with plantar fasciitis smaller forefoot intrinsic muscle volume
  - Many intrinsics attach at the first ray and hallux – decreased ability to generate a plantar flexion moment at the 1st metatarsal when they atrophy

Dysfunction of intrinsic foot muscles

Travel & Simons (1992)

- Intrinsic muscle strain may cause trigger points which can be confused for plantar fascia pain

Rehabilitation of intrinsic foot muscles

Exercises and the role of orthotic therapy

Rehabilitation of intrinsic muscles

Robbins & Hanna, 1987

- Barefoot advocate before it became a fad
- Suggested modern running shoes contributed to high injury rate because they blocked sensory feedback from contact with ground
- Un-shod populations report fewer injuries
- Intrinsic foot muscles could be rehabilitated

Shoes in 1987

Rehabilitation of intrinsic muscles

Robbins & Hanna, 1987

- N=17
- Measurements from x-rays and footprints
- Subjects increased barefoot activity over 4 month period
- Subjects who increased barefoot activity had shorter arches at testing. Those who did not had longer arches

Rehabilitation of intrinsic muscles

Prentice, 2009

- Short foot exercise is performed to activate the intrinsic muscles by pulling the metatarsal heads toward the heel while the long toe flexors are relaxed (vs. curling the toes)

Rehabilitation of intrinsic muscles

Short Foot Exercises

(a) (b)

Rehabilitation of intrinsic muscles

Rothermel et al. (2004)

- Foot posture exercises vs. traditional balance exercises vs. no postural exercise
- Measured centre of pressure velocity (COPV) in single leg stance on force plate

Rehabilitation of intrinsic muscles

Rothermel et al. (2004)

- Traditional balance exercise greatest improvement in balance (reduction in COPV)
- Postulated that subjects were concentrating on foot position in short foot exercise group

Rehabilitation of intrinsic muscles

Jung et al., 2011

- Foot orthoses vs. combined FO and short-foot exercises
- Cross-sectional area of AbdH (ultrasound)
- Strength of hallux flexion (dynamometer)
- Measured pre and post 8 week intervention
- FO + SFE are recommended for improving strength of AbdH muscle in subjects with pes planus

Rehabilitation of intrinsic muscles

Lynn et al. (2012)

- Towel curl vs. short-foot exercises
- Navicular height and COP excursion (proxies for pronation)
- No significant improvement by strengthening intrinsics
- Rehab should include both the SFE and complex single-limb balance tasks to ensure the best results

Exercises

Attempt to isolate the intrinsic muscles

Abductor hallucis

Hallux flexion – isolate the hallux

Toe flexion and arch support