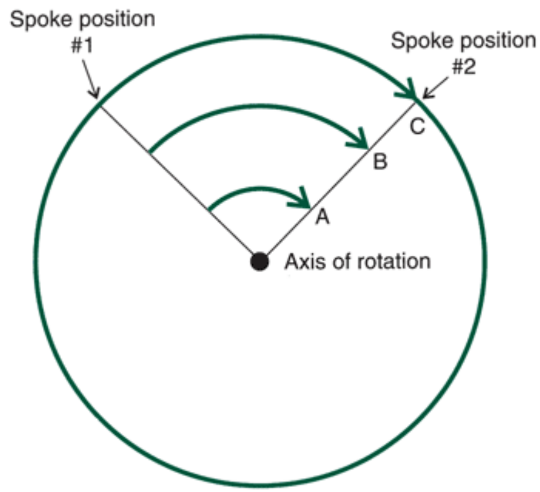
Read a chapter on Angular Kinematics

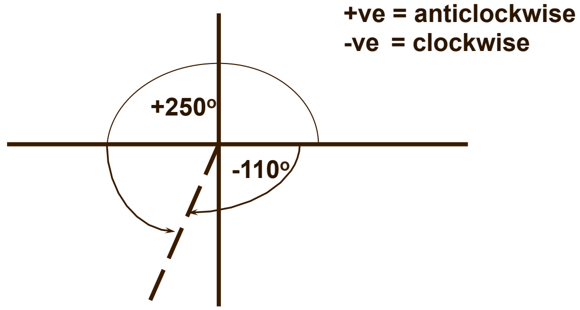
Angular Kinematics

Hamill & Knutzen (Ch 9)

Hay (Ch. 4), Hay & Ried (Ch. 10), Kreighbaum & Barthels (Module I) **or** Hall (Ch. 11)



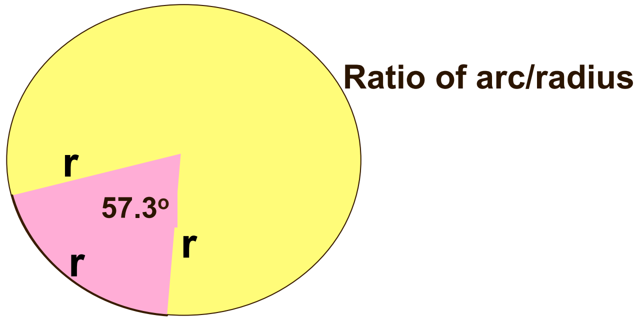
Reporting Angles



Measurement of Angles

- Degrees (arbitrary units)
- Radians (fundamental ratio)
- Revolutions

Radians

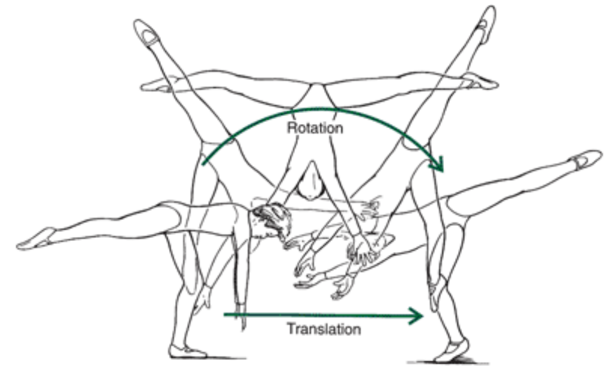


Circumference = $2\pi r$

therefore there are 2π radians in 360°

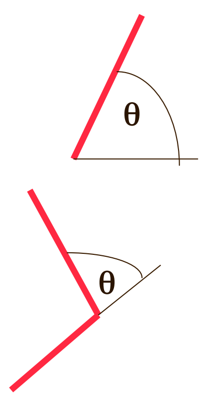
General Motion

(a combination of both linear and angular translations)



Types of Angles

- An absolute angle is measured from an external frame of reference.
- A relative angle is the angle formed between two limb segments.

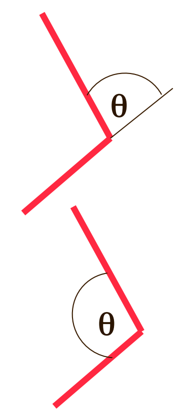


Relative Angles

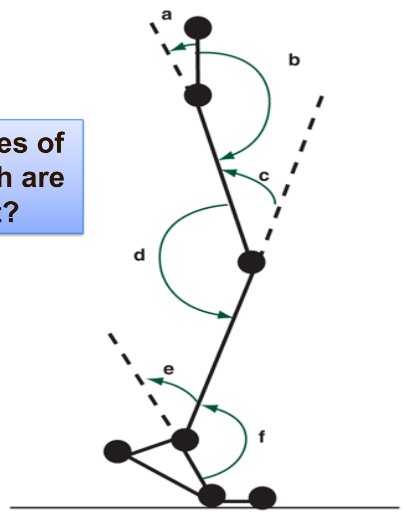
- A relative angle can be presented as degrees of flexion (opposite).

or

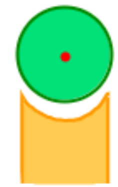
- presented as the angle formed at the articulation (opposite)



Which are degrees of flexion and which are angle at joint?



Axis of Rotation



Stationary Axis for a sphere joint

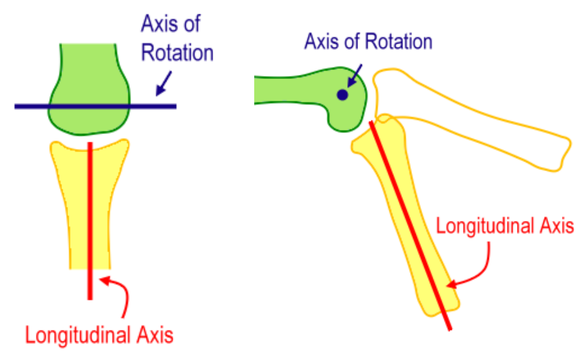
Migrating Axis throughout the whole range for a non-sphere joint

Knee Joint Centre of Rotation

- With machines centre of rotation is usually fixed.
- This is not the case with human joints.

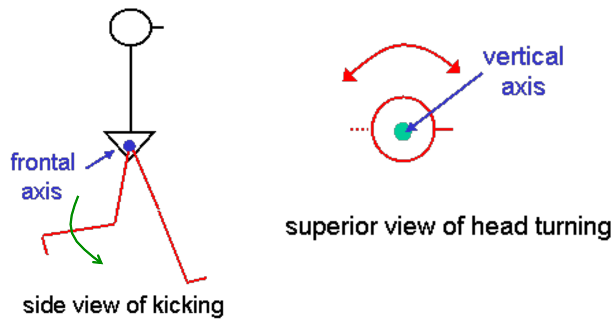
Axis of Rotation

longitudinal axis (axis that extends within and parallel to a long bone or body segment)



Description of Motion

Kicking the leg (leg moves anticlockwise [shown] in the sagittal plane about a frontal axis)
Turning the head (the head moves around a vertical axis in the horizontal plane)

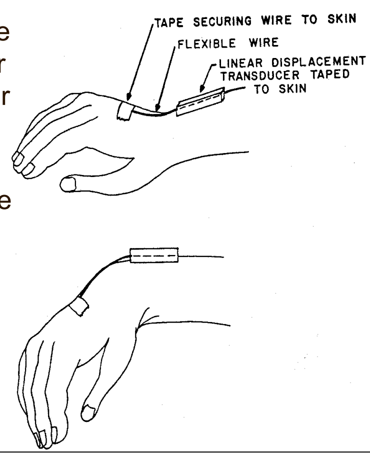


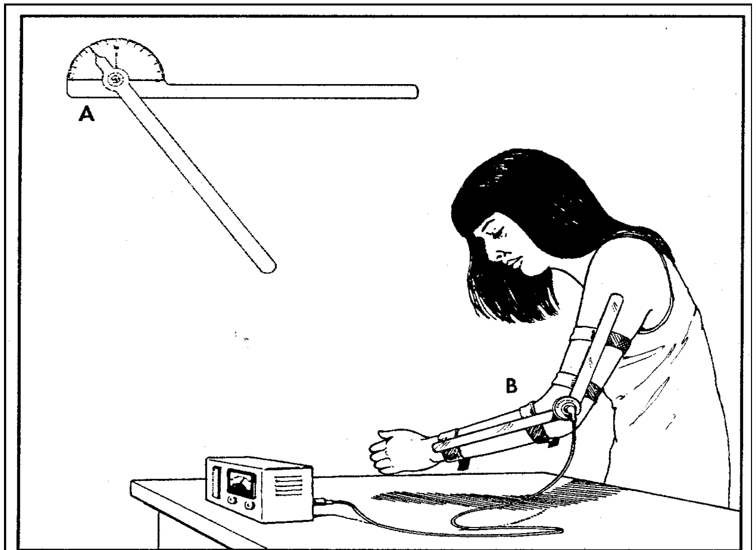
Data Acquisition

- If you really only need data for angular motion about a joint (pangle, angular velocity and angular acceleration) you do not need to collect data via an opto-electrical device.
- Electro-goniometers and other device are more portable.

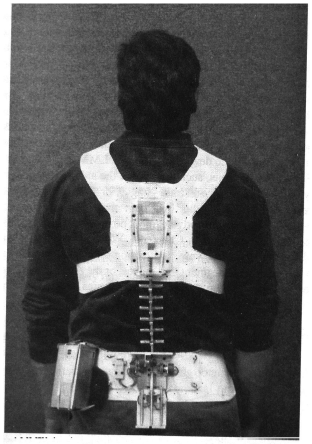
Goniometers

- Simple goniometers like the Leighton flexometer are really only useful for range of motion and static analysis.
- Electro-goniometers are easy to use and can follow changes in posture in dynamic situations (velocity & acceleration)



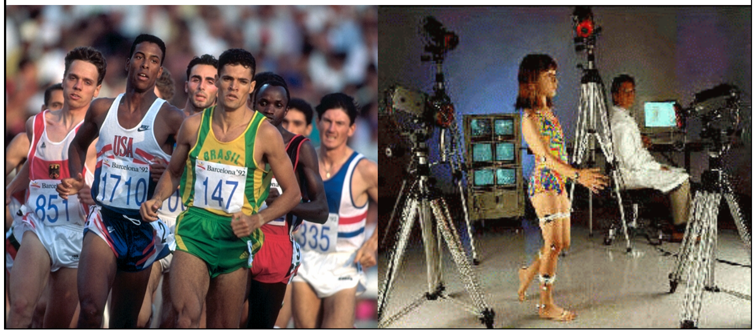


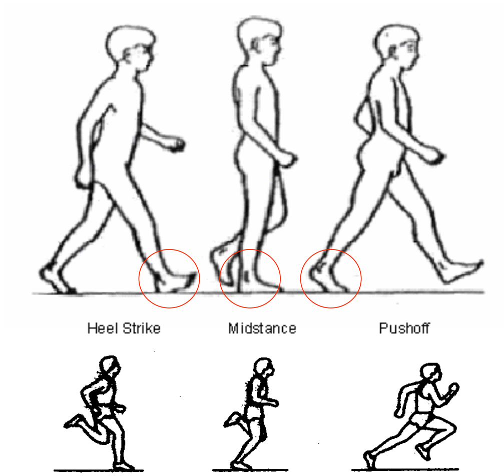
Lumbar Motion Monitor



- The LMM™ lumbar motion monitoring system was developed in the Biodynamics Laboratory at Ohio State University (W. Marras)
- This system allows continuous monitoring of the trunk angle and subsequent analysis can quantify trunk velocities and accelerations.

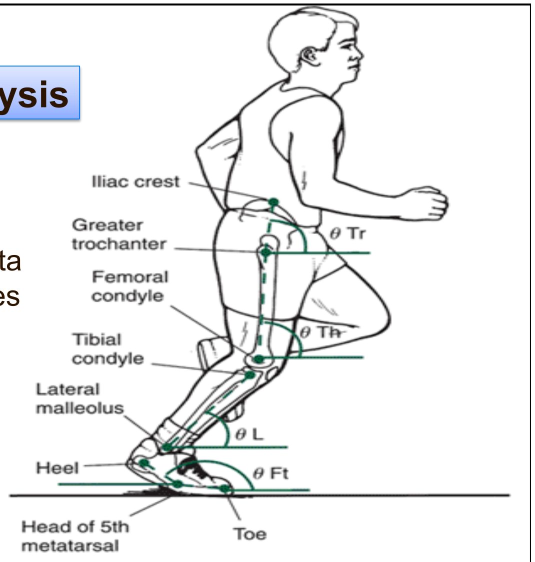
Gait and Running Analysis





Gait Analysis

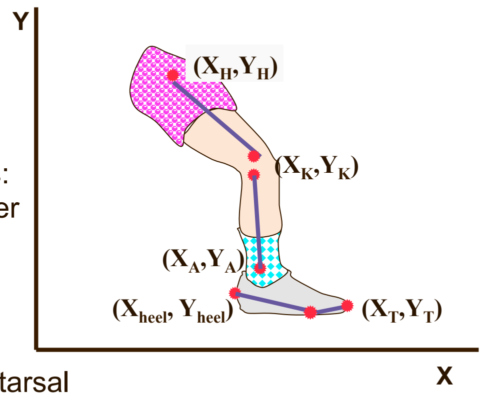
First we need coordinate data for joint centres



Lower Extremity Joint Angles

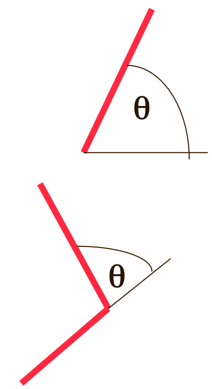
First we need coordinate data for joint centres

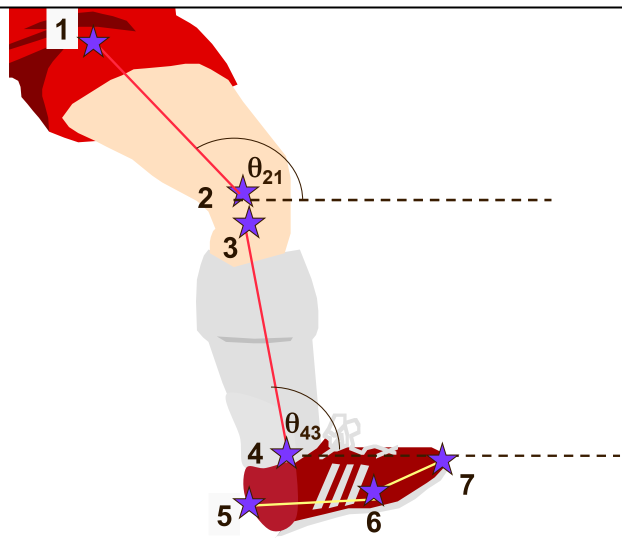
Marker locations:
greater trochanter
femoral condyle
tibial condyle
lateral malleolus
heel
head of 5th metatarsal
toe

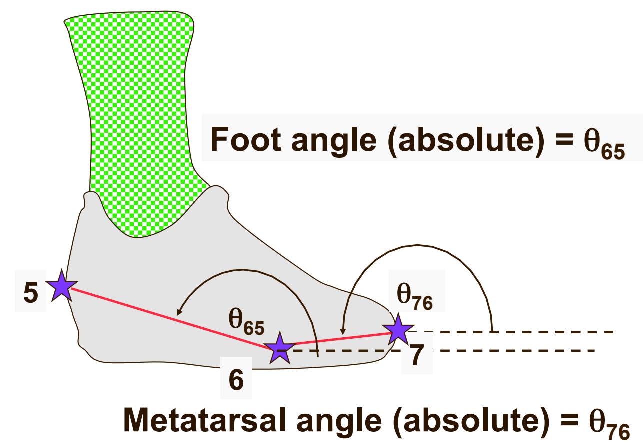


Describing Angles

- An absolute angle is measured from an external frame of reference.
- A relative angle is the angle formed between two limb segments.

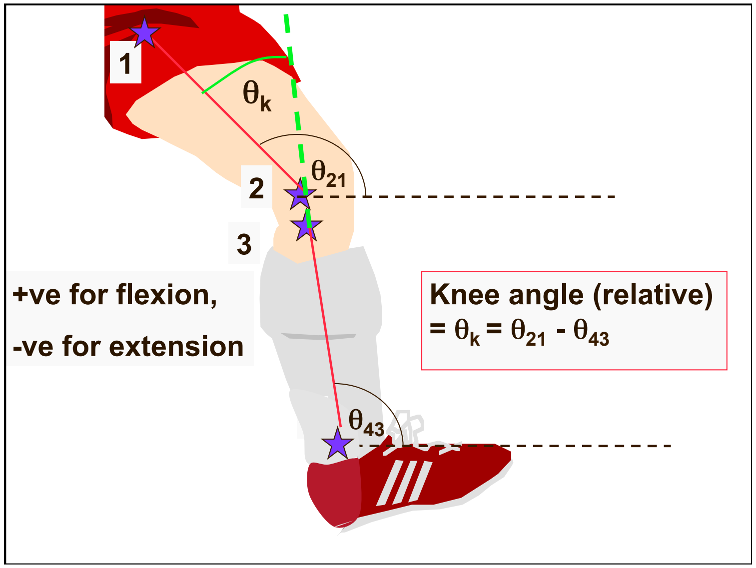






Hamill text, Winter (1979) pages 39-44

- **Diagrams on the next two slides**
- Thigh angle (absolute) = θ_{21}
- Shank angle (absolute) = θ_{43}
- Foot angle (absolute) = θ_{65}
- Metatarsal angle (absolute) = θ_{76}
- Knee angle (relative) = $\theta_{21} - \theta_{43}$
  (+ve for flexion, -ve for extension)
- Ankle angle (relative) = $\theta_{43} - \theta_{65} + 90^o$
  (+ve for plantarflexion, -ve for dorsiflexion)
- Metatarsal-phalangeal angle (relative) = $\theta_{65} - \theta_{76}$

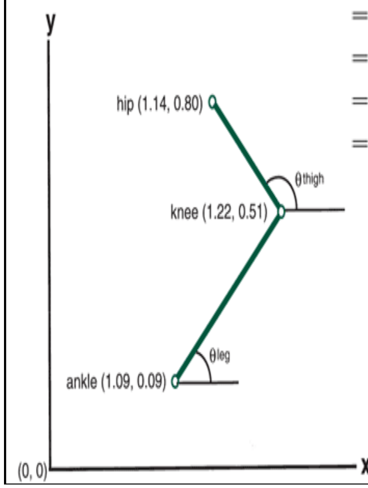


Knee Angle (relative angle) from Co-ordinate Data

$$\theta_{43} = \tan^{-1}\left(\frac{y_3 - y_4}{x_3 - x_4}\right) \quad \theta_{21} = \tan^{-1}\left(\frac{y_1 - y_2}{x_1 - x_2}\right)$$

- Knee angle = $\theta_k = \theta_{21} - \theta_{43}$
- if θ_k is positive the knee is flexed
- if θ_k is negative the knee is extended (dislocated?)

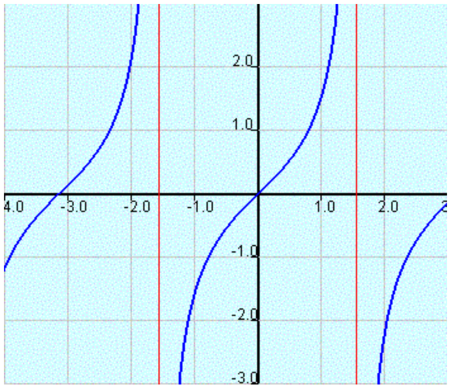
$$\tan\theta_{leg} = y_{distal} - y_{proximal}/x_{distal} - x_{proximal}$$
$$= y_{knee} - y_{ankle}/x_{knee} - x_{ankle}$$
$$= 0.51 - 0.09/1.22 - 1.09$$
$$= 0.42/0.13$$
$$= 3.23$$

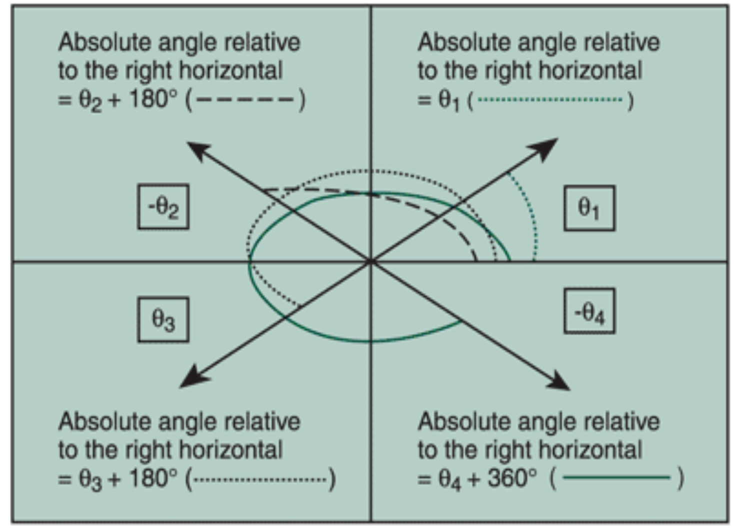


$\theta_{leg} = \tan^{-1}(3.23) = 72.8$ degrees (1.27 radians)

Let's step though the calculation of the angle θ_{thigh}

Tangent Function





Angular Velocity = ω

$$\frac{\text{change in angular displacement}}{\text{change in time}}$$

Angular Acceleration = α

$$\frac{\text{change in angular velocity}}{\text{change in time}}$$

Angular Velocity & Acceleration

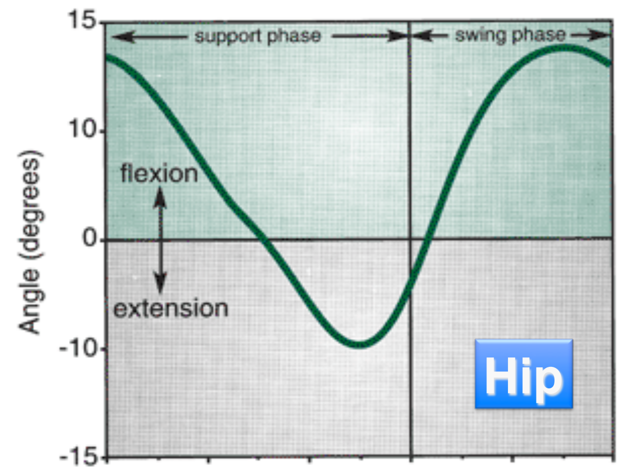
$$\omega_i = \frac{\theta_{i+1} - \theta_{i-1}}{2\Delta t}$$

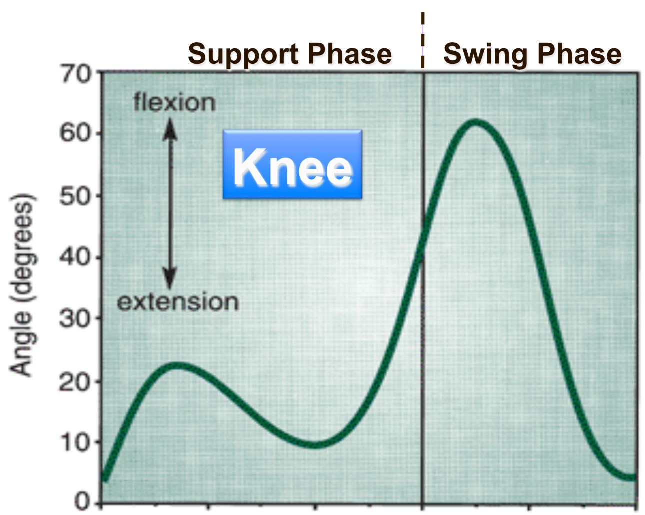
$$\alpha_i = \frac{\omega_{i+1} - \omega_{i-1}}{2\Delta t}$$

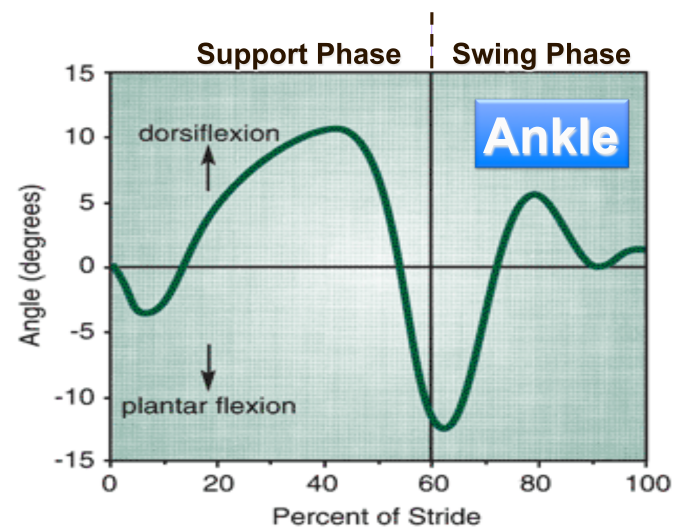
Question

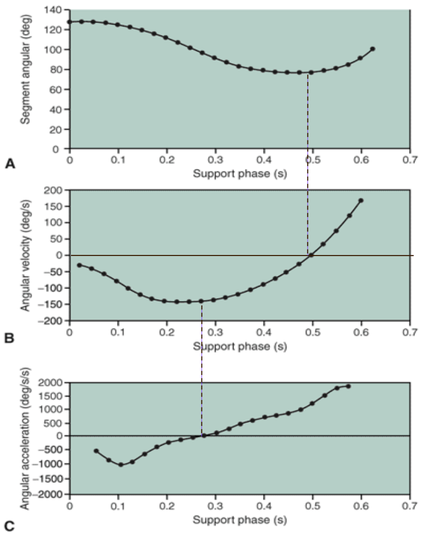
1. Calculate the angular velocity of the shank (lower leg) at frame 3. All values in are in cm. **[6]**

		greater trochanter		femoral condyle		tibial condyle		lateral malleolus		calcaneous		tarsal /metatarsal		toe	
FRAME	TIME [s]	x	y	x	y	x	y	x	y	x	y	x	y	x	y
2.0	0.0500	128.1	92.6	118.0	53.6	114.0	50.6	92.1	17.6	82.1	12.6	100.8	1.0	106.6	2.1
3.0	**0.0667**	**130.9**	**92.2**	**121.3**	**53.2**	**117.4**	**50.3**	**93.7**	**18.6**	**83.4**	**14.6**	**100.7**	**1.1**	**106.5**	**2.0**
4.0	0.0833	133.7	91.9	125.0	52.8	121.0	50.0	95.6	19.7	85.1	16.8	100.8	1.4	106.4	1.9
5.0	**0.1000**	**136.6**	**91.7**	**129.0**	**52.4**	**125.0**	**49.7**	**97.9**	**20.9**	**87.2**	**19.1**	**101.1**	**1.8**	**106.6**	**1.8**

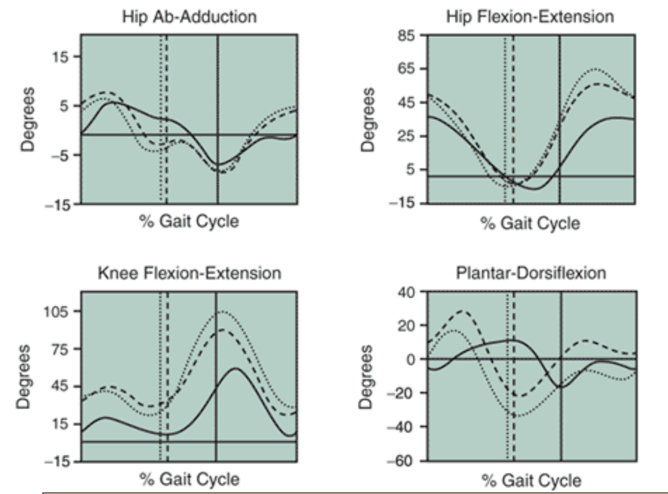








Graphic representations of the thigh's absolute angle (A), angular velocity (B), and angular acceleration (C) as a function of time for the support phase of walking



No need to study this slide.

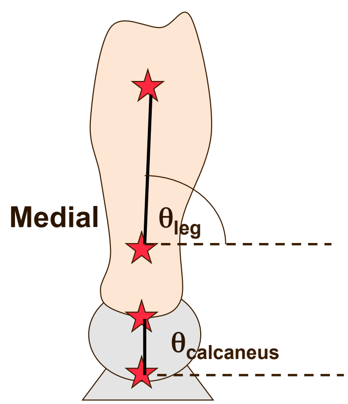
Rearfoot Angle

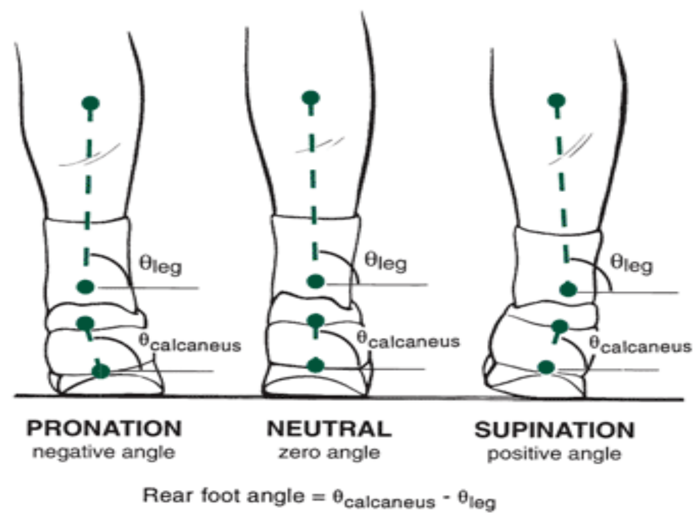
Rearfoot angle = θ_{RF}

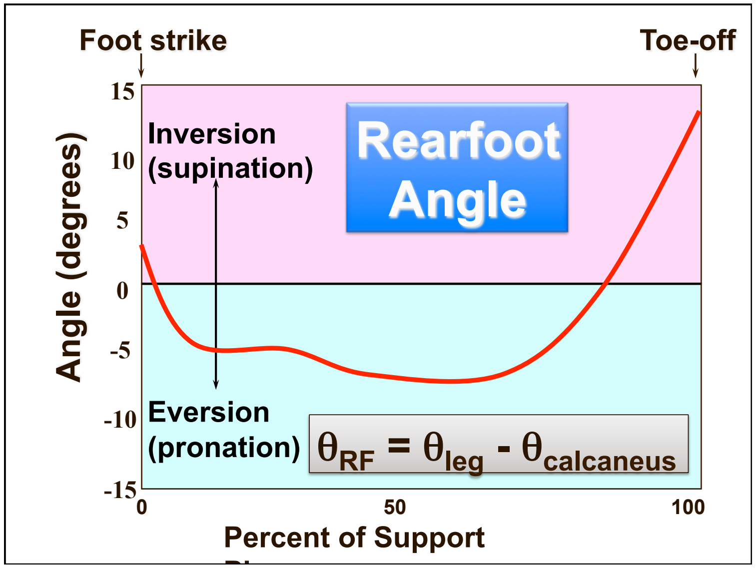
$\theta_{RF} = \theta_{leg} - \theta_{calcaneus}$

Positive angle for supination

Negative angle for pronation

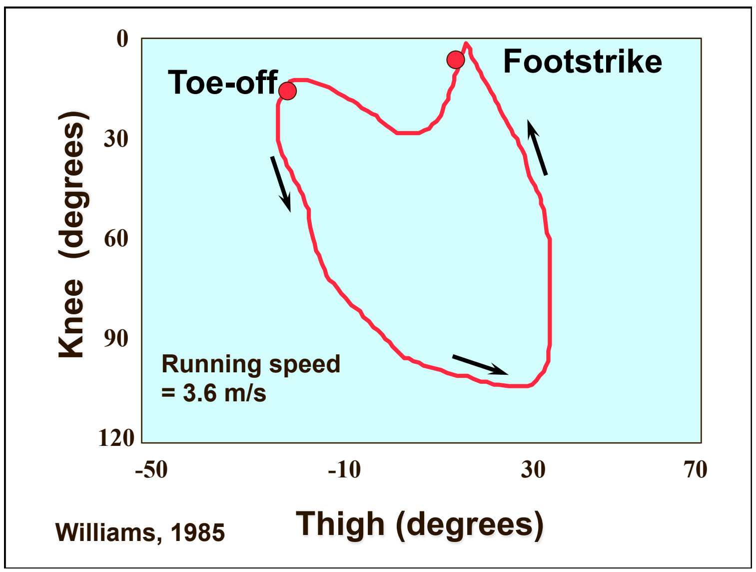


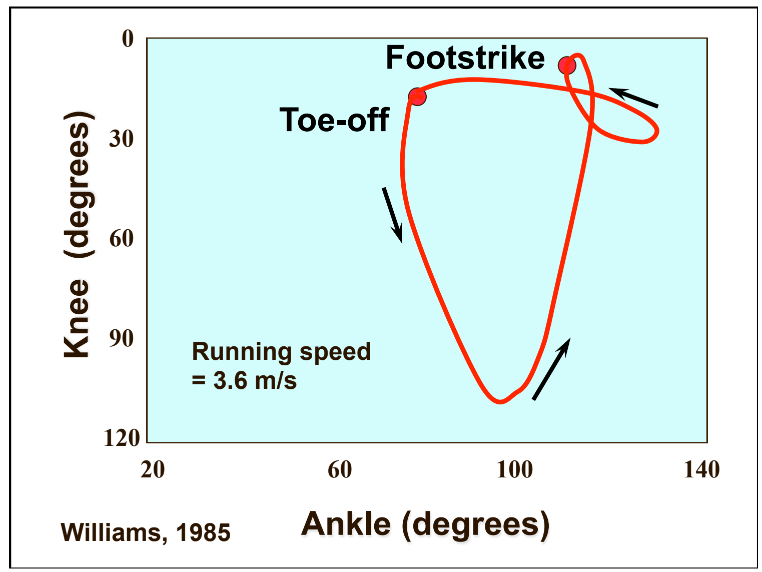


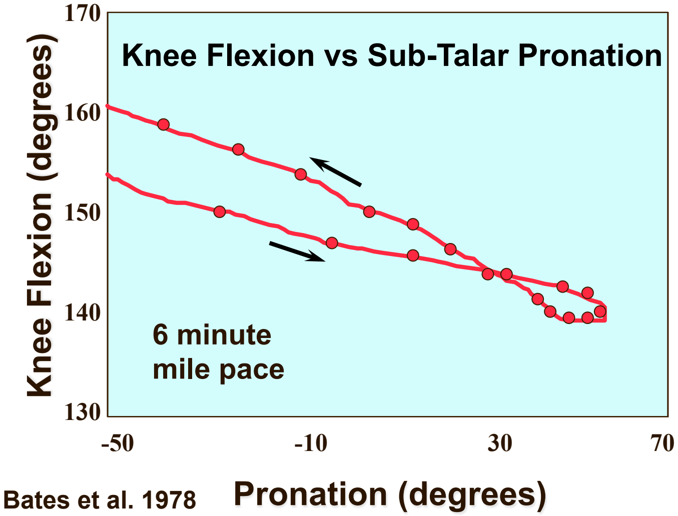


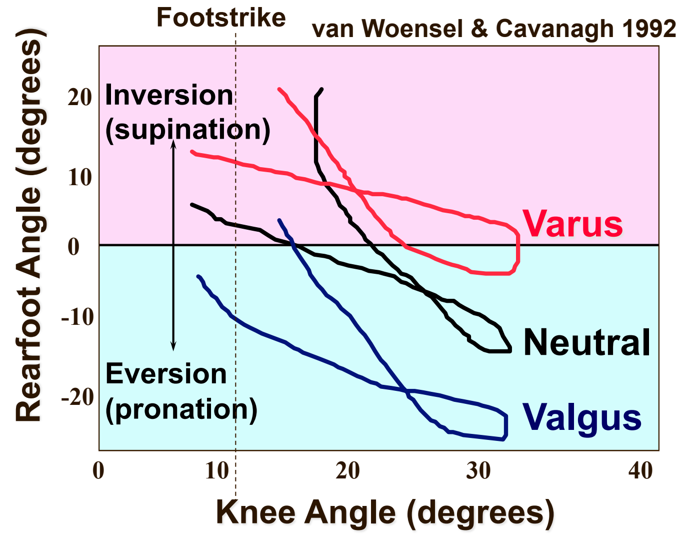
Angle-Angle Diagrams

- Most graphical representations of human movement you will see, plot some parameter (e.g. position, angle, velocity, etc.) against time.
- However, activities like running are cyclic and often it is useful to plot the relationship between two angles during the movement.
- There should be a functional relationship between these angles.





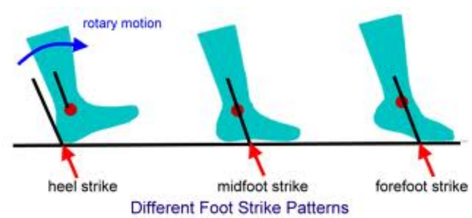




Magnitude of GRF

- Walking = 1 to 1.2 x Body Weight
- Running = 3 to 5 x Body Weight (Hamill & Knutzen 1995)
- As an example of this force magnitude, the patellofemoral joint force during squats can be up to 7.6 times Body Weight at (Reilly & Matens 1972)
- Hamill & Knutzen text on reserve has 7 graphs of GRF's during different types of human movement (pages 400-401)

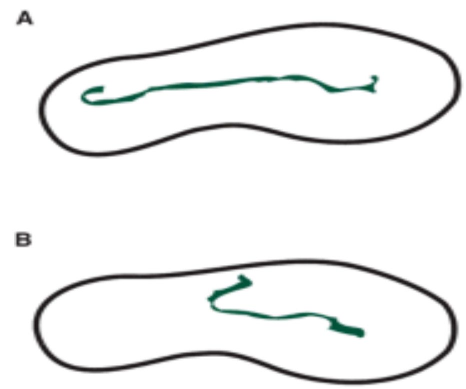
Does Nike® Air (or any substantial cushioning under the heel) reduce injury? Could it possibly increase the likelihood of injury?



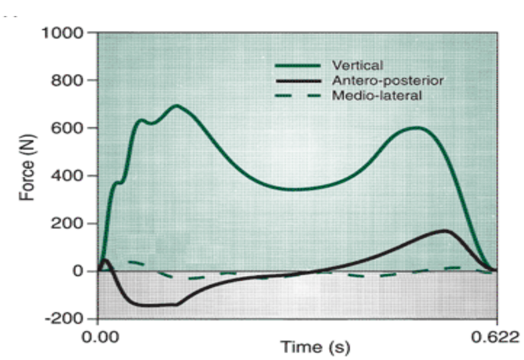
Impact Forces While Running

- The sport of running causes a relatively high injury rate
- Some argue this is due to overuse problems – basically too many foot strikes
- While this is definitely a causative factor, others suggest the heel strike is not a natural movement pattern and is a big contributing factor.

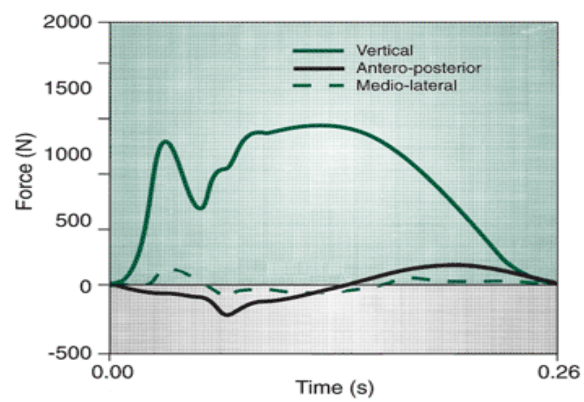
Center of pressure patterns for the left foot.
A. Heel-toe footfall pattern runner.
B. Mid-foot foot strike pattern runner.



Ground reaction force for walking.
Note the difference in magnitude between the vertical component and the shear components

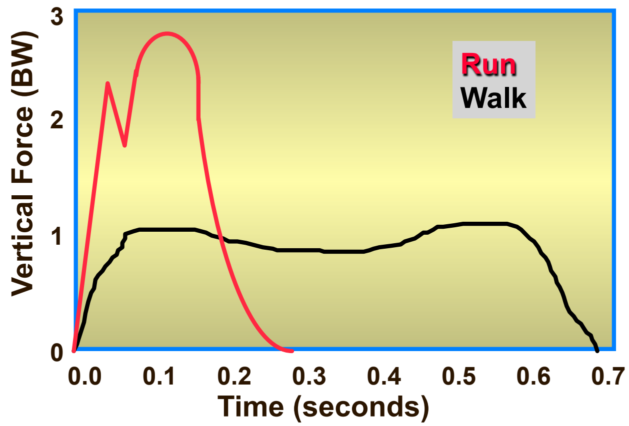


Ground reaction force for running.
Note the difference in magnitude between the vertical component and the shear components

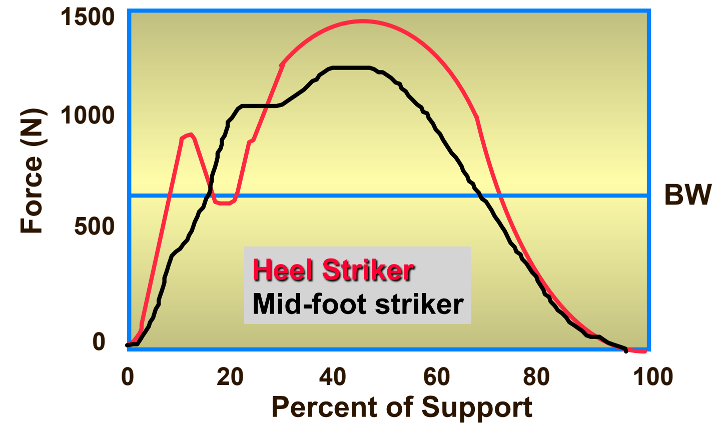


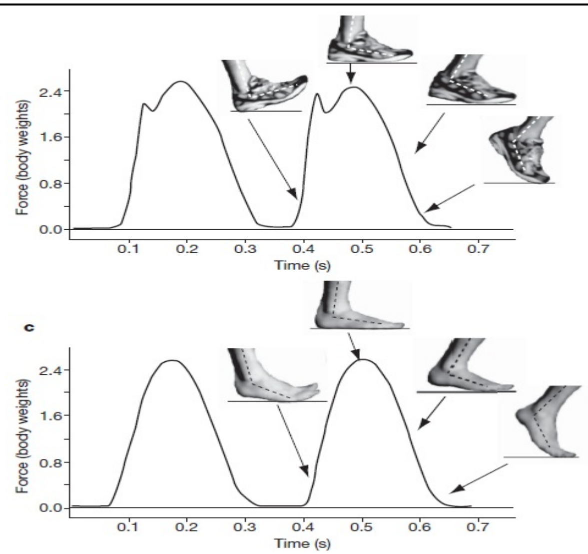
Vertical Ground Reaction Force

Time course of the GRF Impulse



GRF vs. Running Styles





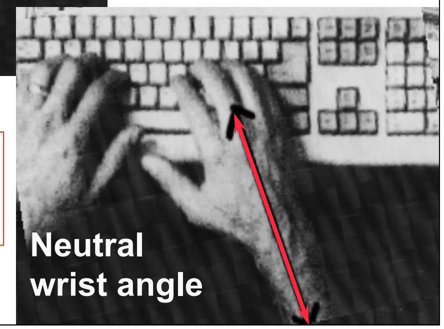
Links of Interest

- The issue of what is a natural foot strike pattern is a relatively hot topic these days, resulting in a resurgence of interest in barefoot running.
- **http://www.barefootrunning.fas.harvard.edu/4BiomechanicsofFootStrike.html**
- http://isiria.wordpress.com/2009/04/24/the-great-marketing-lie-expensive-runners-will-prevent-injury/
- http://www.nytimes.com/2009/10/27/health/27well.html?_r=2
- http://www.vibramfivefingers.com/
- http://www.posetech.com/

Other uses of Angular Kinematics.

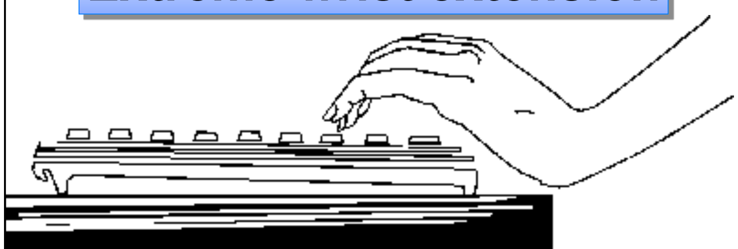
(Angular Kinematics is used a lot in Ergonomics when trying to assess if the workers are having to adopt hazardous postures for too long?)

Awkward Wrist Postures



Radial and ulna deviation are both problematic

Extreme wrist extension



Kin 380 & Kin 481

Prolonged wrist extension is believed to be a significant risk factor for carpal tunnel syndrome (Rempel 1991).

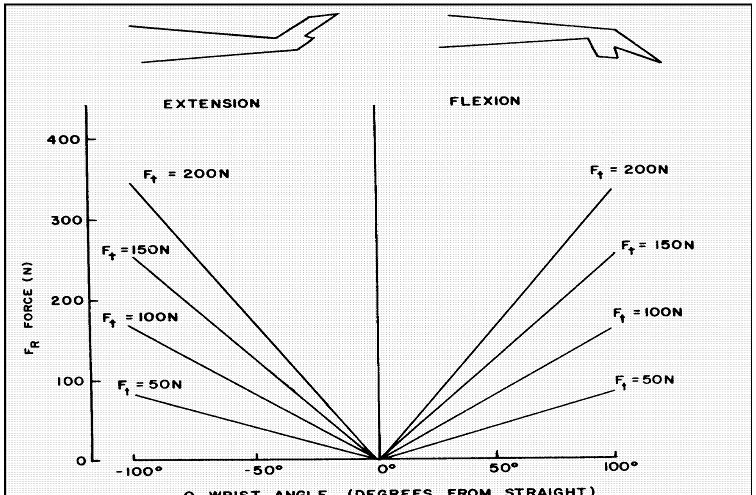
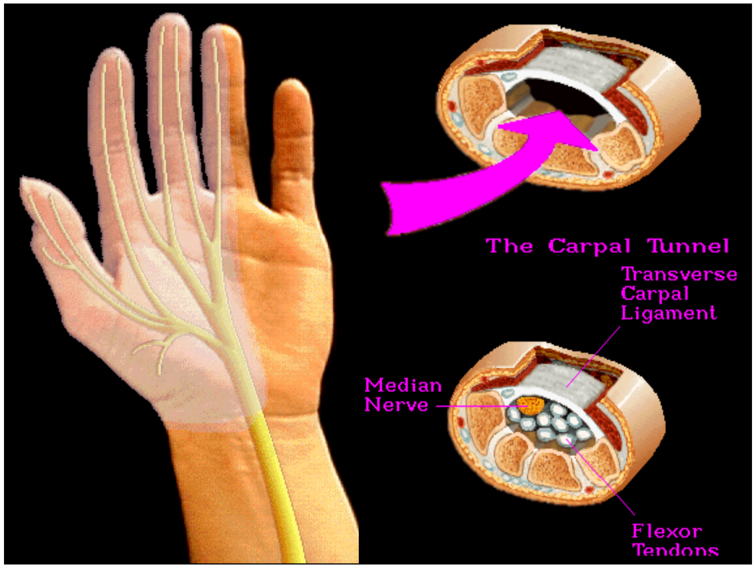
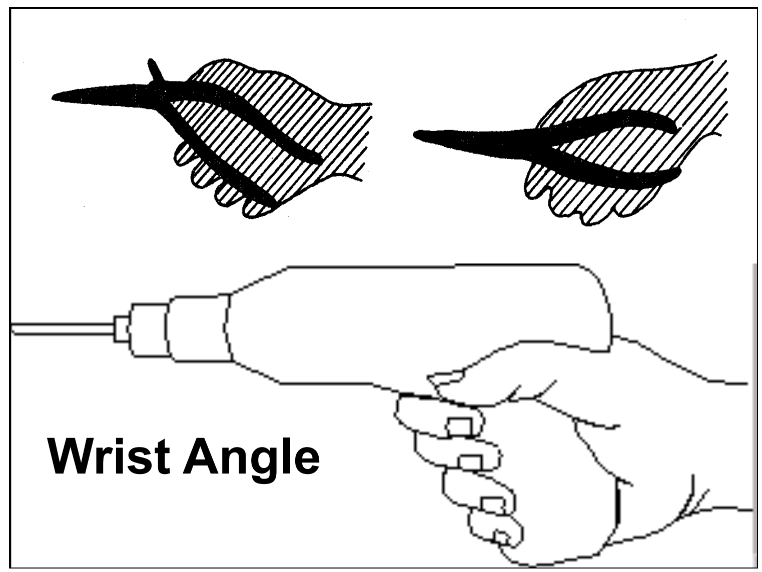


Figure 6.42 The resultant force exerted by tendon on adjacent wrist structures as a function of wrist angle and tendon load. Resultant force is independent of tendon and wrist size (from Armstrong and Chaffin, 1979).

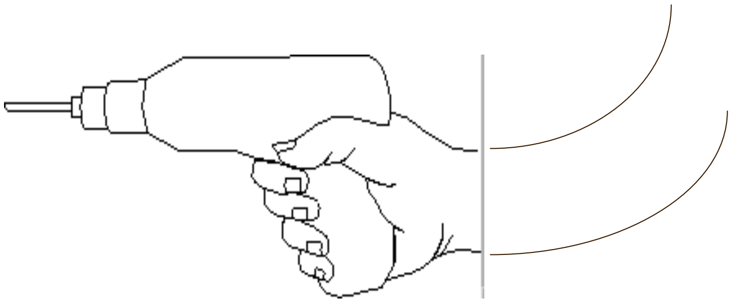

The Carpal Tunnel
Transverse Carpal Ligament
Median Nerve
Flexor Tendons

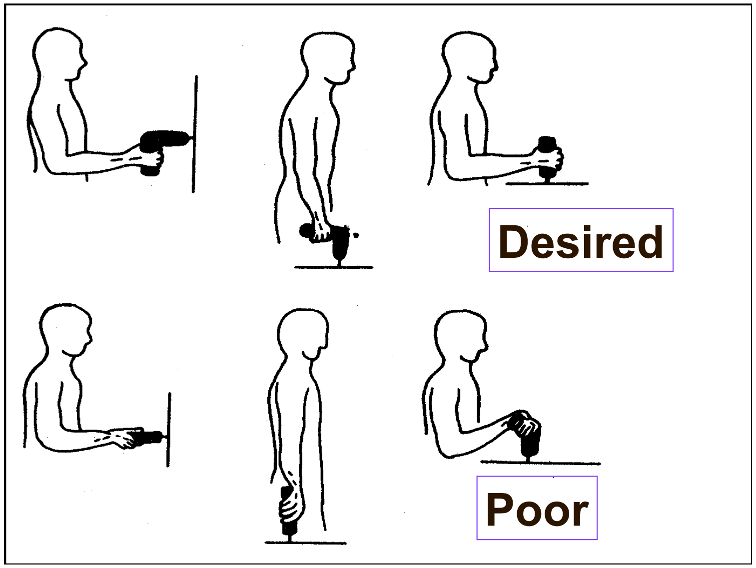

➢ Standard conservative treatment for CTS is splinting plus anti-inflammatory medication, for several weeks.
➢ Usually the splint should be worn at night only.


WRIST REST

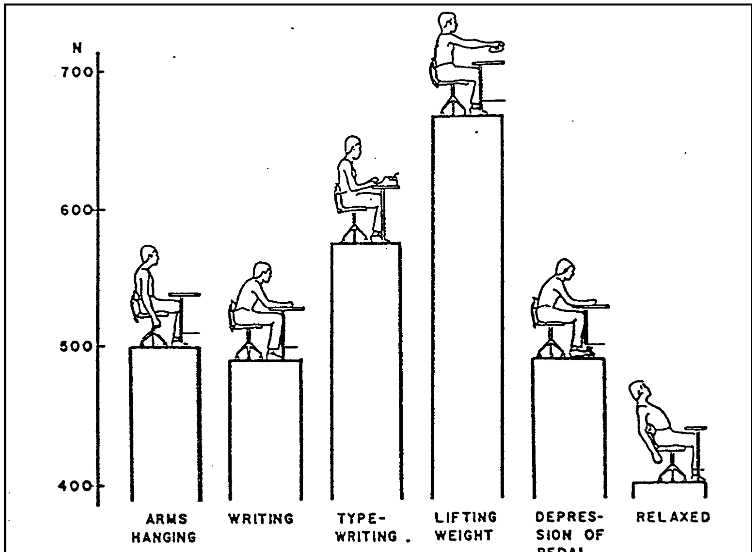

Wrist Angle

The preferred shape of the tool's handle depends the body alignment during use.

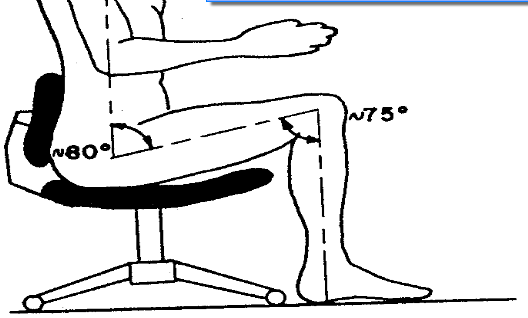




The concept of the only ideal sitting ideal posture being upright (90° at hip and knee) is wrong. Slight extensions to 110° have been show to be acceptable, if not preferred.

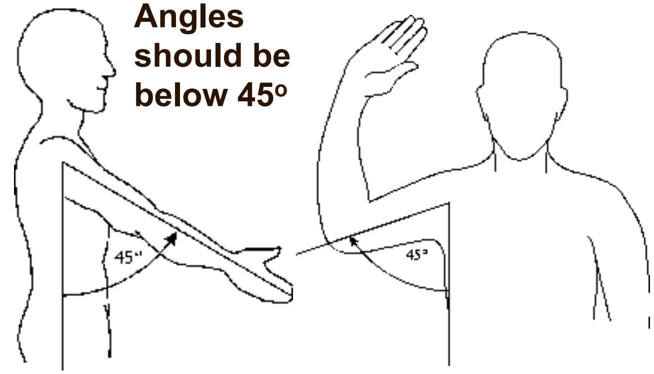


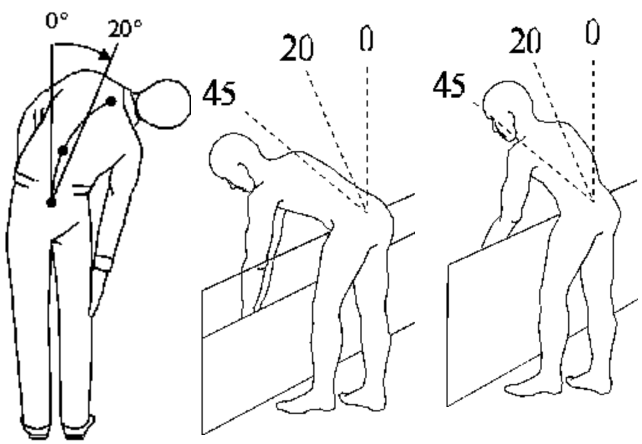
Chair too low: Knee and hip flexion angles are too small, resulting in upper body weight being transferred to a small area at the ischial tuberosities.

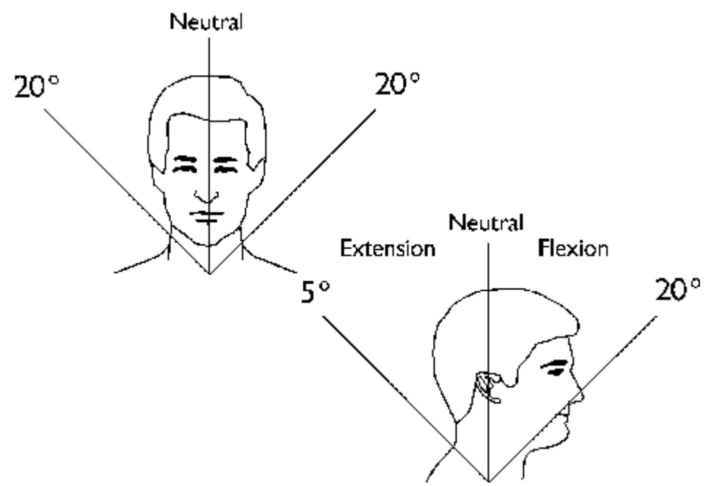


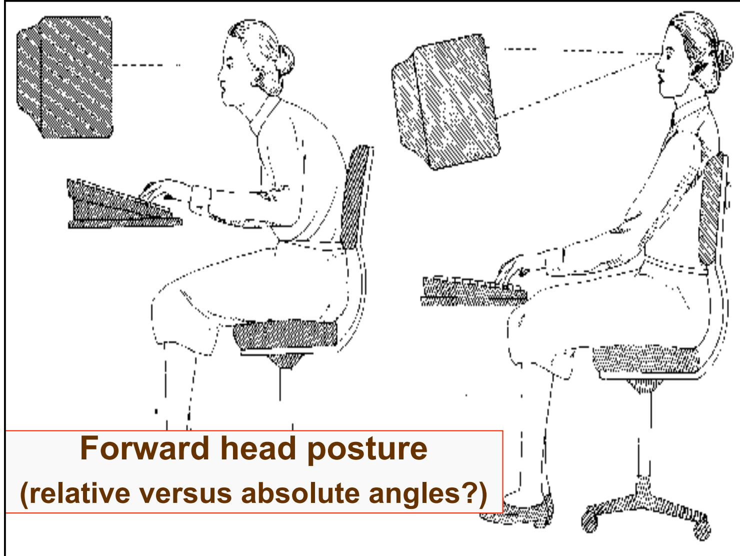
Shoulder Postures

Angles should be below 45°







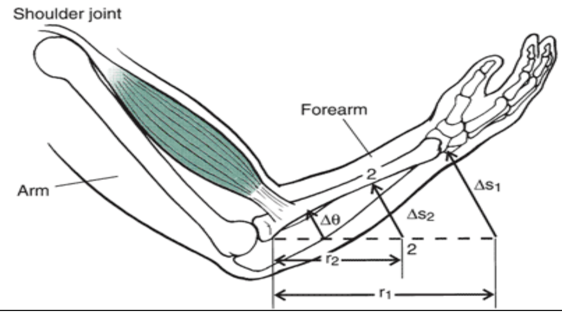


Forward head posture

(relative versus absolute angles?)

Angular & Linear Motions

- All points on the forearm travel through the same angle (angular displacement).
- Each point travels through a different linear displacement



Angular and Linear Displacement

- As we saw, a radian is defined as the ratio of the distance around the arc of the circle to the radius of the circle.

$\theta = s/r$

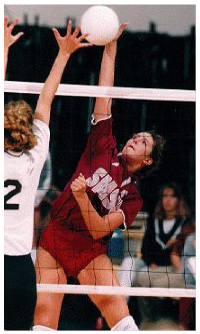
$s = r\theta$ (L => L x unitless ratio)

Additional Relationships

- $v_t = r\omega$ $(LT^{-1} = L \times T^{-1})$
- $a_t = r\alpha$ $(LT^{-2} = L \times T^{-2})$

Note that the angular units must be in radians.

Maximum Linear Velocity?



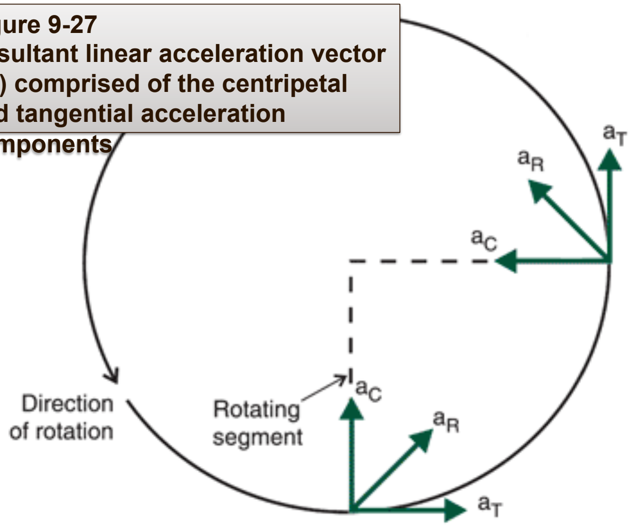
$$v_t = r\omega$$

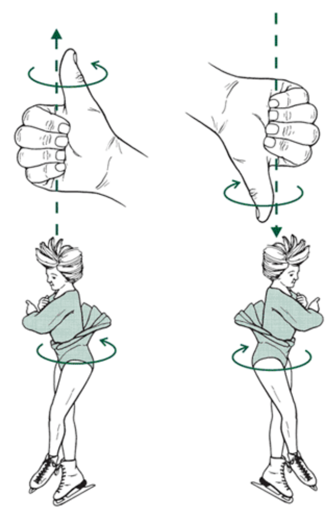
Radial Acceleration

- What is radial acceleration?
- If velocity is a vector then even at a constant angular velocity (and hence constant linear speed) the linear velocity is changing as its directional component is changing. If velocity is changing then there must be acceleration.

$$a_r = v_t^2/r \quad \text{or} \quad r\omega^2$$

Figure 9-27
Resultant linear acceleration vector (a_R) comprised of the centripetal and tangential acceleration components





Right Hand Thumb Rule

- The fingers of the right hand point in the direction of the rotation, and the right thumb points in the direction of the angular velocity vector.