Biomechanics of Sports Injuries in Athletes with Physical Disabilities

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Today's Objectives

This webinar will provide basic sport science insights into how musculoskeletal injuries occur in sport and physical activity. Biomechanical aspects of sport performance and physical training will be explored and common mechanisms of injury explained. The goal is to provide the webinar participant with an understanding of how acute and chronic musculoskeletal injuries occur and ultimately can be reduced or even eliminated through sound training.

1. The webinar participant will learn the basic concepts of sport biomechanics as they relate to sport performance and injury.
2. The webinar participant will learn about the relationship of stress and strain on musculoskeletal tissues and how each relates to both acute and chronic injuries.
3. The webinar participant will learn about basic anatomical considerations of musculoskeletal injury.
4. The webinar participant will learn to identify specific aspects of disability sport and physical activities that may contribute to injury.

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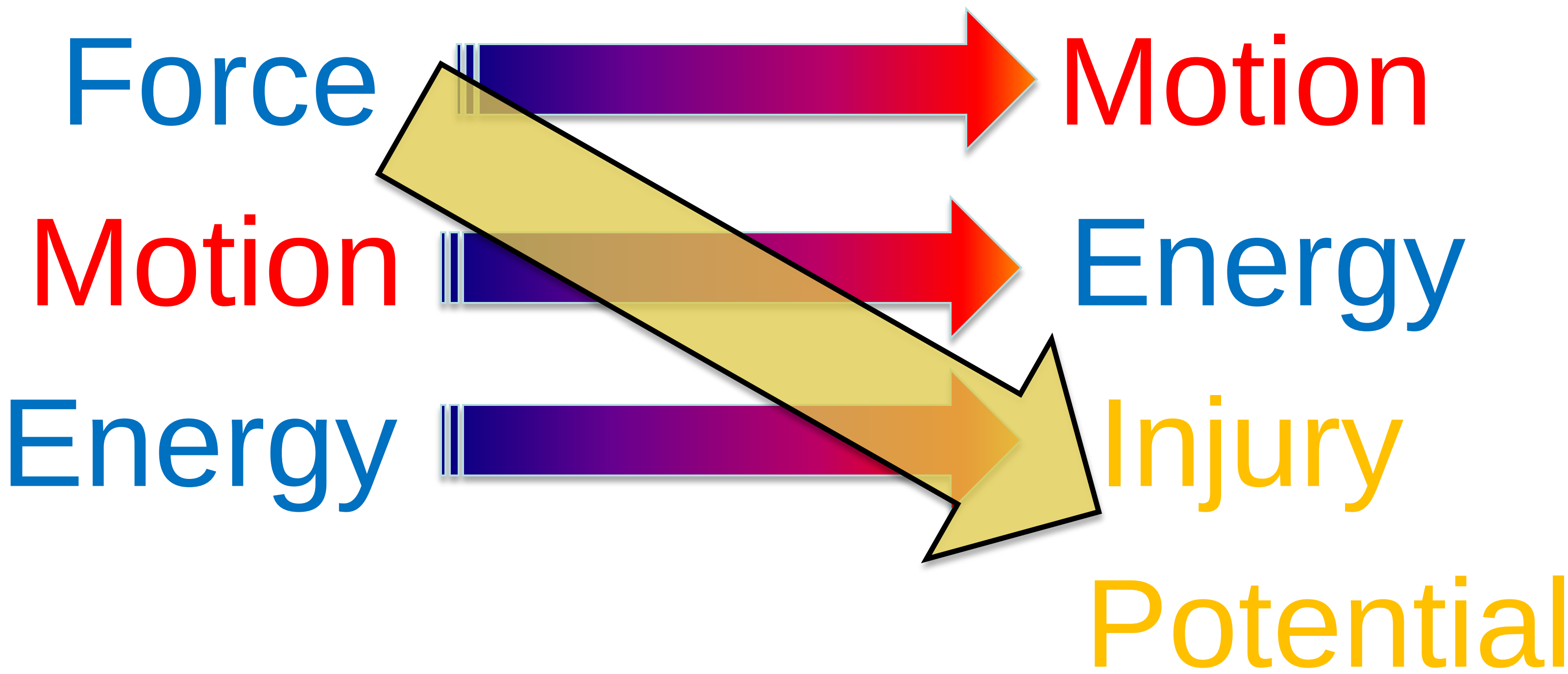
Why Study Biomechanics?
Physics Applied to Human Motion

- To address problems related to human health and performance.
- Useful for:
  – Physical Education Teachers
  – Physical Therapists
  – Physicians
  – Sport Coaches
  – Personal Trainers
  – Exercise Instructors

Basic Concepts of Biomechanics



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Linear Velocity

$$\text{Velocity (v)} = \frac{\text{change in position}}{\text{change in time}}$$

$$v = \frac{\text{displacement}}{\text{time}}$$

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Rotational Velocity

$$\text{Rotational velocity} = \frac{\text{rotational displacement}}{\text{time}}$$

$$\omega$$

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Linear and Rotational Velocity

$$v = r\omega$$

v = linear velocity

r = length of radius or segment

ω = rotational velocity

Newton’s Laws

Law of Inertia

A body will remain at rest or maintain a constant velocity unless acted upon by an external force that changes that state of motion.

Newton's Laws

Law of Acceleration

A force applied to a body causes an acceleration of that body of a magnitude proportional to the force, in the direction of the force, and inversely proportional to the body's mass.

$$F = ma$$

Newton's Laws
Law of Action-Reaction

- For every action, there is an equal and opposite reaction
- When one body exerts a force on a second, the second body exerts a reaction that is equal in magnitude and opposite in direction of the first body

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Mechanical Behavior of Bodies in Contact

Frictional Force

$$F = \mu R$$

μ = Coefficient of friction

- Coefficient of static friction (μ_s)
- Coefficient of kinetic friction (μ_k)

R = Normal reaction force

Mechanical Behavior of Bodies in Contact

Linear Momentum:

Mom = mass x velocity

Principle of conservation of momentum:
In the absence of external forces, the total momentum of a given system remains constant

If momentum changes for an athlete it is typically because their velocity changes and not their mass…therefore to increase velocity or momentum one must create force over a period of time which leads to acceleration.

So…The more force created and/or the longer the time the force is applied the more acceleration that will occur.

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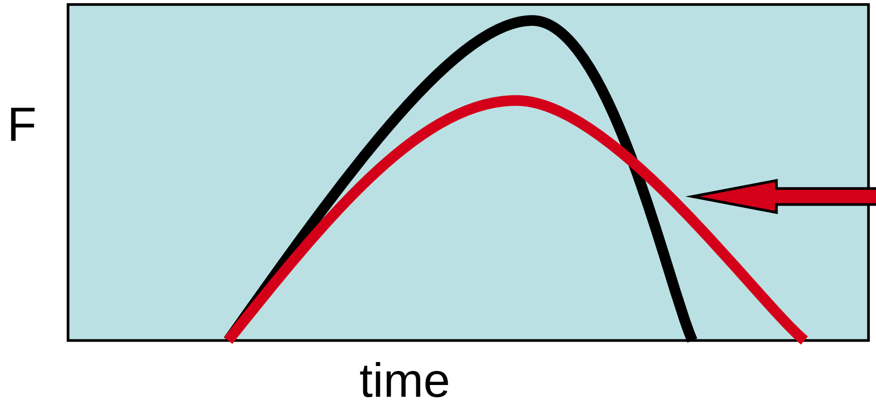
Changing Momentum

Impulse = Ft

Impulse = Change in momentum



Area under curve

Equals IMPULSE

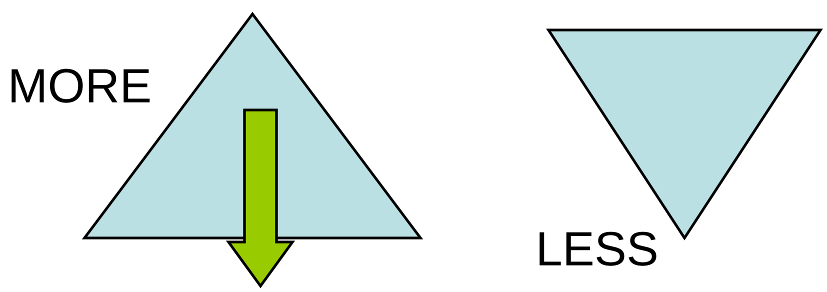
Stability and Balance

Stability:

- Factors that affect:
  - Mass, friction, center of gravity & base of support

Balance:

- Foot position affects standing balance
- Wheelchair wheel width/depth side-to-side & front-to-back

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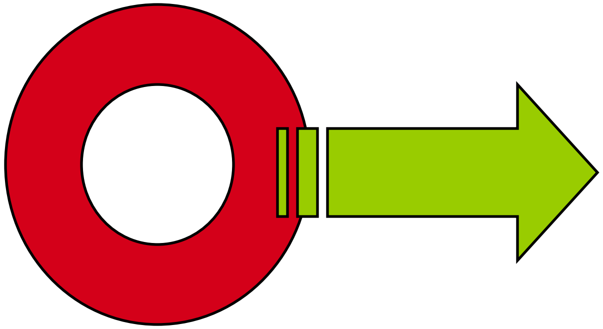
Resistance to Motion

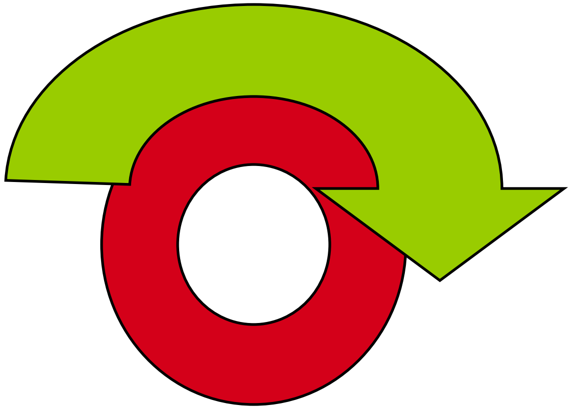
Mass and Rotational Inertia

- Resistance to <u>linear acceleration or motion</u>
  - Mass (directly related to weight)
- Resistance to <u>rotational acceleration or motion</u>
  - Mass
  - Distribution of mass with respect to axis of rotation
  - Length of limb or segment

Momentum

- For linear motion: $M = mv$
- For rotational motion: $H = I\,\omega$



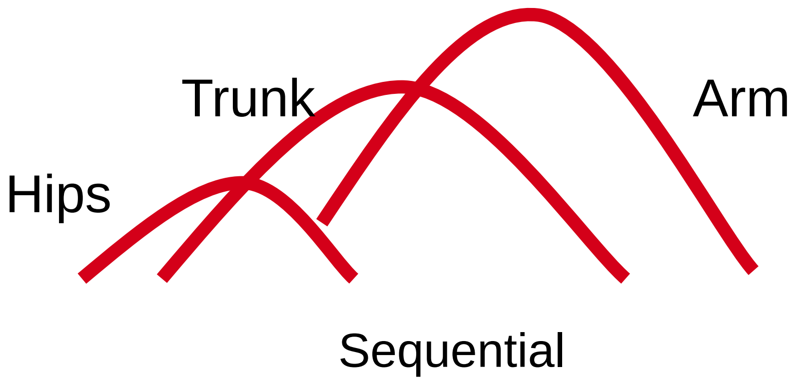


Transfer of Rotational Momentum

- Transferring rotational velocity
- Changing total body axis of rotation
  - Asymmetrical arm movements to balance legs in running
  - Rotation of the hips (termed hula movement) when running or throwing
  - Hips to Trunk to Arm to Implement

Kinetic Link Principle - Coordination

- **Sequential**: very high-speed motions requiring good coordination (javelin);
- Energy/velocity flows from most massive segments to least massive segments;
- **Simultaneous**: slower motions requiring strength and mass (shot put);
- Energy/velocity created all at once due to higher resistance/forces.



$F = m\,(\Delta v / t)$

Maximize or Minimize Force???

Force =	↑	↓
Mass =	↑	↓
Change in Velocity =	↑	↓
Time =	↓	↑

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$$v_f = (Ft/m) + v_i$$

Maximize or Minimize Final Velocity???

Force =	↑	↓
Time =	↑	↓
Mass =	↓	↑
Initial Velocity =	↑	↓

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Work

Force x Distance object is moved

$$Work = F \times d$$

Positive Vertical Work is more challenging than Horizontal Work because positive vertical work must be performed against force of gravity

Power

Power = Work / time

Power = Fd / t

Since d/t = velocity…

Power = Force x Velocity

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Pressure

Force / Area

The greater the area that can be utilized to distribute the force applied to the body the less likelihood of a serious injury (fracture, concussion, etc) or deep contusion…helmet, shin guards, gloves, prosthesis, etc.

Internal Forces

Muscles/Tendons
Bones
Ligaments
Cartilage
Fat
Skin Layers

Internal tissues provide forces to either withstand forces imposed on the body from the environment or to create forces to move the body…but only muscles can do the latter as all the other tissues are reactionary.

External Forces/Actions

Earth / Ground / Floor / Track / Court

Opponents

Implements (balls, weights, racquets, wheelchairs, etc)

Gravity

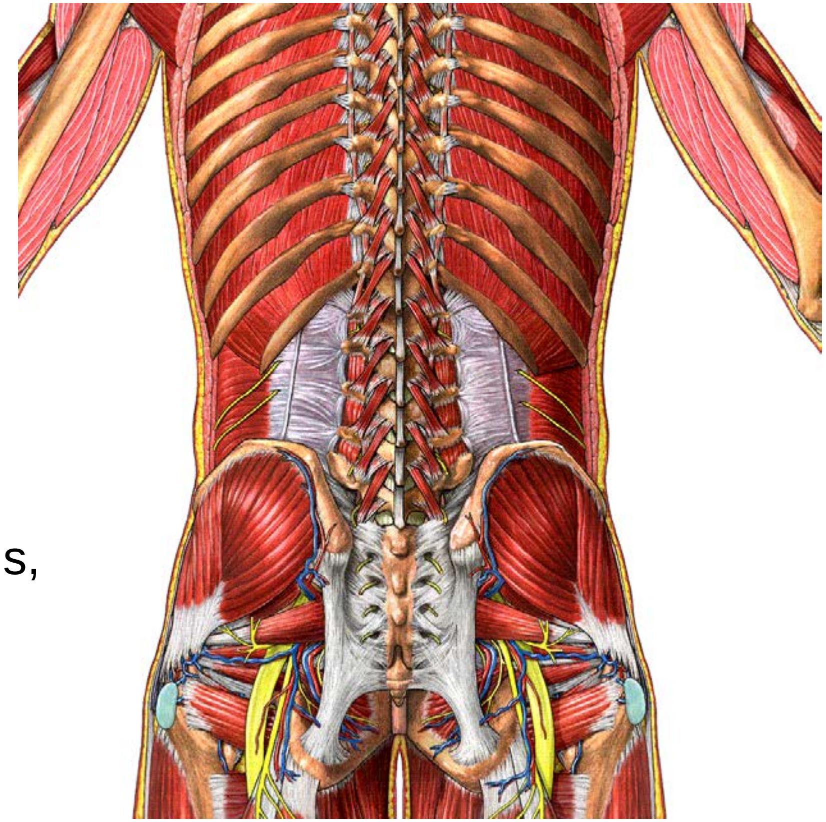
Stress and Strain on Tissue

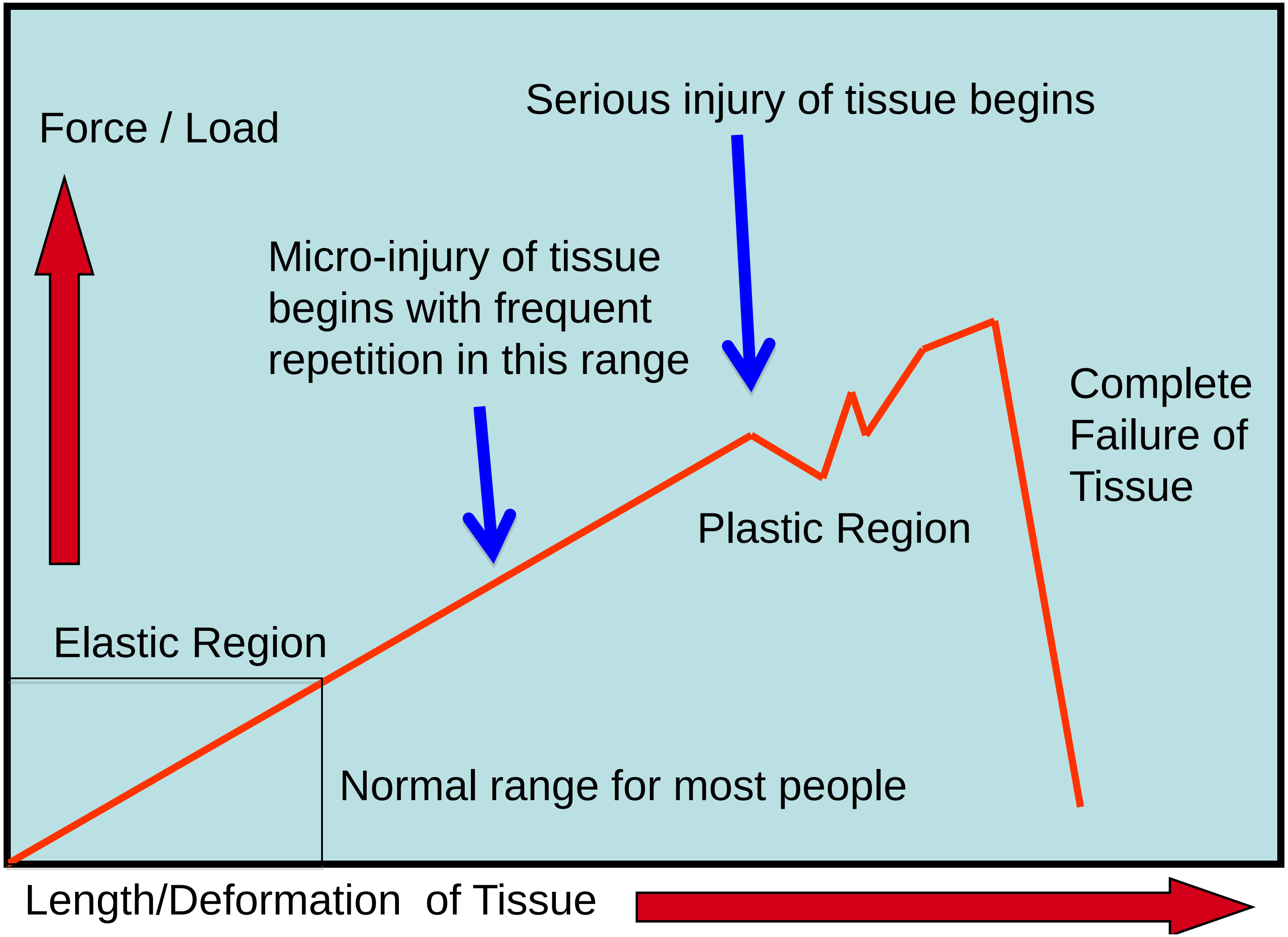
Loading or Force
Tension
Compression
Shear
Bending
Torsion

Deformation
Change in shape/length

Elastic limits of bone, tendons, ligaments and cartilage

Failure point of tissue




Force / Load
Serious injury of tissue begins
Micro-injury of tissue begins with frequent repetition in this range
Complete Failure of Tissue
Plastic Region
Elastic Region
Normal range for most people
Length/Deformation of Tissue

The Effects of Loading

Deformation of Tissues

When an external force is applied to the human body, several factors influence whether an injury occurs:

- Magnitude and direction of force
- Area over which force is distributed
- Load-deformation curve
- Yield point (elastic limit)
- Failure

Repetitive vs. Acute Loads

- Repetitive loading (Wheelchair propulsion)
- Acute loading (Wheelchair crash)
- Macrotrauma (tendon or ligament rupture)
- Microtrauma (minor tendon strain)

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Overuse/Chronic Injuries

Repetitive Motion Injuries

Bursitis / Tendinitis

Plantar fasciitis

Patellofemoral syndrome

Sprains and strains

Stress fractures

Lower back injuries

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Acute Injuries

Sprains/Tears

Strains/Tears

Dislocation

Fractures

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Momentum

mass x velocity

Impulse

change in momentum

F t = mass x (change in velocity)

Pressure = Force / Area

Bone Hypertrophy

- Bone grows in response to regular physical activity
  - Ex: tennis players have muscular and bone hypertrophy in playing arm.
- The greater the habitual load, the denser and larger the bone becomes.
  - Also relates to amount of impact of activity/sport

Bone Atrophy

- Bone decreases in size and density
- Decreases in:
  - Bone calcium
  - Bone weight and strength
- Seen in bed-ridden patients, sedentary elderly and lower extremities of chair-users

Joint Stability

- Ability of a joint to resist abnormal displacement of the articulating bones
  - To resist dislocation
  - To prevent injury to ligaments, muscles, and tendons
- Includes:
  - Shape of articulating bone surfaces
  - Arrangement of ligaments and muscles
  - Other connective tissues

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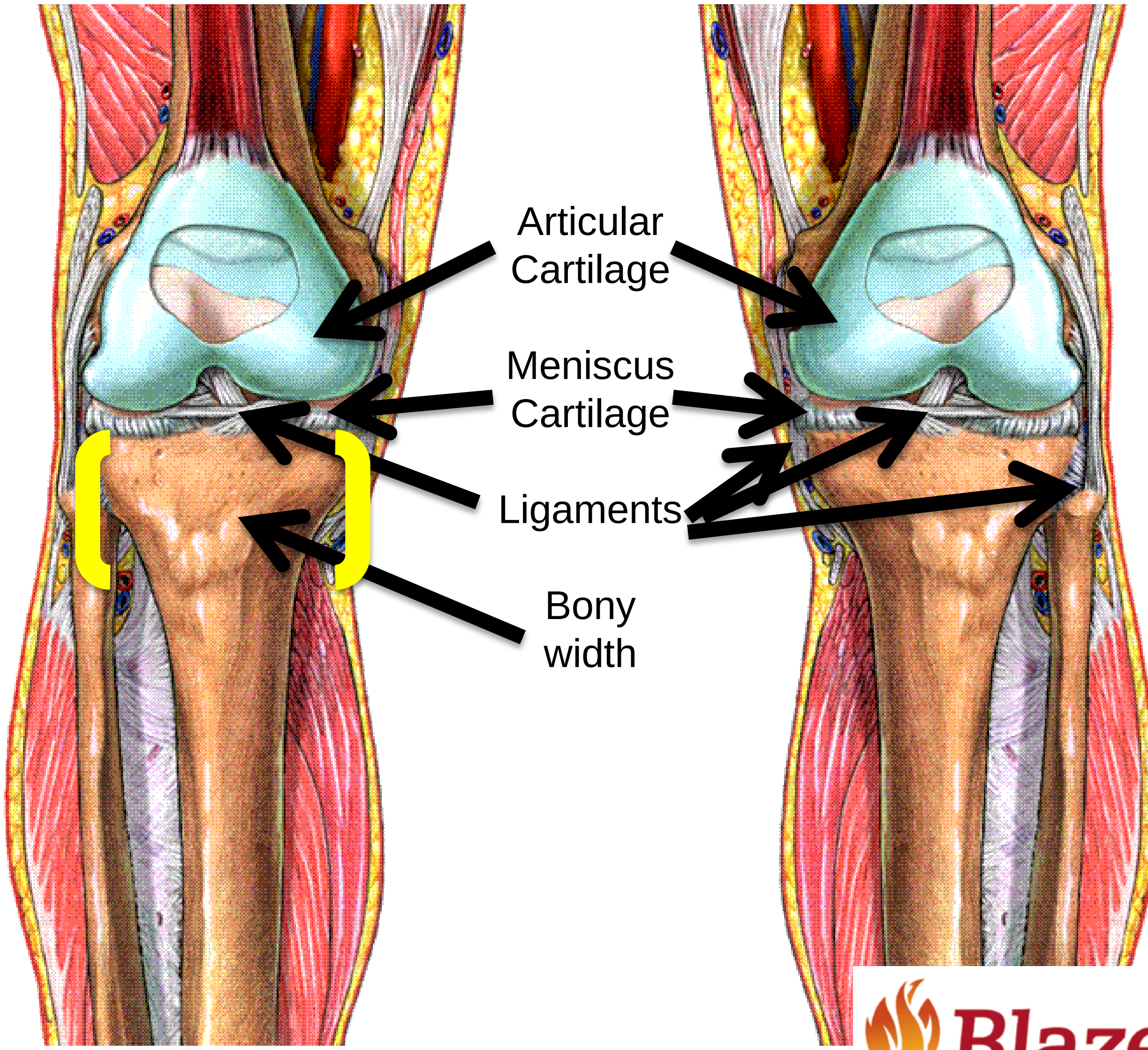

Articular
Cartilage
Meniscus
Cartilage
Ligaments
Bony
width

Joint Flexibility

- Joint Flexibility
- Range of motion (ROM)
- Static flexibility
- Dynamic flexibility
- Research indicates that the two flexibility components (static and dynamic) are independent of one another
- Flexibility is joint-specific

Factors Influencing Joint Flexibility

- Shapes of articulating bone surfaces
- Intervening muscle
- Fatty tissue
- A function of:
  - Relative laxity or extensibility of collagenous tissues and muscles crossing joint.
- ROM inhibited by tight ligaments and muscles

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Flexibility & Injury

- Limited (tight) joint flexibility can increase tearing or rupturing of collagenous tissues at joint.
- Lax joint flexibility (low stability) leads to displacement-related injuries *i.e. shoulder vs knee joint*
- Flexibility decreases with aging
  - In part, due to decreased levels of physical activity and increasing loss of collagen (gives elasticity to tissues)
- No changes in flexibility during growth in adolescence.

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Common Joint Injuries

Due to: acute and overuse injuries, infection, degenerative conditions.

- Sprains
- Dislocations
- Bursitis
- Arthritis
- Rheumatoid Arthritis
- Osteoarthritis

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Injury Prevention Strategies

Individualization of training

Warning signs of impending injury

Warm-up, stretching and cool-down

Appropriate equipment

Appropriate training prescription (mode, duration, frequency, intensity, progression)

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Prevention

Conditioning

Specificity – to sport activity
Progression – gradual increase in intensity
Flexibility - static and dynamic
Strength and muscular development – general vs specific

Rest and Recovery

FATIGUE FATIGUE FATIGUE

One's chance for musculoskeletal injury increases significantly when fatigued

Equipment

Shoes – specificity to activity

Wheelchair – proper fit, seating, wheel camber, etc.

Proper fit - helmets, implements, shoes, orthoses, prostheses, etc.)

Protection - eyes, hands, head, etc.

Maintenance – wheelchair, orthoses, prostheses, etc

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Sport-Specific Skill Development

Progression: Basic skills to more advanced skills

Fit to play: Base fitness followed by sport-specific fitness

Proper instruction: Proper techniques with proper equipment

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Takeaways from this Presentation

Use basic **common sense** and **logical thinking** to prevent or reduce injuries!

Remember that **FORCE** leads to **MOTION** that leads to **ENERGY** that leads to **INJURY**

The body's tissues have physiological/biomechanical **limitations** that, if exceeded, will lead to injury

One must **limit or reduce force** applied to and by the body while also avoiding **extreme deformation** of body tissues in unnatural positions.

Chronic fatigue and **overtraining** is the enemy of the athlete with or without a disability

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