UNSW

Musculoskeletal Modelling in Physical Rehabilitation

Lauren Kark (lauren.kark@unsw.edu.au)

Never Stand Still | Faculty of Engineering | Graduate School of Biomedical Engineering

Aims and Objectives

This lecture aims to:

- Introduce musculoskeletal modelling in physical rehabilitation

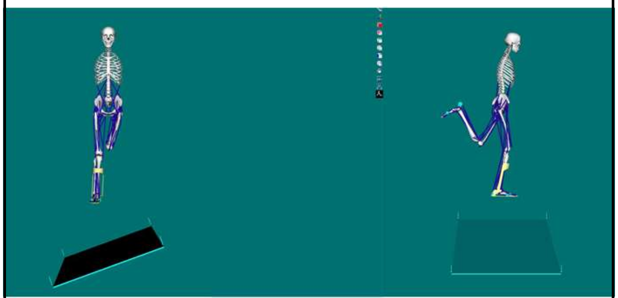
Following this lecture you should be able to:

- Describe the anatomy of the ankle
- Discuss the biomechanics of the ankle
- Describe the ways in which the ankle can be injured
- List current methods for preventing ankle injuries
- Develop design criteria for an optimal ankle brace
- Discuss how musculoskeletal modelling can be used to assess the efficacy of new designs of medical technology associated with human movement

does ~~what~~ it's meant to.

UNSW Graduate School of Biomedical Engineering

Introduction



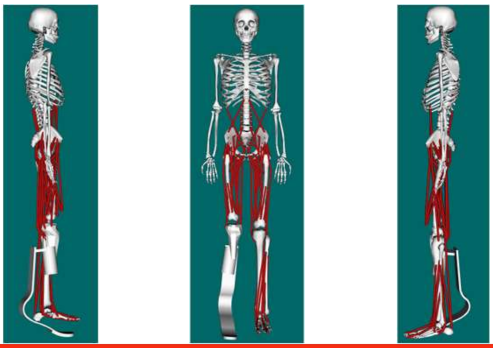
UNSW Graduate School of Biomedical Engineering

Today

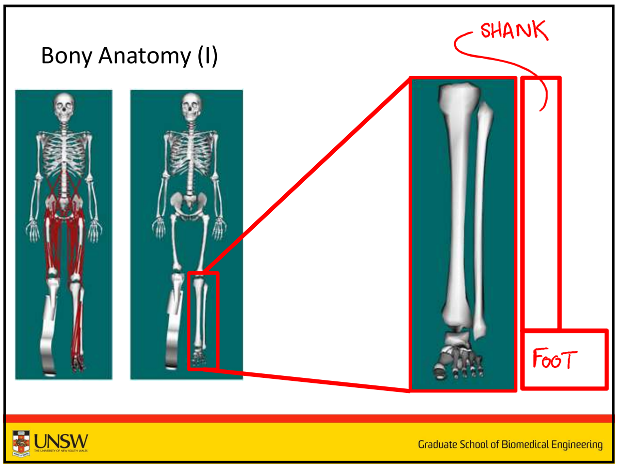
1. Anatomy
2. Injuries
3. Mechanics of Injuries
4. Prevention
5. Musculoskeletal modelling

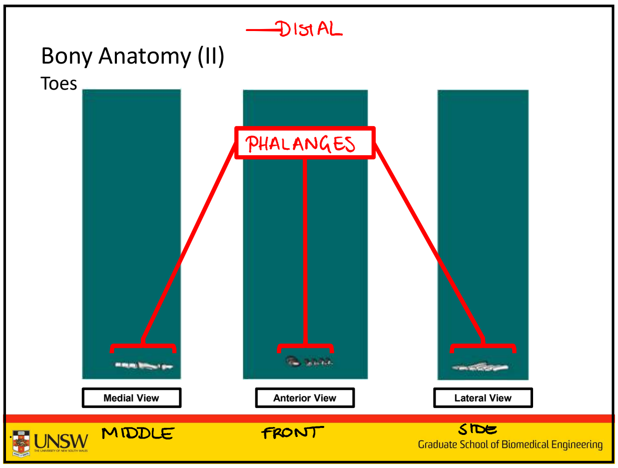
UNSW Graduate School of Biomedical Engineering

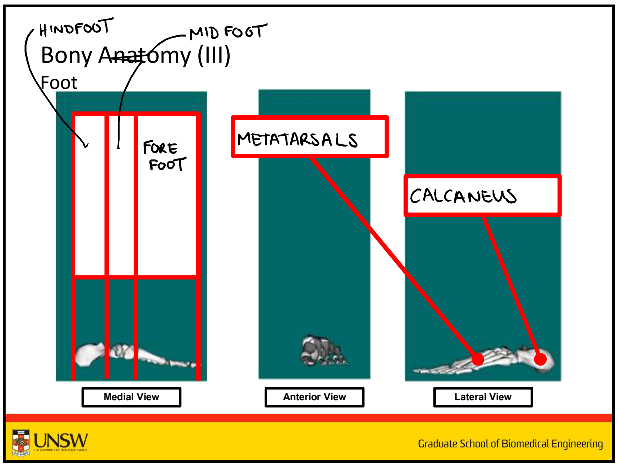
Anatomy

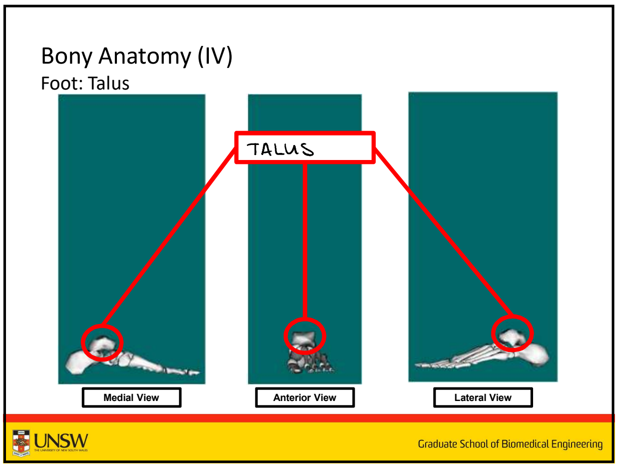


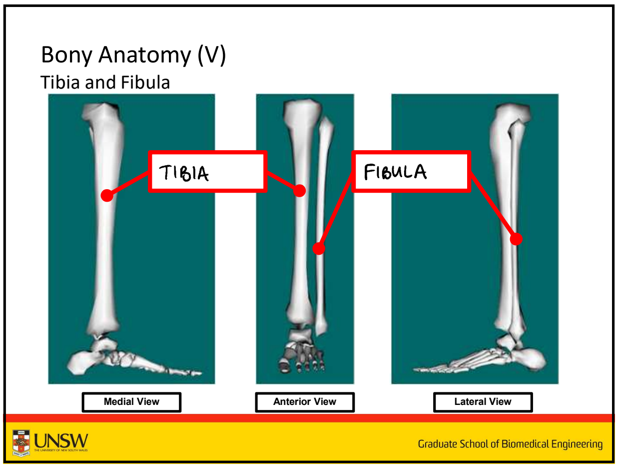
UNSW Graduate School of Biomedical Engineering

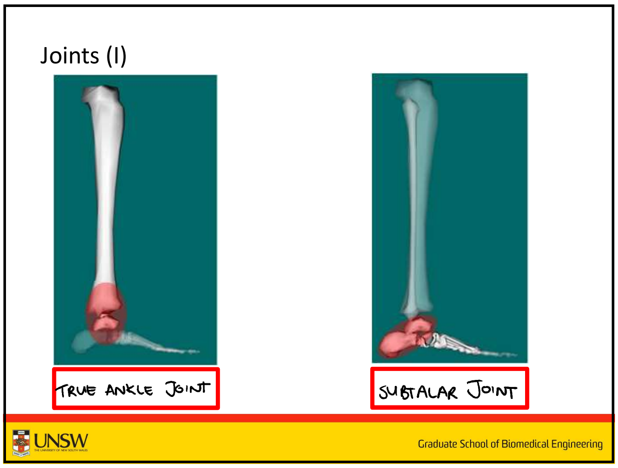

Bony Anatomy (I)
SHANK
FOOT
UNSW
Graduate School of Biomedical Engineering


Bony Anatomy (II)
Toes
DISTAL
PHALANGES
Medial View
Anterior View
Lateral View
MIDDLE
FRONT
SIDE
UNSW
Graduate School of Biomedical Engineering


HINDFOOT
MID FOOT
Bony Anatomy (III)
Foot
FORE FOOT
METATARSALS
CALCANEUS
Medial View
Anterior View
Lateral View
UNSW
Graduate School of Biomedical Engineering


Bony Anatomy (IV)
Foot: Talus
TALUS
Medial View
Anterior View
Lateral View
UNSW
Graduate School of Biomedical Engineering


Bony Anatomy (V)
Tibia and Fibula
TIBIA
FIBULA
Medial View
Anterior View
Lateral View
UNSW
Graduate School of Biomedical Engineering


Joints (I)
TRUE ANKLE JOINT
SUBTALAR JOINT
UNSW
Graduate School of Biomedical Engineering

Joints (II)
True Ankle

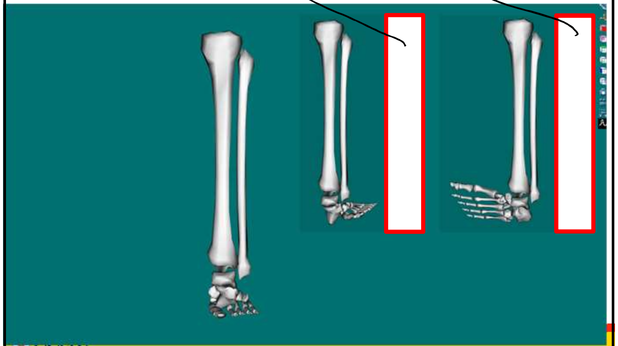
PLANTARFLEXION

DORSIFLEXION

Joints (III)
Subtalar

EVERSION

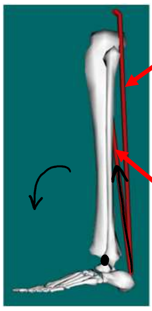
INVERSION



Muscles (I)
Plantarflexors

Moments → turning effect of force.

$\vec{M} = \vec{r} \times \vec{F}$

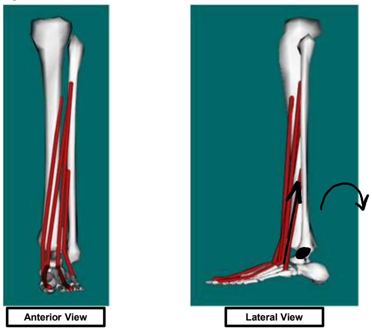


GASTROCNEMIUS

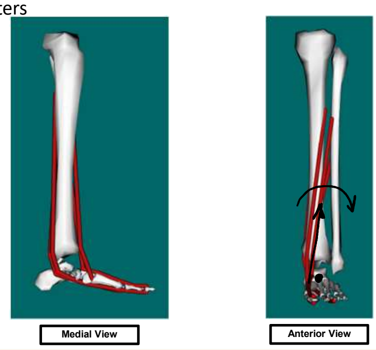
SOLEUS

TRICEPS SURAE

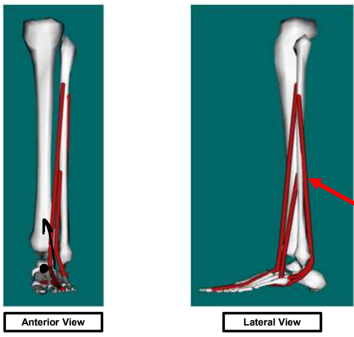
Muscles (II)
Dorsiflexors



Muscles (III)
Inverters



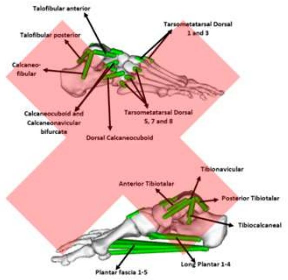
Muscles (IV)
Evertors



PERONEUS MUSCLES

Ligaments (I)

- Connect bone to bone
- Important for joint stability



https://estudogeral.sib.uc.pt/bitstream/10316/29704/1/Ana%20Carolina%20Pinto%20da%20Silveira.pdf

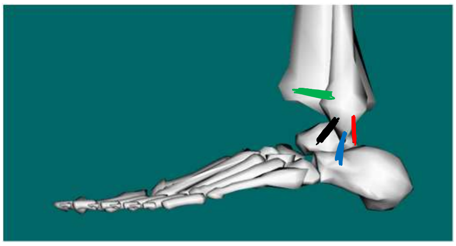
UNSW Graduate School of Biomedical Engineering

Ligaments (II)

Lateral

ANTERIOR TALOFIBULAR

ANTERIOR TIBIOFIBULAR



CALCANEOFIBULAR

POSTERIOR TALOFIBULAR

UNSW Graduate School of Biomedical Engineering

Ankle Injuries

Structure	Injury
Bone	FRACTURE
Ligament	SPRAIN
Muscle	STRAIN
Tendon	TENDINOPATHY
CARTILAGE	TEAR

UNSW Graduate School of Biomedical Engineering

Ankle Sprains (I)

Statistics

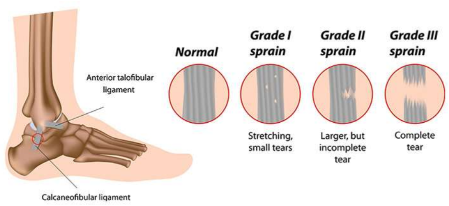
- Account for nearly half of all sports injuries
- 25,000 people per day in US alone (9 million per year)
- > 80% of ankle sprains are a result of inversion
- 41% of ankle sprains related to basketball
- History of ankle injury makes re-injury 5 times more likely

http://anklerollguard.com/ankle-sprain-stats--info.html

UNSW Graduate School of Biomedical Engineering

Ankle Sprains (II)

Grades

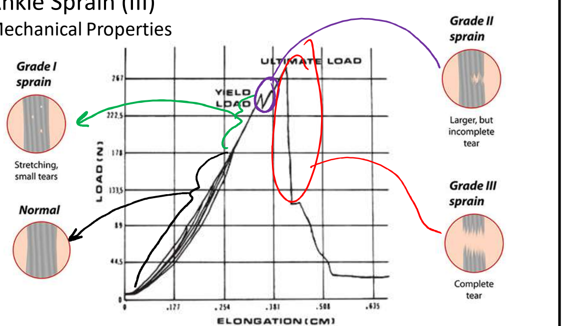


http://chicagofootcareclinic.com/footproblems/ankleproblems.html

UNSW Graduate School of Biomedical Engineering

Ankle Sprain (III)

Mechanical Properties



https://books.google.com.au/books?id=xAi7enaRlAIC&pg=PA536&lpg=PA536&dq=The+tensile+strength+of+the+anterior+talofibular+ligament.&source=bl&ots=GIXNr_gmfn&sig=bEYqGOwXAXsX8KBneBrlkQMSUHs&hl=en&sa=X&ved=0ahUKEwj68tCLjIHPAhXNNpQKHf4FAd0Q6AEIOjAE#v=onepage&q=The%20tensile%20strength%20of%20the%20anterior%20talofibular%20ligament.&f=false

UNSW Graduate School of Biomedical Engineering

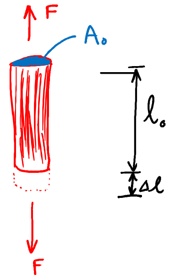
Ankle Sprains (IV)

Mechanical Properties: Stress, Strain and Young's Modulus

$F \Rightarrow \sigma = \frac{F}{A_0}$

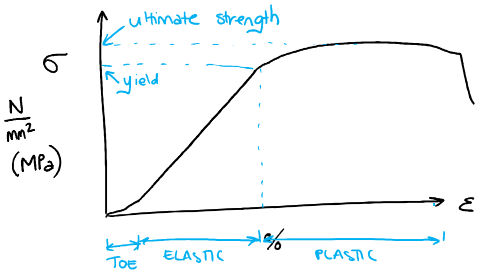
$l \Rightarrow \varepsilon = \frac{\Delta l}{l_0}$

$E = \frac{\sigma}{\varepsilon}$ } only in linear section



Ankle Sprains (V)

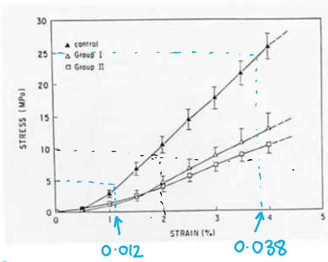
Mechanical Properties: Stress-Strain Diagram



Example (I)

The ATFL has an original cross-sectional area of 10mm² and an original length of 15mm (made up numbers!). For each of the groups shown in the stress-strain diagram on the right, calculate:

- Young's modulus
- Length at ~~yield~~ 10MPa.



Control:

$E = \frac{\sigma}{\varepsilon} = \frac{25-5}{0.038-0.012} = 769\ MPa$

$(E_1 = 500MPa;\ E_2 = 313MPa)$

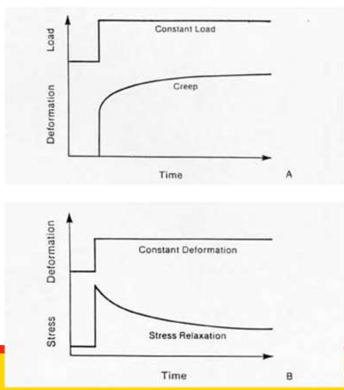
@10MPa: $\varepsilon = 0.02 = \frac{\Delta l}{l_0} = \frac{\Delta l}{15}$

$\Rightarrow \Delta l = (0.02)(15) = 0.3mm$

$l_f = l_0 \pm \Delta l = 15.3mm$ #

Example (II)

Viscoelasticity



Break (~2mins)

Ankle Sprains (IV)
Risk Factors

- Previous or existing ankle injury (biggest factor)
- Lack of strength and stability in the ankle
- Lack of, or extreme, flexibility in the ankle
- Poor balance
- Acceleration or deceleration (sudden change in direction)
- Increasing age

http://sma.org.au/wp-content/uploads/2011/01/719-SMA-InjuryBrochure-ankle_web.pdf

UNSW Graduate School of Biomedical Engineering

Ankle Sprains (V)
Prevention

- Balance training
- Ankle strengthening
- Flexibility
- Adequate preparation
- Taping and bracing

UNSW Graduate School of Biomedical Engineering

Taping and Braces

Taping		Braces	
Pros	Cons	Pros	Cons
Customisable	Cost	Reusable	
Less bulky	Qualified person	Cost	
Proprioception	Lost effectiveness*	Easy to apply	
		ROM restriction	
		Better prevention	

* Taping support declines by 40 – 50% within 5 – 20 minutes of activity (Paris et al., 1995)

UNSW Graduate School of Biomedical Engineering

http://www.braceup.com/ankle_01.htm

Ankle Braces (I)
Types

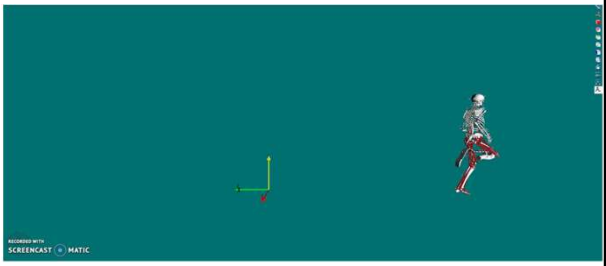
UNSW Graduate School of Biomedical Engineering

Ankle Braces (II)
Design Requirements for Hinged Braces

ENGINEERING FUNCTIONAL AESTHETIC

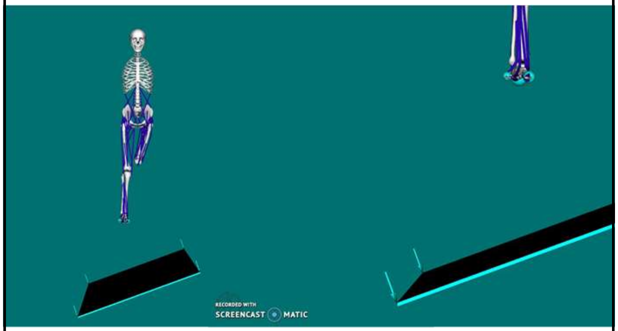
UNSW Graduate School of Biomedical Engineering

Musculoskeletal Modelling (I)



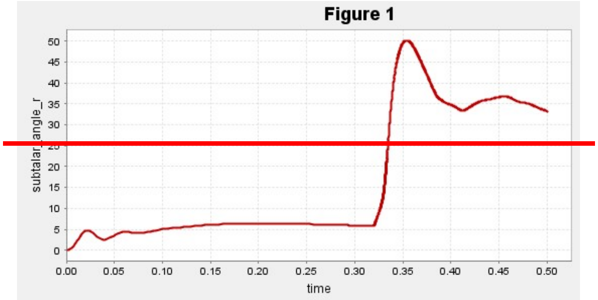
UNSW Graduate School of Biomedical Engineering

Musculoskeletal Modelling (II)



Musculoskeletal Modelling (III)

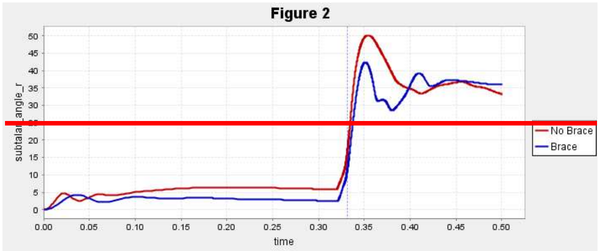
Ankle Inversion Angle



Musculoskeletal Modelling (IV)

Musculoskeletal Modelling (V)

Comparison of Inversion Angles



Musculoskeletal Modelling (VI)

- Your job in the tutorial this week is to design the optimal ankle brace!
- Two types of braces: passive and active (challenge)
- Minimum passive design requirements:
  - Prevent ankle injury (inversion angle<25°)
  - Minimal stiffness, for maximal comfort
- Minimum active design requirements:
  - As for passive, but also:
    - Smallest torque required for smallest motor
    - Minimal active time for maximal battery life
- Don't forget to include any other design criteria you think important.

Good luck! Have fun!

UNSW

Thank you!

Questions?

Never Stand Still | Faculty of Engineering | Graduate School of Biomedical Engineering