

# Nonstandard Feet & Ankle

## Nomenclature

- lexicon is expected to be known by all in profession
- diverse application creates issues
  - + clinical, commercial, industrial, comparative and/or evolutionary
- many attempts made since 1890's

- focused term/definition based on discipline is counterproductive, as research is often cross-disciplinary

+ element of hubris

- here we will identify common misconceptions

## Anatomical Descriptions

### Persistence of Eponyms

- continuation of tradition of unifying logic

- eponym: use of name of discoverer

- linguistically difficult, carries a sense of membership and identity

+ creates exclusionary effect!!!

### Regional Descriptions

- Distal Element of lower limb

+ shank has problems

\* element between knee and ankle

\* some terms include ankle

- \* also description of shoe
- \* non-english description weird
- + solution? "crus" in Latin = "leg" between ankle & knee
- + "femur" = Latin for "thigh"
- + "membrum inferius" or "membrum pelvium" = "lower" or "pelvic member"
- Forefoot & Hindfoot
- + forefoot often same as hand in non-animal descriptions
- \* some own bother
- + "distalis pedis" = distal foot
- + "proximalis pedis" = proximal foot

## Applying Anatomical Position

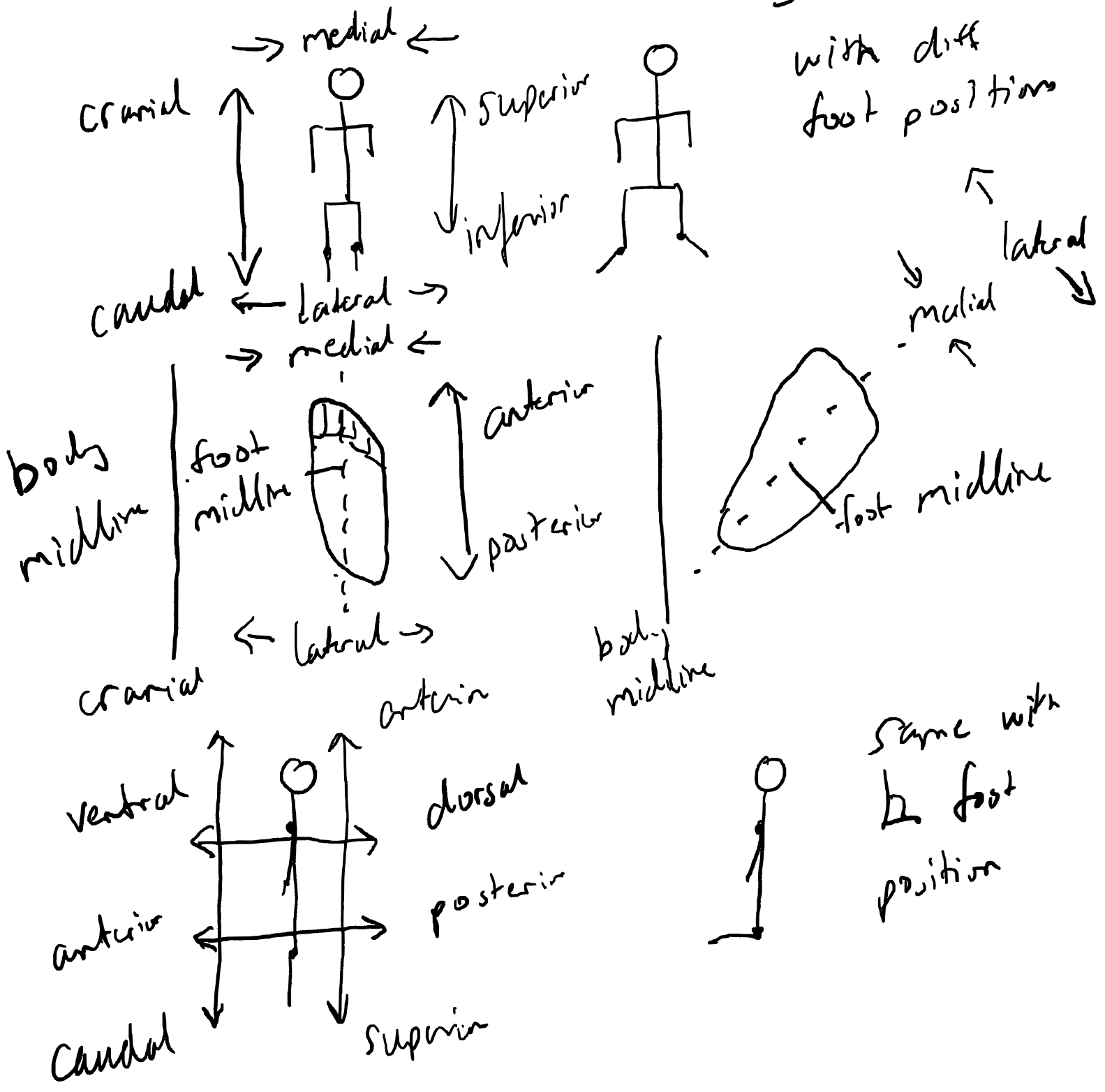
- assumed, no technical strong definition
- strong arm description to ensure parallel bones.
- + lack of it for legs, feet position is rather vague.

- is foot parallel to leg or perpendicular?
- are feet parallel to each other or do toes diverge at some angle?
- Tetrapoda = superclass of vertebrate animals with homologous foot & ankle structure
- + unguligrade: horses, cows, walk on phalange supported by hoof
- \* akin to ballerina "en pointe"
- + digitigrade
- + plantigrade = most reptiles, primates.
- \* full plantigrade = tuberosity from heel touching ground
- HAP legs parallel foot perpendicular most absent to all species (↳ uniquely human)

### Application specific HAP

- Vague definition of foot placement does help studies collect data without immediately applying clinical eval
- LAP (leg anatomical position) local reference frame by ISB (International Society of Biomechanics)
- + uses malleoli and condyles of tibia/fib

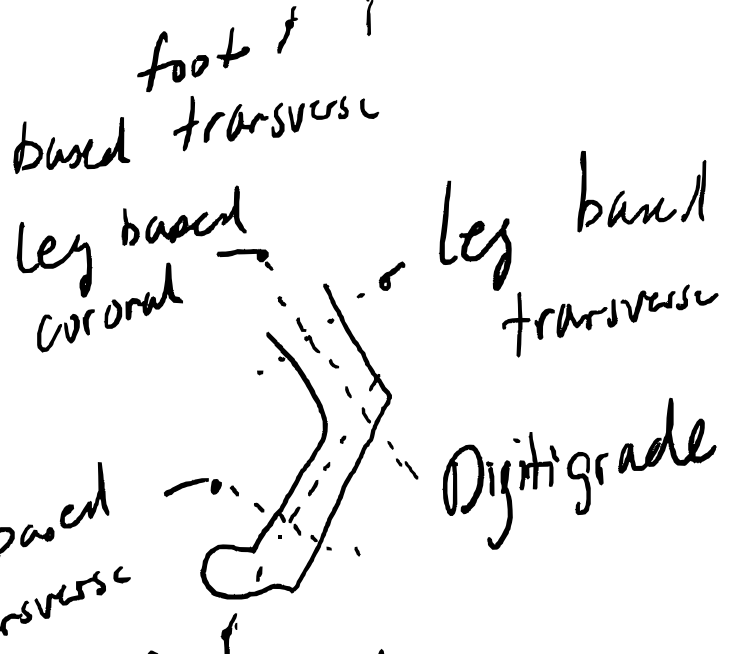
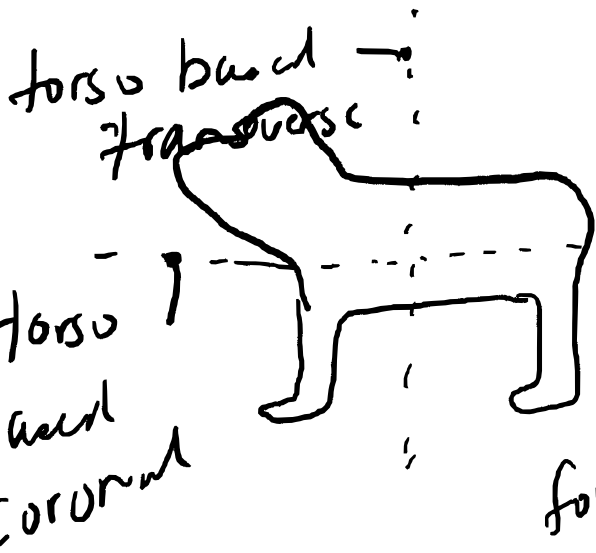
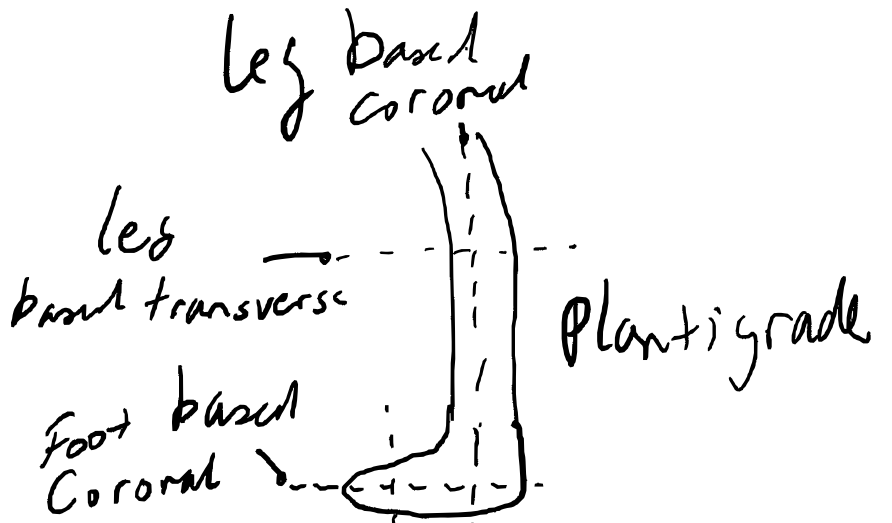
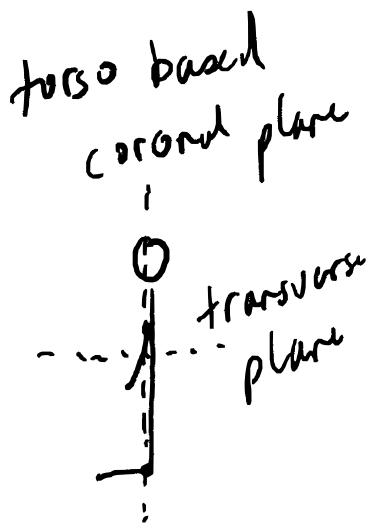
- Tibial torsion can be studied due to free foot frame



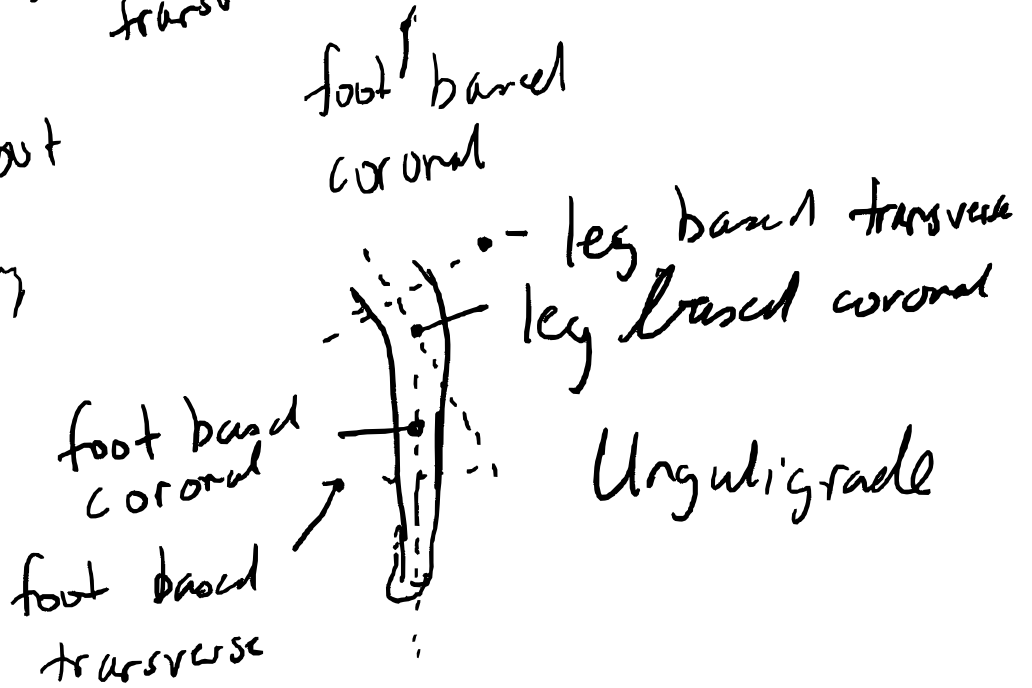
Same but with diff foot positions

Same with diff foot position

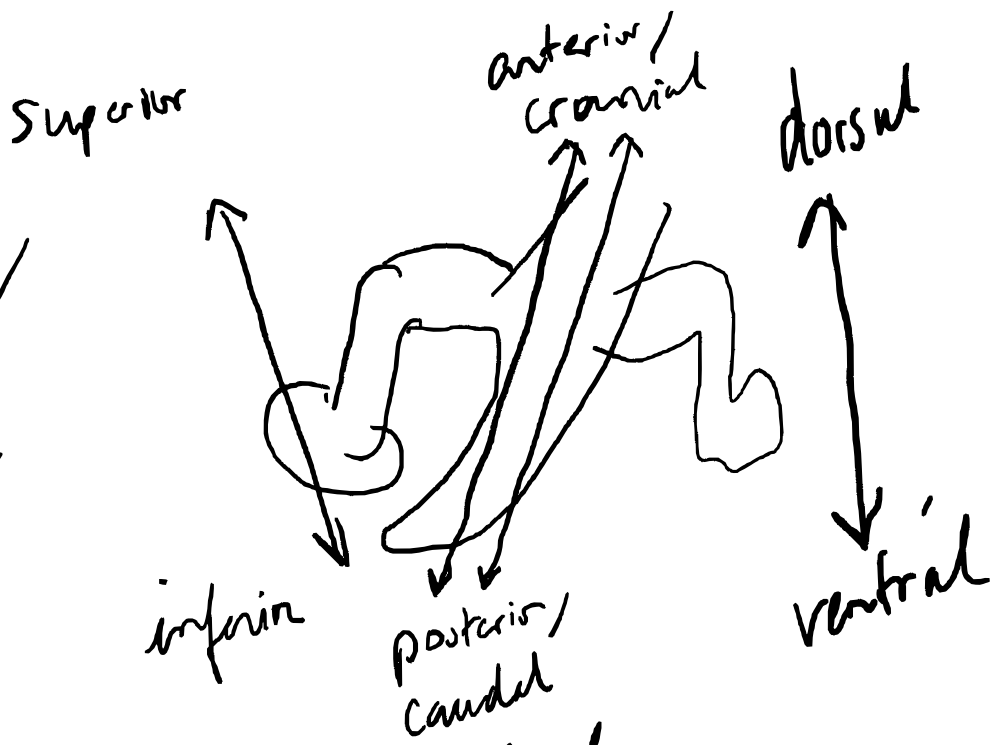
- anterior-posterior is "free axis" as it is relative to foot orientation. Cross product medial/lateral & inf/sup.



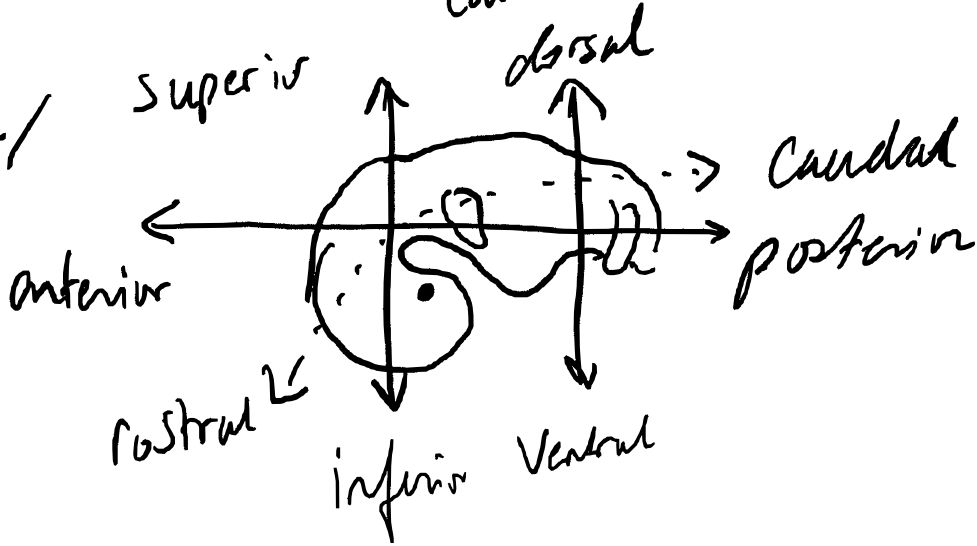
Differences in foot evolution & labeling schemas

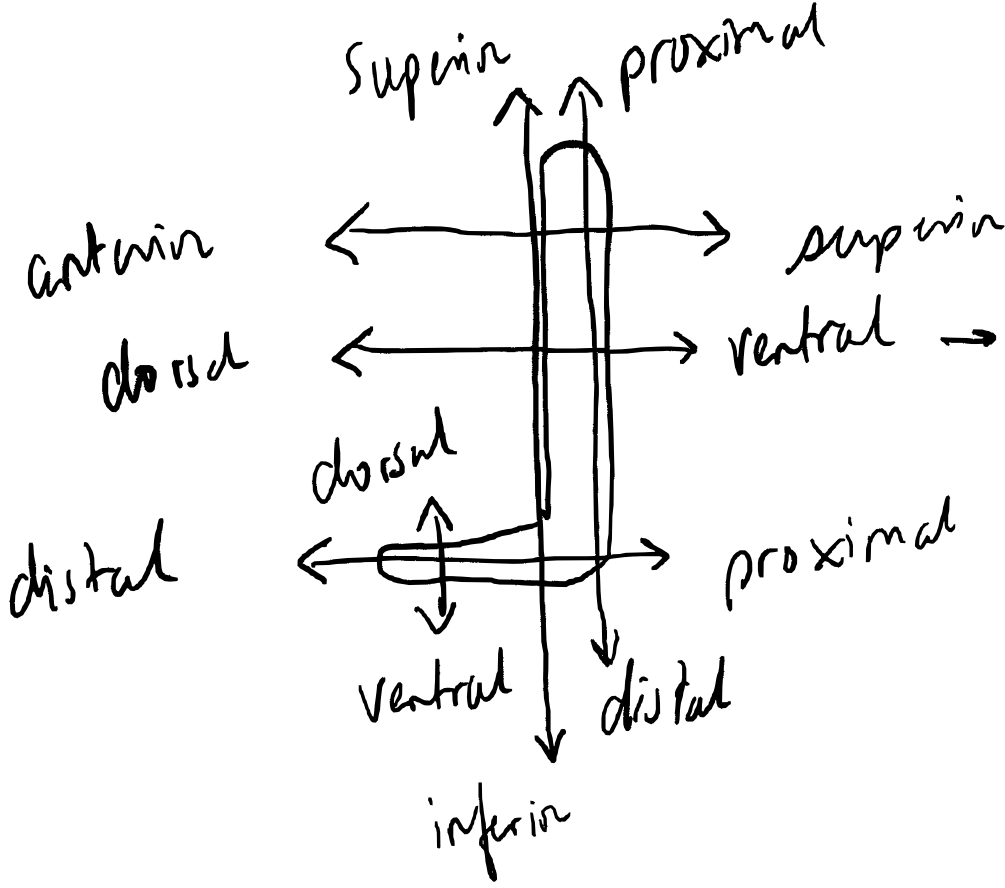


Primitive / Ancestral



Embryonic / Primitive





LOL but why??



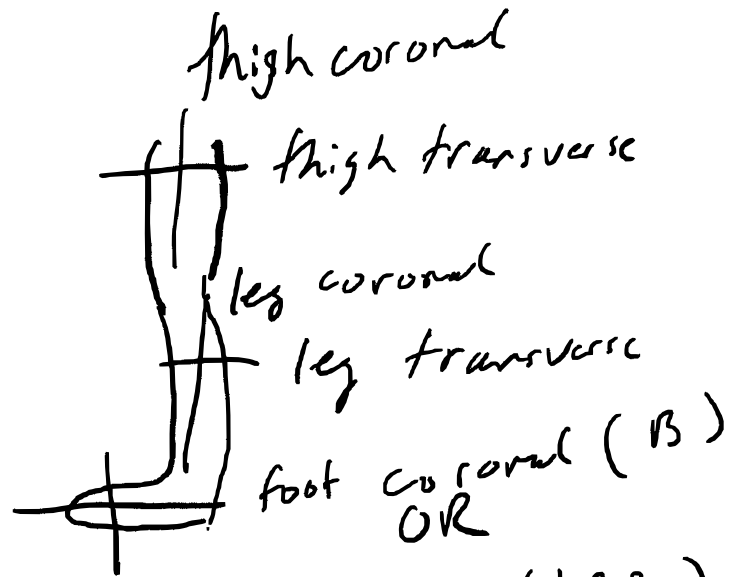
- research with just LAP neglects HAP or assumes common ground. BLIND SPOT
- worse when just FAP (foot) applied with no leg or body landmarks
- + e.g.: domain's work
- other places tough too, e.g. shoulder

## Defining Directions, planes, axes

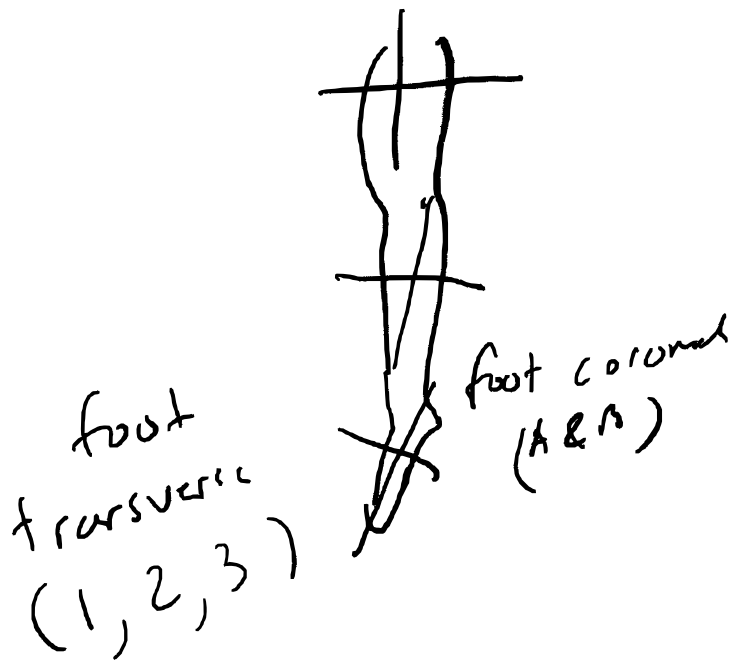
- posterior - anterior vs ventral dorsal
- + anterior = front / forward travel
- + ventral = of the belly
- + in most HAPs, treated synonymously
- + non HAP, superior / inferior = dorsal / ventral
- \* foot dorsal associated with HAP superior, similar to embryology
- \* similar happens to heart & brain
- Anatomical Planes
- + paramedian / parasagittal plane describes divided LAP / FAP sagittal

- + functional, not geometric, median
- + Coronal separates anterior/posterior OR ventral/dorsal (B)  
(A)
- + Transverse separates superior/inferior (1) OR cranial/caudal (2) OR proximal/distal (3)
- + Not easy single plane description works

\* leg parallel looks great from planes but you forget the flip in directions



foot coronal transverse (1 & 2)  
 (A) OR  
 transverse (3)

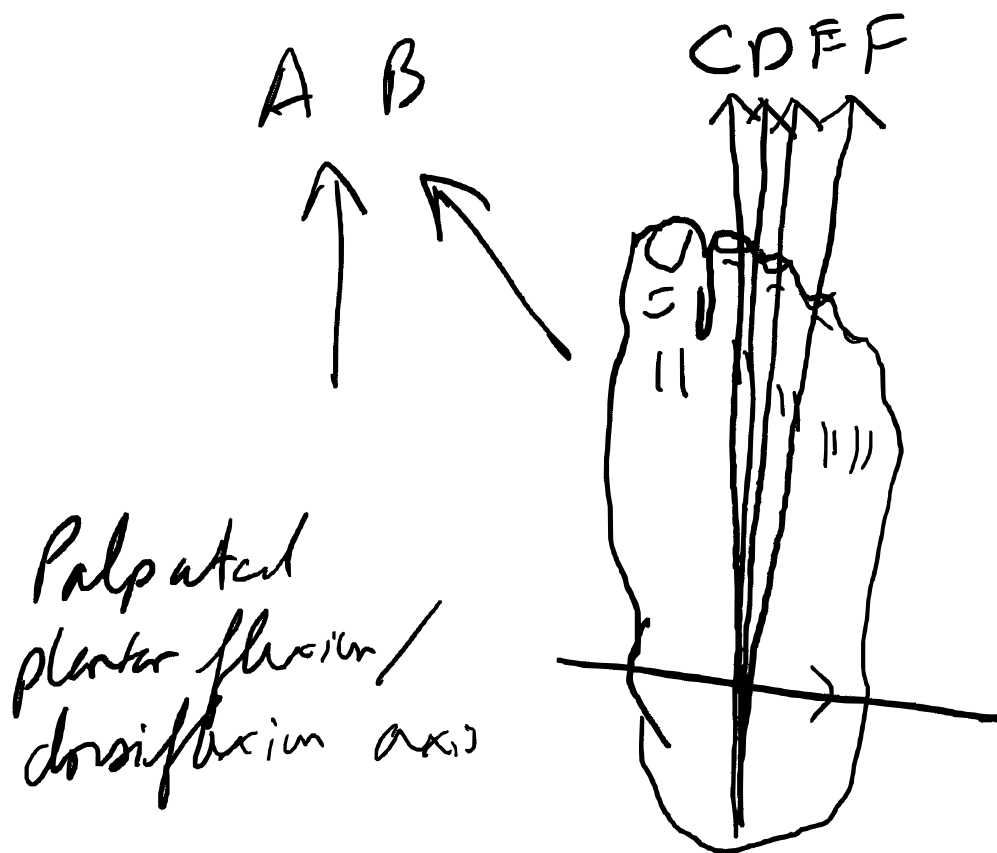


motions described often used artificial  
 definitions of motion

- Foot midline
- + definition of angle varies, creating problems
- + "valgus" = away from midline
- \* hallux valgus: which midline? which joint
- \* if to foot midline, what is often the case for foot issues, it is 1st MTP that is in valgus, not proximal phalanx
- \* such a simple condition, so difficult to name

## Foot Motions

- Defining motion is done in GRAYS ANATOMY as such:
  - + flexion/extension  $\perp$  to sagittal plane
  - + ad/abduction  $\perp$  to coronal plane
  - + lateral/medial rotation  $\perp$  transverse
- obv. difficult because of prev. def. issues



Palpated  
plantar flexion/  
dorsiflexion axis

A: Sagittal plane with forward toes

B: Sagittal plane with outward toes

C: midline def. that splits 2<sup>nd</sup> digit, "functional axis". Pedal dorsal interossei reflected around 2<sup>nd</sup> digit

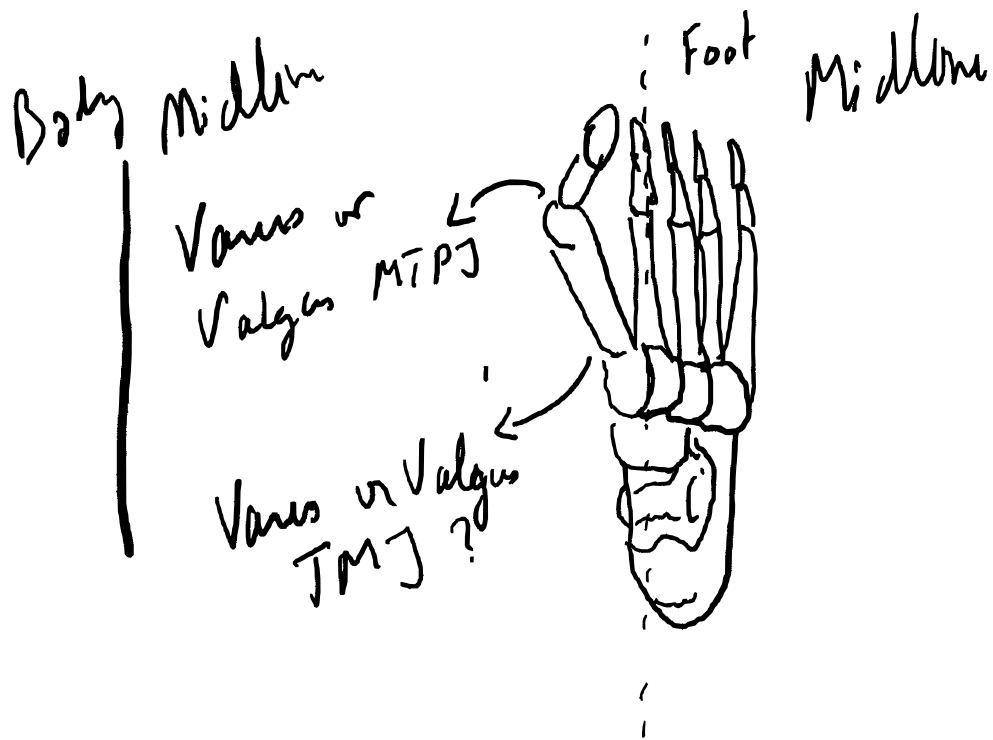
D: between 2<sup>nd</sup>/3<sup>rd</sup> in Lamer's work

E: Split 3<sup>rd</sup>, most geometric split

F: bisection of malleoli defining flexion/extension axis

- Flexion/Extension

+ flexion: bring distal structure to ventral surface



- + extension: same, to dorsal surface
- + embryonic def. aligns with neurological org.
- \* e.g. all ventral division nerves innervate depressors (foot/ankle flexors), all dorsal division nerves innervate elevators
- + NOT FOLLOWED IN PRACTICE
- \* when defined kinematically, always occurs about local medial/lateral axis
- \* variation amongst individuals local kinematic frame inside anatomic position
- \* NOT ALWAYS THE SAME

- Add/Abduction vs Ext/Internal rotation
- + adduction = rotation of segment along coronal plane to midline. Ab = opposite
- + phalanges of foot ab/adduction occurs about foot midline.
- \* in  $\perp$  HAP, transverse plane motion.
- \* in  $\parallel$  HAP, coronal
- + RHR says abduction of hallux is positive. Then little toe abduction is negative
- + External/Internal rotation often defined long axis of limb.
- \* Often confused if refering motion to body midline or foot midline
- \* in this book, movement about the talocrural joint & subtalar = external/internal rotation for toe/out

## Whole foot motions & complexity

- cannot isolate muscle actions + consequences
- Plantarflexion - Dorsiflexion
- + often seems synonymous with flexion/extension

- + Triceps Sural group pull via calcaneus
- + cascade of ligament strain due to motion of tarsal joints
- + FHL, FHB, TP create oblique medial twist due to wrap around medial malleolus
- + PL, PB create lateral flexion moment, small
- + Plantar flexion defined by Jenkins: action of all posterior compartment muscles in foot. Dorsiflexion = anterior compartment.
- \* foot twist part of it, particularly inward twist
- \* outward foot twist needs separate term
- + Most kinematic studies assume all rotation about talocrural, and other twist occur in other, unspecified joints

- Inversion/Eversion



- + 45% published literature agree it is a rotation about the long axis so the sole faces medial/laterally
- + 21% say subtalar movement so sole of hindfoot faces medial/lateral
- + anatomical plane definition under inversion/eversion either an abduction/adduction in coronal or transverse ER/IR
- + Using 11 foot HAP, abduction thanks to Tibialis posterior and peroneals
- \* However, FHL, FHB provide medial twist too
- + 2<sup>nd</sup> definition suggest separation of movement between fore and hind foot, distal vs proximal action
- + further complications include metatarsal/phalange action and their foot influence
- \* e.g. extend helix medial lobe lifts up, inversion of forefoot.

- Pronation / Supination
- + only defined w.r.t. radius / ulna rotation
- + abuse in foot definition
- + most popular is a movement of subtalar joint oblique to all planes, involving all actions (dorsi/plantar flexion, eversion/inversion, add/abduction)
- \* definition can be cleaned up with identification of planes and assumptions
- + DOES NOT ACCURATELY DESCRIBE MOTION
- \* what is overpronation?
- \* equal extra motion from all actions? just one?
- \* results in impressions, not useful for outcomes
- + 2<sup>nd</sup> popular definition = inversion / eversion
- \* BASICALLY, nobody can say for sure what the hell has happened, but the foot looks different
- + only plantaris, soleus, and gastroc are extrinsic connectors to calcaneus to "twist" hindfoot
- \* few intrinsic muscles connect, very limited twisting force capacity

- + cannot be considered normal function, must be a result of other function
- + does it even deserve to be an action??

## Terminological Implications of Mathematical Choices

- rotation matrices suffer from definition of initial planes & order of angular rotations
- X, Y, Z rotation values (Cardan / Tait-Bryan angles, subset of Euler) combined into lot of 6 diff. Sequences
- kinematic impact of order has impact
- + often values interpreted in isolation without known order
- + Woltring suggests "attitude" vector, independent of sequence for rotations.
- + low adoption
- great lack of mathematical understanding and validity

# Effect of foot orientation based on rotation expression

Rotation Axis	Anterior foot orientation	Lateral foot orientation
X (medial/lateral)	15°	2°
Y (posterior/anterior)	18°	23°
Z (inferior/superior)	5°	40°

XYZ  
decomp



33°  
rotation



new XYZ  
decomp

Rotation Matrix:

$$\begin{bmatrix} 0.66 & -0.50 & 0.50 \\ 0.74 & 0.61 & -0.30 \\ -0.14 & 0.56 & 0.81 \end{bmatrix}$$

Sequence	X	Y	Z
XYZ	20	30	40.0
XZY	42.8	37.0	33.8
YXZ	17.2	31.6	50.3
YZX	25.9	11.9	47.3
ZXY	34.3	9.8	42.4
ZYX	39.0	8.1	47.9
Attitude	29.2	21.8	43.9

## Conclusion

- Communication is hard
- no serious standard
- publishers glossary?
- + acceptable eponyms
- + limb segment names (Leg, Shank, Humerus, etc)
- + anatomical positioning of foot, foot + leg
- + plane definitions
- + movement definitions, whole foot or joint sp.
- + rot. sequence. Either universal or joint spec.