Sports Biomechanics

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-Sports biomechanics is a sub discipline of exercise science that provides insight into human movement associated with sports and exercise.

-The sciences that deal with biomechanics allow for descriptions of HOW and WHY the human body moves the way it does and why certain individuals perform at varying levels of success in sports.

Instrumentation—Measuring Human Motion

- A **qualitative analysis** of an activity involves observation of the performance, NOT the collection of numerical data.
- The individual performing this type of analysis observes the performance & through understanding concepts of biomechanics, gives their opinion on what needs to be improved.
- A **quantitative analysis** of an activity involves numeric measurement of the performance, often with high-tech instrumentation, such as high speed video-recording systems and subsequent motion analysis performed via computerized video-digitizing and data processing designed to mathematically model the human body.
- The data in a quantitative analysis are used to evaluate how an athlete performs a skill so movement patterns can be determined and compared to normative values.

Basic Biomechanical Concepts

- Sports biomechanists generally classify various forms of human motion analysis into the following categories:

- Static or Dynamic
- Kinematic or Kinetic
- Linear or angular

Statics and Dynamics

- **Statics** is the study of the body under conditions in which no accelerations are occurring.
- Static means the body is either completely stationary or moving at a constant velocity.

- Example in sports & activities: Headlock or pin hold in wrestling and a flexibility position when warming up or cooling down for a certain activity.

Statics and Dynamics Cont'…

- **<u>Dynamics</u>** is the study of a body undergoing acceleration.
- Body segments are increasing & decreasing in velocity as certain skills are performed.
- For example: One's legs in walking/running and the arm in a throw or tennis strike are all examples of dynamic segments in performing activities.

Kinematics and Kinetics

- **Kinematics** is the description of human motion in terms of position (displacement), velocity, and acceleration.
- These variables describe motion resulting from forces produced by the muscular system or forces externally to the body such as: gravity, other individuals, or objects.
- **Kinetics** is the study of the forces generating the kinematic qualities described above.

Linear and Angular Motion

- **Linear motion** is the point-to-point, straight-line movement of a body in space.
- Depending on how complex the activity is monitored, the motion can be measured in a 2-D or 3-D Cartesian coordinate system.
- **Angular motion** is the measurement of how a rigid lever is rotating about an axis and is quantified through the use of a polar coordinate system.
- A good example of angular motion represented in the human body is: upper arm rotating about the shoulder joint (axis of rotation).

Cartesian Coordinate System

- This system consists of:
  - Z axis: Forward and backward movements
  - Y axis: Up and down movements
  - X axis: Movements from side to side

Forces that are applied in these directions lead to acceleration or velocity changes of specific body points. Linear forces may be applied by muscles, gravity, ground, or any other number of objects.

- A **scalar** is a variable that can be described in terms of magnitude only.
- A **vector** has a magnitude that is measured in a particular direction or along a particular axis or plane.

Terms to know…

- Linear displacement – a vector that shows how an object moves in a particular direction in a straight line
- Angular displacement – a vector giving a numerical value to how far a lever has rotated relative to a reference over time
- Linear distance – a scalar (number) that describes the movement of an object between two points on its path (not necessarily a straight line)
- Angular distance – a scalar that describes the total rotational motion of an object about a joint between two positions
- **Velocity** – a vector showing the change in position divided by the change in time
- **Speed** – the magnitude of velocity
- **Acceleration** – change in velocity divided by the change in time
- **Gravitational acceleration** – force that pulls an object towards the earth (denoted *g*)

…continued

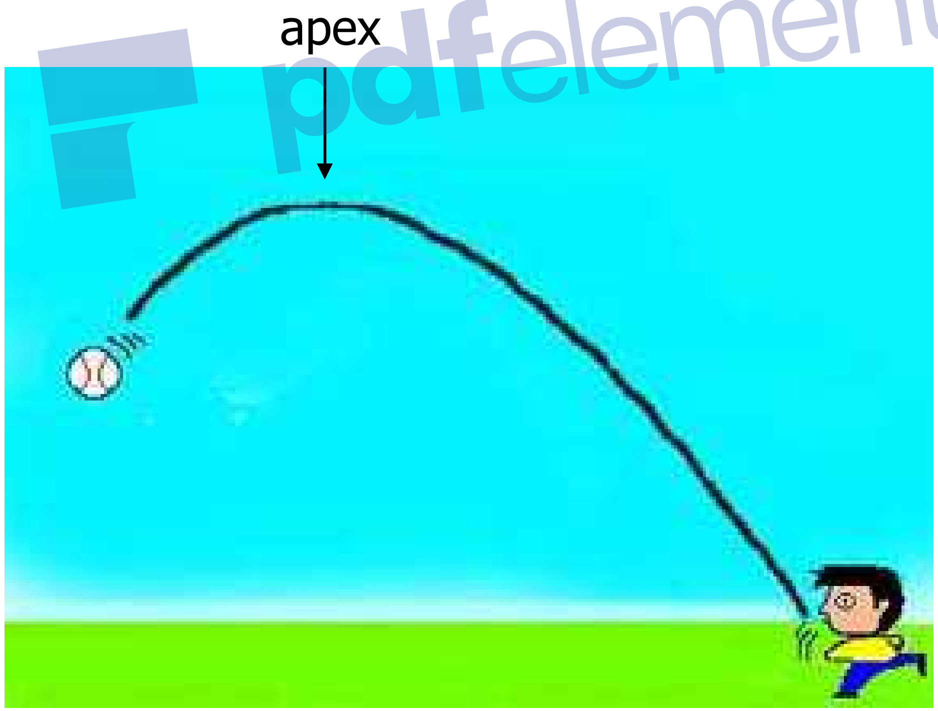
- **Mass** – amount of matter an object possesses within its physical boundaries
- Center of mass – theoretical point at which an object's mass is concentrated; in practice, the point where balance occurs
- **Weight** – the force of gravity pulling a mass towards the earth (mass X *g*)
- Inertia – an object's resistance to change in velocity (speed or direction)
- **Force** – mass x acceleration
- **Torque** – force applied to lever X shortest distance of the force's line of action
- Angular momentum – rotational inertia X angular velocity
- Linear momentum – mass X velocity
- **Work** – force X displacement
- **Power** – work / time
- **Energy** – the capacity to do work
- **Kinetic energy** – energy of motion
- **Potential energy** – energy depending on position or shape of an object
- Pressure – concentration of force at any given point on the object

Projectiles

- A projectile is any object that flies through the air free of external forces (with the exception of gravity and air friction).
- This projectile is in a free-fall state, but as soon as an external force (besides gravity and air friction) is applied, the projectile is no longer in free-fall.
- Projectiles can be described along the three axes (horizontal, lateral, and vertical) of the cartesian coordinate system.

- Projectile mathematics can be greatly simplified by assuming that the only force acting on the object is gravity. This would only actually ever occur in a vacuum.
- Gravity only effects vertical (Z-direction) motion, not horizontal (X-direction) or lateral (Y-direction) motion.
- Gravity is a constant acceleration of -9.8 m/s^2 .

- In the example of a ball being thrown, the velocity in the X and Y directions will remain constant throughout the entire flight, only velocity in the Z-direction will change.
- The maximum vertical (Z-direction) height of the ball's arc during flight is called the **apex**.
- In assuming that no air resistance occurs, the ball would travel in a **parabolic path**, which means that the arc is symmetrical along the apex.



- As a ball is released at some initial angle, θ, and some initial velocity, V_o , and travels along the parabolic path, the velocity can be broken down into horizontal and vertical components. The horizontal velocity remains constant throughout the flight. However the vertical velocity is constantly changing.

- As the ball ascends, the velocity decreases until reaching 0 m/s at the apex, and then increases on the downward path. This is due to the force of gravity constantly pulling the ball downward.

- On the upward path, gravity acts in opposition to the ball’s momentum, while on the downward path, gravity acts with the ball’s momentum.

Ground Reaction Forces (GRFs)

- Ground reaction forces are forces applied on a person by the ground or other surfaces with which the person's body is in contact.

- GRFs are applied with an equal and opposite reaction as the force applied to the surface by the person.

- GRFs are generally represented in a cartesian coordinate system like projectiles except the axes are labeled anteroposterior (AP) for forward and backward forces, mediolateral (ML) for left and right forces, and vertical for upward and downward forces.

- In the example of a long jumper, the person applies a force to the ground that is composed of both horizontal and vertical forces.

- The combination of horizontal and vertical forces generate an **<u>angle of takeoff</u>** of the body.

- A large vertical effort creates a large angle of takeoff which allows the body to travel high but not far. A large horizontal effort creates a small angle of takeoff which may not provide sufficient air time to allow for horizontal travel.

- In jumping, forces placed on the ground must exceed the person's body weight in order for a jump to occur.
- In the initial phase of jump preparation, the vertical GRF falls below the body weight. Then, as the person pushes downward with great energy, the force exceeds the body weight and thus results in upward movement.
- The greater a person's ability to generate forces above their body weight, the higher they will travel.
- Characteristics for producing the vertical GRFs are strength, muscle fiber type, coordination, and mechanical technique.

Kinetic Link Principle

- Skilled athletes possess an ability to capitalize on the body’s **kinetic link system**.
- The kinetic link principle basically means coordination and refers to the fact that the body segments are linked together and must create well-timed movements through muscle contractions in order for the performance to be appropriate.
- There are two basic principles that guide the kinetic link system: **sequential movements** of the body segments and **simultaneous movements** of the body segments

- The sequential kinetic link principle means that segmental motions or joint rotations occur in a specific sequence in order that time elapses between peak velocities of each segment.

- This generally means that energy comes from the core of the body and flows toward the appendages.

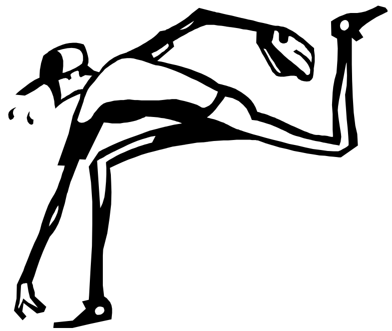
- Example: Pitching – actions are produced in the lower body, through the trunk, then the arm, the hand, and finally the fingers, which leads to the maximum velocity.

- The simultaneous kinetic link principle means that major body motions occur simultaneously so that no observable time exists between the contributions of each involved segment.
- Example: shot-put – the athlete uses more of a pushing motion than a throwing motion to accelerate the shot.
- The simultaneous motion does not allow for as great a magnitude of velocity as a sequential motion, however it leaves less chance for injury.
- The stronger an athlete, the more his/her movements can approach a sound sequential pattern even when moving very heavy objects
- There are some activities that use the best qualities of the simultaneous and sequential kinetic link principles. Example: tennis serve – body is propelled upward and outward toward the ball and net in the simultaneous motion, then the sequential motion which propels the trunk, shoulder, arm, and finally the wrist; volleyball hit.

Biomechanical Analysis of Movement Activities

Sprinting

Overhand Baseball Pitch



Sprinting

Characterized by:

Support Phase: High muscle forces are generated to accelerate or maintain the sprinter’s velocity.

Swing Phase: The runner is airborne and the leg segments are in recovery, one preparing to strike the ground and the other beginning to swing forward.

Sprinting

Horizontal velocity = stride rate x stride length

Stride rate: number of strides taken per unit of time

Stride Length: distance measured along the ground between foot positions at takeoff and landing for the same foot.

Over-striding results in slower running velocity.

Sprinting

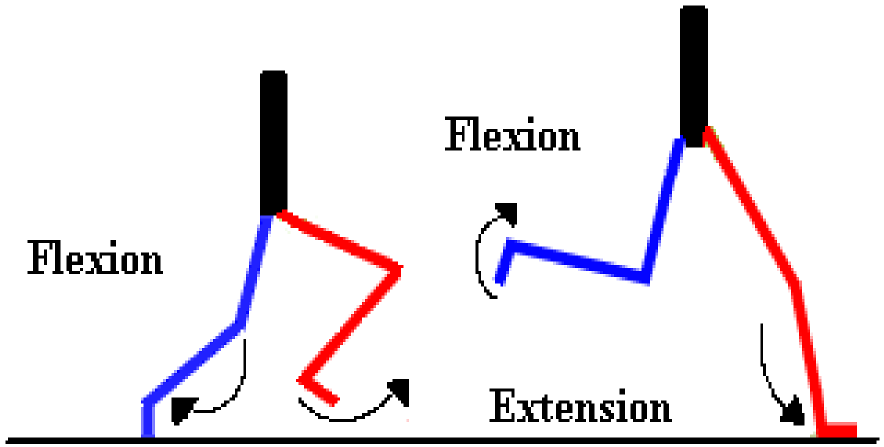
To create a high stride rate along with a suitable stride length:

1. Leg flexion/extension
2. Hip flexion/extension

Sprinting

Leg Flexion/Extension

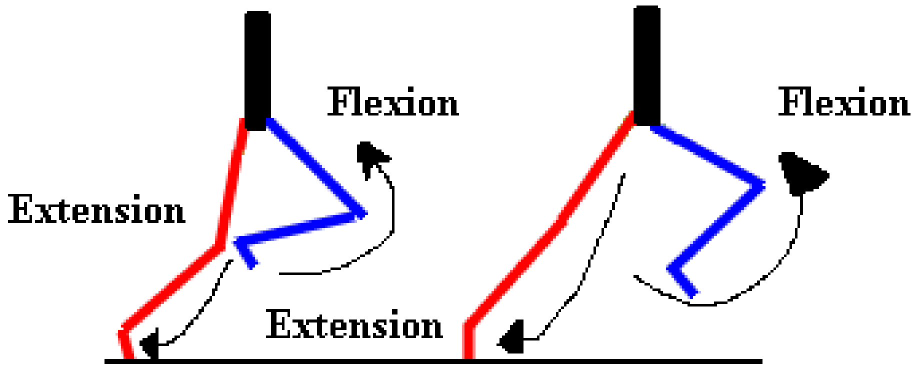
- Upper leg must be able to rotate rapidly around the hip joint in the body's sagittal plane in both flexion and extension.
- The faster the flexion motion, the shorter the swing time, the better performance of the sprinter.



Sprinting

Hip Flexion/Extension

- The upper leg rotates to the ground with the initiation of hip extension.
- The greater the amount of hip flexion, the more distance the sprinter has to accelerate the upper leg into extension.
- Maintaining fast rotation of hip extension means the sprinter is able to accelerate at a higher rate or maintain running velocity while requiring a shorter time of the foot on the ground (increases stride rate).



Sprinting

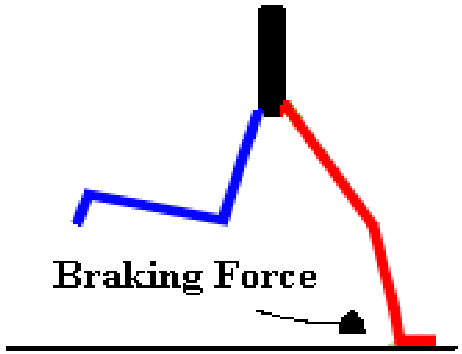
Role of the Knee

- To enhance recovery of the leg from the takeoff position until foot contact, the knee joint must be flexed to an extreme angle and maintained there for a substantial portion of the swing phase.
- Shortly after hip flexion, the knee flexes towards the body shortening the leg lever which makes it easier to swing the leg forward.
- Incomplete or premature knee flexion is often associated with the mechanics of poorer sprinters or fatigue.

Sprinting

Braking Forces

- Defined as a force applied to the body by the ground, a person, or an object that causes it to slow down.
- The knee flexion reduces the braking force that occurs when the foot strikes the ground.
- The more successful the sprinter is at rapidly extending the hip and flexing the high knee lift position until ground impact, the less the braking force will be.
- Lower braking forces means less deceleration of the body resulting in less amount of energy and time used per step.



Overhand Baseball Pitch

Goal is to throw a ball at near maximum horizontal velocity with accuracy.

High speeds are built from complex series of body movements rather than large muscular force production.

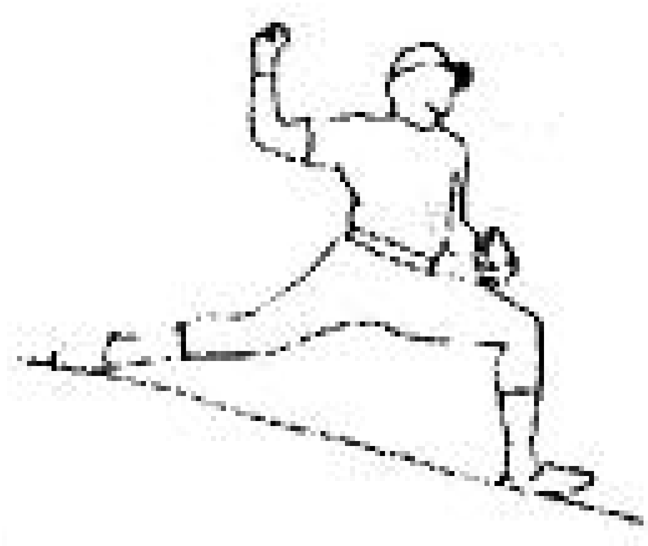
Overhand Baseball Pitch

Lower body starts by contacting the ground with the lead foot at the completion of the stride toward home plate.

Forces created by ground contact and forward movement of the body cause rapid rotation of the lower trunk/pelvic area.

Overhand Baseball Pitch

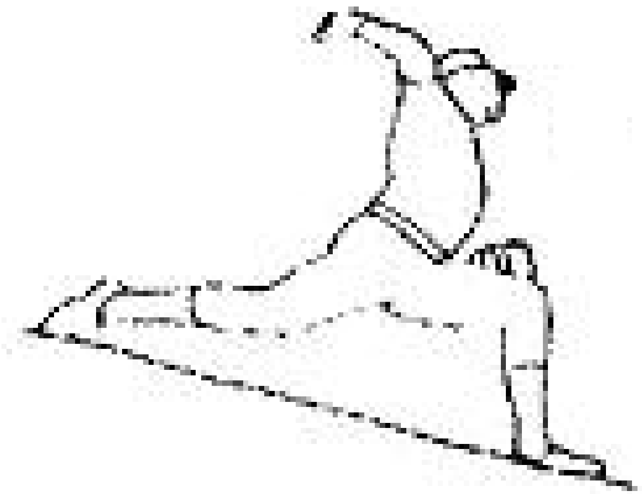
As the trunk rotates, the upper arm segment is brought to a horizontal position with the elbow flexion at a 90^0.



Overhand Baseball Pitch

The upper and lower trunk segments accelerate toward their peak velocity, the arm segments are left behind through inertial lag.

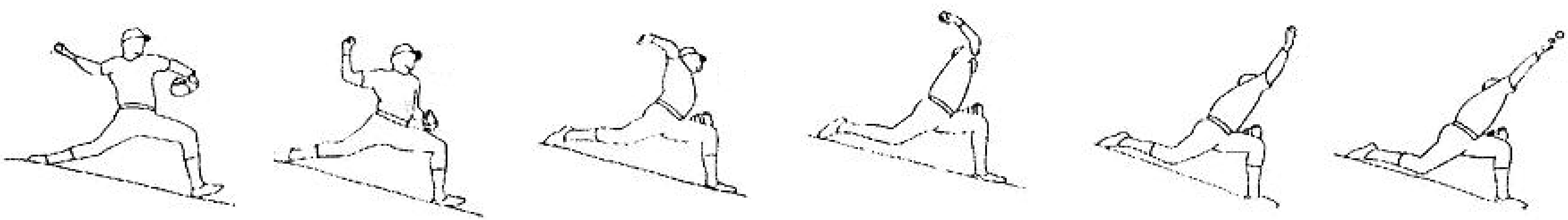
Inertial lag causes the upper arm to externally rotate around the shoulder, cocking the arm.



Overhand Baseball Pitch

Momentum builds with each body movement causing the kinetic energy of the ball to increase and reach a peak at the release point.

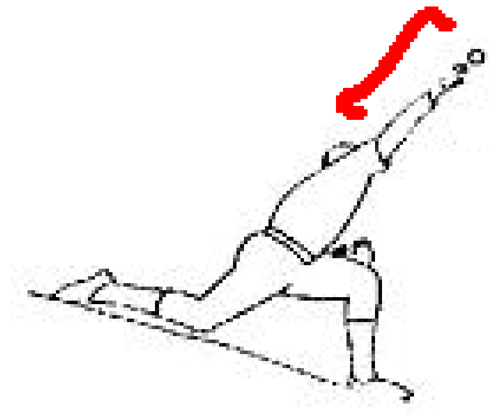
The release point is where the hand reaches maximum velocity.



Overhand Baseball Pitch

The end of a long lever rotating at a particular speed is moving faster linearly than the end of a shorter lever rotating at the same speed.

Meaning……the longer the arm, the greater velocity of the ball.



Overhand Baseball Pitch

The pitcher has a lot of time to build up the shoulder internal rotation to throw the ball, but has little time to stop the motion.

The short time period for deceleration means the torques around the shoulder joint are high.

Rotator cuff muscles (supraspinatus, infraspinatus, teres major, and subscapularis) are used to stop shoulder internal rotation.

As more pitches are thrown, the muscles fatigue and experience wear and tear, often leading to injury.

Advances in Sports Biomechanics

Two of the most important concepts of the advancement of sports biomechanics:

Stretch-Shortening Cycle

Kinetic Link Principle

They describe the interaction of muscle energy production with the movement patterns necessary to perform a sporting skill.

Advances in Sports Biomechanics

Stretch-Shortening Cycle

The stretch phase involves lengthening of the muscle tissues to place them on a stretch, creating potential energy which is released as the muscles begin the shortening phase.

The shortening phase is characterized by the concentric contraction of the muscle, which adds to the energy production.

Advances in Sports Biomechanics

Kinetic Link Principle

Describes the mechanical coordination required for success in a movement activity.

Research into the movement patterns required for success in sports has led to insights into the requirements for enhancing performance and has explained important aspects of injury potential.

Advances in Sports Biomechanics

Instrumentation-Computer Modeling

Tremendous advances have been made in the sophistication of 3-D computer graphics models which are used to measure performance.

3-D computer animations of the athlete can be viewed from any position allowing scientists, coaches, or athletes to see and measure sports performance.

THE END