Basic Biomechanics

- typical mechanical engineering
- review core math

Terminology

- $F = ma$

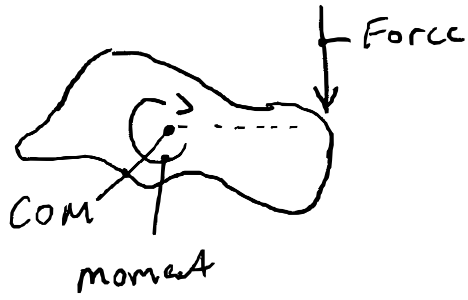
- stress = action of force wrt given area
  + 1 N/m^2 stress = 1N for every square meter of area
  + if perpendicular to surface of object, denoted as "normal stress"
  + parallel to surface, shear stress
  + moment = force acting a distance from a certain point
  * biomechanics: torque, since often fixed point of rotation
  + change in shape of object due to stress = deformation
  + strain = expression capturing amount of deformation from original geometry

- strain perpendicular to cross section = normal
- parallel = shear strain
- equilibrium = state where $\sum$ forces & moments = 0 written as:

$$\sum F(x, y, z) = 0$$

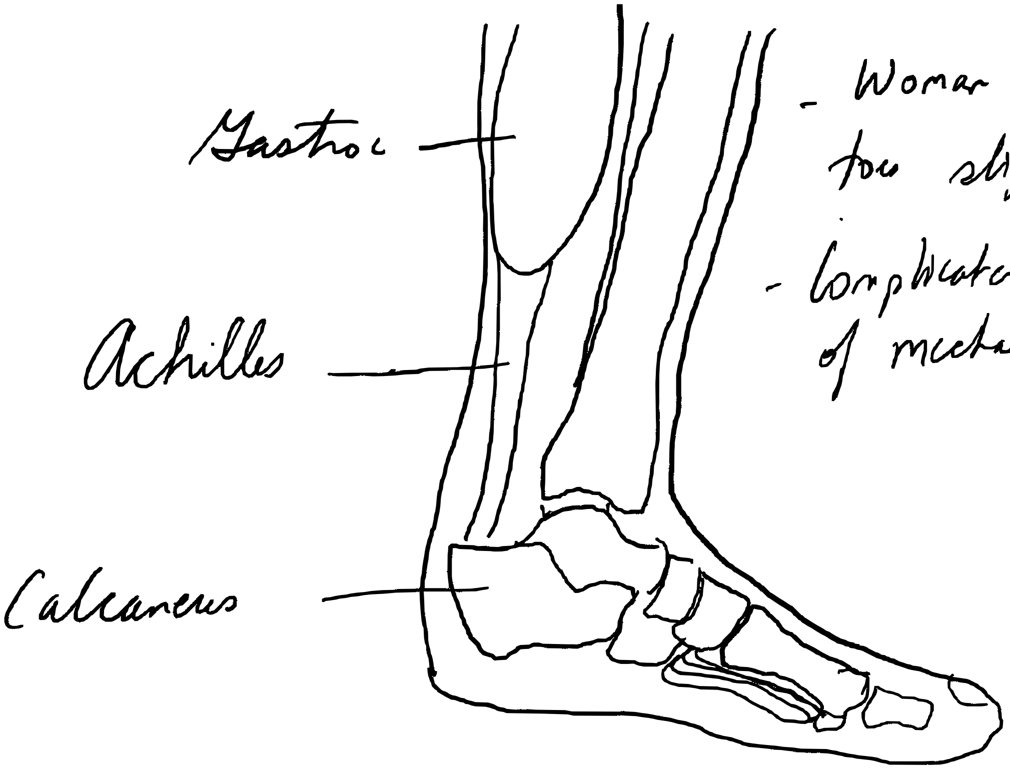
$$\sum M(x, y, z) = 0$$

E.g: Talus, lateral view



Statics

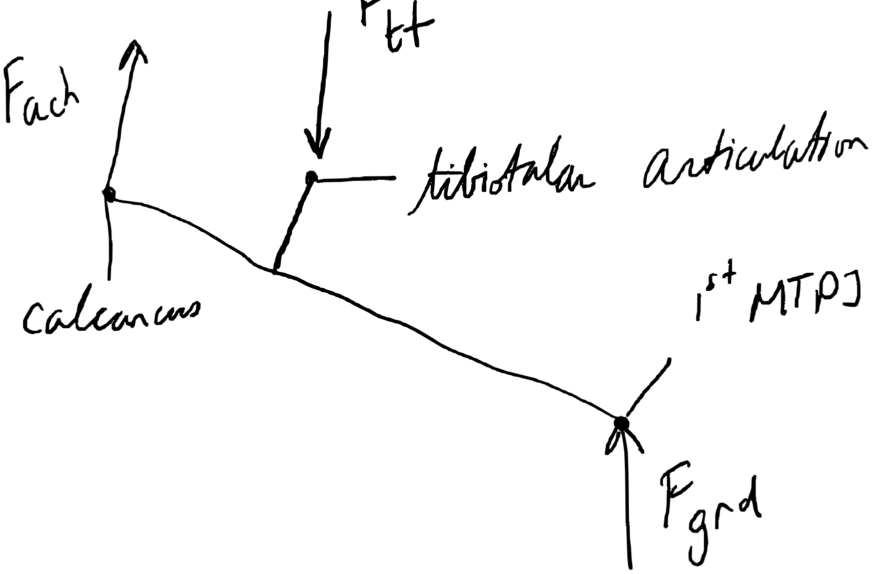
- study of external force on a system in equilibrium
+ human body, either still or momentarily still
+ gravity + internal forces and moments = 0
* assume bodies are rigid and non deformable
- FBD (free body diagram) for biomechanics require deep anatomy knowledge.
+ when model is wrong or what assumptions to make

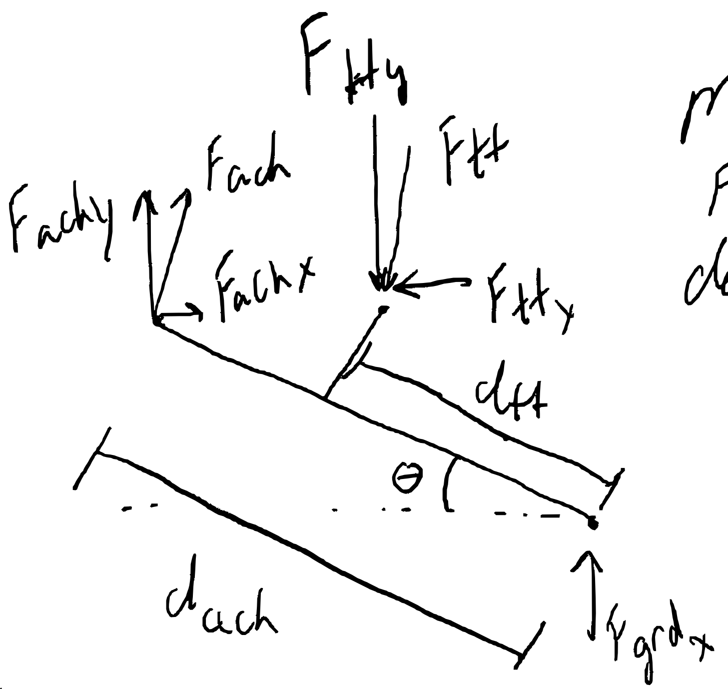


- Woman standing on toe slightly.
- Complicated representation of mechanics

FBD

hind & midfoot fused to form single segment





More complete FDB with decomposition

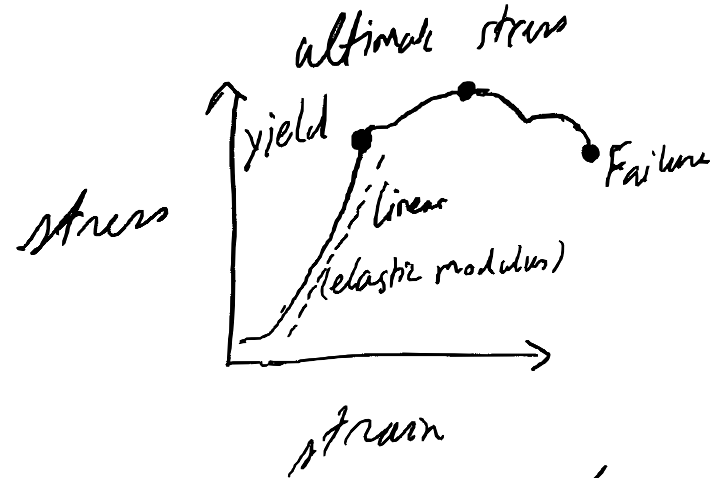
Helps identify assumptions (segment rigidity, singular muscular element)

Dynamics

- External forces acting on an object, resulting in change in motion
+ net forces on system ≠ 0
+ kinematics - study of motion regardless of forces that create it.
* time, position, velocity, acceleration, geometry
* NOT forces, stresses, deformation, strain
+ kinetics study of forces and moments causing motion
+ Kinesiology = study of human movement.

Strength of Materials & Deformation

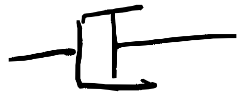
- rigid useful of human biomechanics
- however, tissues deform to mechanical tension
+ stress and strain on cells, trigger response in the cell ECM
* Wolf's law for bones



* adipose tissue structural role in cushioning sole and heel

- core concepts:
+ elastic modulus = material property, ratio of stress to strain in region of elastic response
+ stiffness = structural property, resistance to deformation
+ failure = complicated, but in biomechanics, catastrophic breakdown
+ yield / ultimate / failure load and strain: points on curve for end of elastic response, end of maximal load, catastrophic failure
+ Poisson's Ratio = ratio of transverse to axial load
* e.g. tendon gets thinner under axial load
- deformation
+ elastic = change when perturbed, return to state
+ plastic = change when perturbed, permanent
+ fluid flow

Viscoelasticity

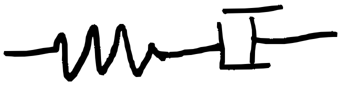


$F_{spring} = kx$

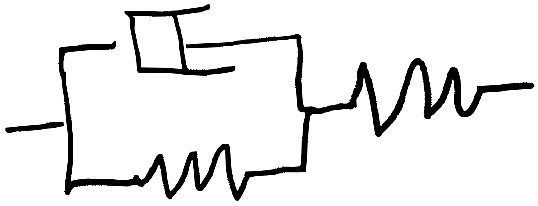
- k: spring constant
- x: strain

$F_{dashpot} = \mu \dot{x}$

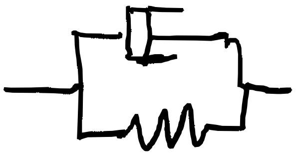
- μ: coefficient of viscosity
- $\dot{x}$: rate of strain



Maxwell



Standard linear



Kelvin-Voigt

- biological tissue often complex blend of elements for substantial motion and deformation
- fluid content implies **viscosity** = resistance of fluid to shear
  + **viscoelasticity** = combined consideration of solids and fluids
- 3 models, all use spring + dashpot
  + Kelvin-Voigt
  + Maxwell
  + Standard Linear

* ligaments, organ tissue, bone, cartilage, skin, etc.