CHAPTERONE

Introduction to kinesiology

1.1 Definition of kinesiology

Kinesiology is the study of the body's infinite number of movements, positions, and postures and is grounded in the principles of two sciences: anatomy and mechanics. In other way it is the scientific study of human movement; including anatomical and physiological elements that carry out movements. It is also the biomechanical analysis of different sport techniques and athletic performances.

Kinesiology is the scholarly study of human movement, and biomechanics is one of the many academic sub disciplines of kinesiology. Biomechanics in kinesiology involves the precise description of human movement and the study of the causes of human movement. The study of biomechanics is relevant to professional practice in many kinesiology professions. The physical educator or coach who is teaching movement technique and the athletic trainer or physical therapist treating an injury use biomechanics to qualitatively analyze movement.

Generally **Kinesiology** is the term referring to the whole scholarly area of human movement study, while **bio mechanics** is the study of motion and its causes in living things.

1.2. Function /Purposes of kinesiology

Within kinesiology, many biomechanics have been interested in the application of biomechanics to sport and exercise. The applications of biomechanics to human movement can be classified into two main areas: the improvement of performance and the reduction or treatment of injury.

Biomechanics is the analysis of biological systems in mechanical terms, and kinesiology is the study of body movement. The body has muscle spindles and Golgi tendon organs to help us with body position (proprioception). The benefits of using proper body mechanics for massage include the following:

- Increased strength and power
- Increased pressure
- Decreased possibility of injury
- Enhanced quality and effectiveness of massage
- •Increased career and life span as a therapist/ body worker

Generally the application of Kinesiology to human movement helps:

- To move safely, effectively, efficiently
- To improve performance
- To prevent and treat injury
- For qualitative and quantitative analysis of performance

1.3 Relation of kinesiology to biomechanics

- Kinesiology is the study of human movement, and biomechanics is one of the many academic sub-disciplines of kinesiology.
- Biomechanics in kinesiology involves the precise description of human movement and the study of the causes of human movement.
- The study of biomechanics is relevant to professional practice in many kinesiology professions.
- The physical educators are teaching movement technique and the athletic trainer or physiotherapists treating an injury using biomechanics to qualitatively analyze movement
- Kinesiology brings together the fields of anatomy, physiology, physics, geometry, and relates them to human movement. Thus, kinesiology utilizes principles of mechanics, musculoskeletal anatomy, and neuromuscular physiology
- Biomechanics is the study of the movement of living things using the science of mechanics. It is the study of the structure and function of biological systems by means of the methods of "mechanics."

Biomechanics uses the application of the principles of mechanical physics to understand movements and actions of human bodies and sport implements like ball, racket, crutch, prosthesis, or some other implement, their biomechanical interaction must be considered as well.

Mechanics is a branch of physics that is concerned with the description of motion and how forces create motion or Mechanics is a branch of applied mathematics that deals with movement and tendency to movement. It is also the 'science of machines'.

In practice there is no difference between biomechanics and mechanics except what is studied.

Within "mechanics" there are two sub-fields of study:

1. **Statics**, which is the study of systems that are in a state of constant motion, moving with a constant velocity, or at rest, with no motion; and
2. **Dynamics**, which is the study of systems in motion in which acceleration is present; it is divided into:
   - √ **Kinematics:**- the study of the **motion of bodies with respect to time**, displacement, velocity, and speed of movement (either in a straight line or in a rotary direction), and
   - √ **Kinetics: -** the study of the **forces associated with motion**, including forces causing motion and forces resulting from motion (either in a straight line or in a rotary direction).

Even though kinesiology is an umbrella term, Kinesiology and biomechanics are intricately related. Principles of these two fields can be applied to the fields of biology, physiology, engineering, physical and occupational therapy, and medicine as well.

1.4 Basic Terminology

Kinesiology is the study of movement

Mechanics is the study of forces and the motions that they produce

Biomechanics is Mechanical principles applied to the human body .What forces act on the human body? What are the results of those forces?

Biomechanical systems can be considered: Static or dynamic

Linear Motion

- √ Rectilinear Motion (straight)
- √ Curvilinear Motion (curved)

Angular Motion (circular

Linear Motion(translator)

- √ All the parts of the object move the same distance, in the same direction, and at the same time
- √ can be broken down into 2 categories:
  - Rectilinear motion = movement that occurs in a straight line
  - Curvilinear motion = movement in a curved path that isn't necessarily circular

Angular motion (rotary motion)

- √ Movement of an object around a fixed point
- √ All the parts of the object move through the same angle, in the same direction, and at the same time, but they do not move the same distance.

The Anatomic Position of the human body:

- √ Standing in an upright position
  - √ Eyes facing forward
  - √ Feet parallel and close together
  - √ Arms at the sides of the body

- √ Palms facing forward

Midline

- √ Of the body
- √ Of a body part

Medial and Lateral

- √ Medial = a location or position toward the midline
- √ Lateral = a location or position farther from the midline

Anterior and Posterior

- √ Anterior = refers to the front of the body or to a position closer to the front (synonymous with *ventral*)
- √ Posterior = refers to the back of the body or to a position more toward the back (synonymous with *dorsal*)

Proximal and Distal

- √ Proximal = toward the trunk
- √ Distal = away from the trunk

Superior and Inferior

- √ Superior = the location of a body part that is above another (or to refer to the upper surface of an organ or a structure)
- √ Inferior = indicates that a body part is below another (or refers to the lower surface of an organ or a structure)

Cephalad and Caudal

- √ Cephalad = a position or structure close to the head
- √ Caudal = a position or structure closer to the feet

Superficial and Deep

- √ Descriptions used to refer to relative depth of a structure.
- √ For example, when describing the layers of the abdominal muscles, the external oblique is deep to the rectus abdomen is but superficial to the internal oblique.

Supine = When a person is lying on his back with his legs extended.

Prone = when a person is lying on his stomach.

Side lying = when a person is lying on his side.

Hook lying = when a person is lying on his back with his hips and knees flexed, so that his feet are on the surface of the bed or table.

Short Sitting = when a person is sitting with his hips and knees flexed to approximately 90 degrees.

Long Sitting = when a person is sitting with his hips flexed to approximately 90 degrees and the knees extended.

Quadruped = the position consisting of being on four points (knees and hands)

Bilateral and Unilateral

- √ Bilateral = refers to two, or both, sides.
- √ Bilateral above knee amputation means both the right and left legs were amputated
- √ Bilateral quad sets means both quads were working (typically at the same time)
- √ Unilateral = refers to one side.

Ipsi lateral and Contra lateral

- √ Ipsi lateral = refers to the same side of the body
- √ Contra lateral = refers to the opposite side of the body

CHAPTERTWO

Biological and Structural Bases

Anatomical descriptions of motion and its limitation

What is the need of learning anatomical description of motion? Anatomical descriptions of motion are essential for understanding of biomechanics and it is important that many of the terms that are used in both the study of anatomy and biomechanics are explained in more detail.

- **Anatomical position**

Anatomical position	**Location**
Superficial	close to surface
deep	away from surface
anterior	Front
posterior	Rear
Medial	near mid-line
Lateral	away from mid-line
superior	relative highest position
inferior	relative lowest position
Proximal	near point of attachment to body
Distal	furthest away from body attachment

- **Joint movement**

Joint movement	**Description**
Abduction	take away from mid-line
adduction	bring towards mid-line
internal–external rotation	lower leg inward and outward rotation about long axis
plantar- and dorsi flexion	pointing toes or bringing toes towards the shin
extension and flexion	straightening or bringing segments closer together
hyper-extension	excessive extension
Inversion and eversion	heel rolling outwards or inwards
Pronation	complex tri-planar movement in foot involving eversion, abduction and dorsi flexion
Supination	tri-planar movement in foot involving inversion, adduction and plantar- flexion

- **Special joint movement**

Special joint movement	**Description**
Valgus	lower limb segment rotated about anterior–posterior axis through knee away from mid-line of body
Varus	as for valgus but rotation towards mid-line horizontal abduction and adduction (arm held out in front in transverse plane and then abducted or adducted)
Circum duction	rotation of a part or segment in a circular manner

- **General movement**

General movement	**Description**
Parallel	equidistant and never intersecting
degrees of freedom	method used to describe movement or position
diagonal plane	a surface that is slanted
Tension	to stretch or pull apart
Compression	to squeeze together
Elevate and depress	to rise up or push down
Origin	starting or beginning point
Insertion	anatomical attachment point
coordinate/s	a number or set of numbers corresponding to a system of reference
Perpendicular	at 90 degree
Translate	change in position but without rotation
Rotate	move through an angle
Vertical and horizontal	in a two-dimensional space usually upwards (in the y direction) and along (in the x direction

- **Planes of motion**

Imaginary sections or planes are made in the body in order to examine the internal anatomy and describe body position of one body part to another. These sections are called planes of motion. There are three planes of motion.

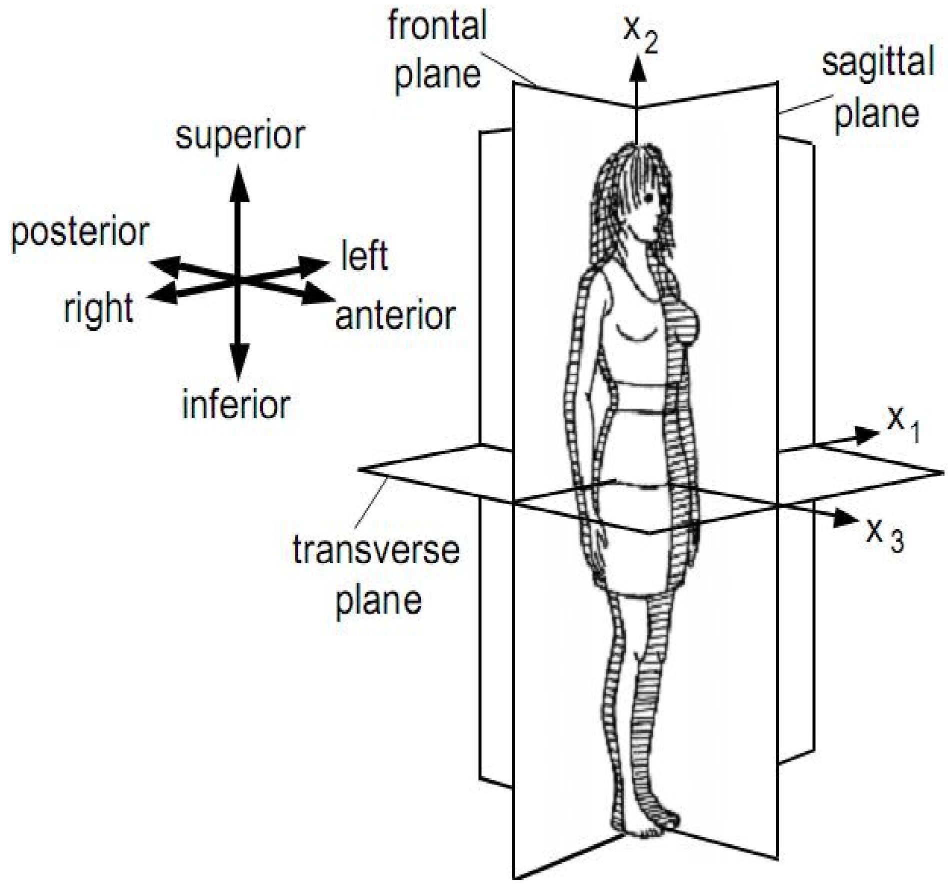
1. **Sagittal plane**
   This plane separates the body into left and right. Motions that occur in the sagittal plane run parallel to the plane (or an imaginary line splitting the body into left and right). Those motions would be flexion, extension, dorsi flexion, and plantar flexion.

2. **Transverse plane**
   This is the plane that separates the body into top and bottom. The motion that occurs in the transverse plane runs parallel to the plane (or an imaginary line splitting the body into top and bottom). This motion is rotation (medial, lateral, trunk).

3. **Coronal (frontal) plane**

   The coronal (frontal) plane separates the body into front and back. Motions that occur in the coronal (frontal) plane run parallel to the plane (or an imaginary line splitting the body into front and back). These motions are abduction, adduction, shoulder elevation, and shoulder depression.

Plane and axis of motion	**Description**
Anatomical position	facing forwards, arms by side, feet forwards and parallel, palms forward and fingers extended
cardinal plane	plane passing through center of mass
sagittal plane	divides body or part into left and right portions
transverse axis	perpendicular to sagittal plane
frontal plane	divides into front and rear portions
anterior–posterior axis	perpendicular to frontal plane
transverse plane	divides into upper and lower portions
Longitudinal axis	perpendicular to transverse plane



o **Coordinates**

Abscissa (often the “x” axis),

ordinate (often the “y” axis),

Intersect (cross each other).

The x axis is often termed the **abscissa** and the y axis the **ordinate**. The point at which the two axes **intersect** (cross) is called the **origin** and

it is important to point out that these two axes would always be expressed perpendicular (at 90 degree) to each other

o **Cavities of the body**

The body has two main cavities: the ventral and dorsal cavities

1. **Ventral cavity:**

   √ This cavity is more anteriorly located on the body and

- √ contains the following:
- √ The thoracic cavity (heart/lungs and area above the diaphragm)

2. **Dorsal cavity**

- √ This cavity is more posterior on the body and contains the following:
  • The cranial cavity (contains the brain)
  • The spinal cavity (contains the spinal cord and vertebrae), also known as the vertebral canal.

o **The limitations of anatomical description**

Anatomy classifies muscles into functional groups (flexors/extensors, abductors/adductors, etc.) based on hypothesized actions. These muscle groups Are useful for general classifications and are commonly used in fitness education, weight training, and rehabilitation. These hypothesized muscle Actions in movements and exercises are used to judge the relevance of various exercise training or rehabilitation programs. This shows that such qualitative estimations of muscle actions are often incorrect.

Functional anatomy classifies muscles actions based on the mechanical method of muscle action analysis. This method essentially examines one muscle's line of action relative to one joint axis of rotation, and infers a joint action based on orientation and pulls of the muscle in the anatomical position.

Biomechanical data and analysis are necessary to determine the actual actions of muscles in movement. There are even cases where muscles accelerate a joint in the opposite direction to that inferred by functional anatomy.

- **Mechanics of muscle-skeletal system**

This part will provide an overview of the mechanical properties of materials, specifically muscles, tendons, ligaments, and bone. The deformations of muscles, tendons, and bones created by external forces, as well as the internal forces created by these same structures, are relevant to understanding human movement or injury.

Tissue loads

When forces are applied to a material, like human musculoskeletal tissues, they create **loads**. Engineers use various names to describe how loads tend to change the shape of a material. These include the principal or axial loadings of compression, tension, torsion and shear.

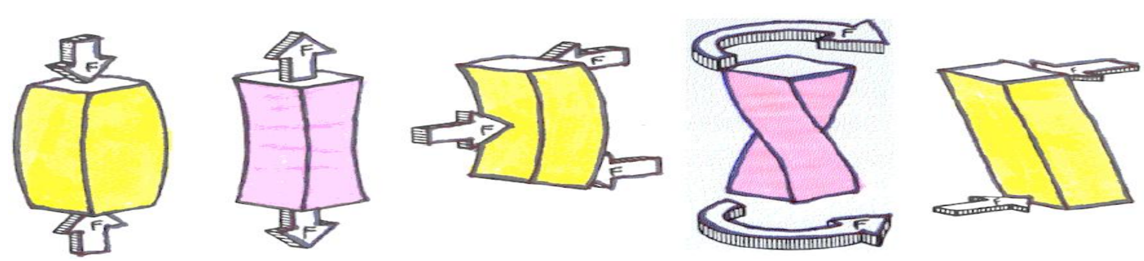
Compression is when an external force tends to squeeze the molecules of a material together.

Tension Is when the load acts to stretch or pull apart the material.

Torsion When many forces are acting on a body they can combine to
create combined loads called **Torsion** and **bending**.

Shear is a right-angle loading acting in opposite directions.

Tissue loads and deformations



Compression **Tension** **shear** **Torsion**
Shear

Biological tissue, including the human body, is by nature, deformable. It can absorb forces, it can stretch, bend, compress. With regards to gross human movement, these deformations are relatively small, and for the sake of simplicity.

Each segment of the body is considered as a rigid body linked together by joints. The mechanical properties of a material are determined by the way it reacts to a **load**. The applied load can be categorized as a **force** or a **torque** (or twisting moment) or a combination of these. The applied load can either be **gradual** (such as when lifting a barbell), or **impulsive** (such as heel strike impact in running). The applied load can either be applied once (**acute loading**) or several times (**repetitive loading**).These latter two load characteristics are useful when considering the injury effects of loading, as an acute load can lead to a fracture of the bones or a torn tendon, while a repetitive load can lead to an overuse injury.

Stress and strain

Stress is defined as the force per unit area(Stress=F/A) and describes the way the force is distributed through the material.

Strain is defined as the increase in length divided by the original length(Strain=IL/OL) and is often expressed as a percentage.

For many materials, stress is linearly related to strain, and this relationship is known as Hooke’s law. This relationship holds until a material reaches its elastic limit or yield point where the material begins to disintegrate.The **linear region** of Hooke’s law implies that as the force (or stress) increases the deformation (or strain) increases in the same proportion and so the force-to-deformation ratio and the stress-to-strain ratio are constant. This constant is known as the **stiffness.**

Stiffness and modulus of elasticity

The elasticity of a material can be computed from the way it deforms under load.If the force which causes a deformation is used, their ratio is the stiffness. If the stress (force per unit area) and strain (percentage length change) are used, their ratio is called the **modulus of elasticity**. The stiffness is more widely used in sport and exercise bio mechanics. When the force and deformation are used to describe the behavior of the material and the **modulus of elasticity** the stress and strain are used.

In sport and exercise science it is more common to measure force (F) and deformation (d) so the term, stiffness (k) is often used and is expressed as:

Force (Forw▲L) = stiffness (k). Deformation (d) F = k. d

As the force is applied it moves its point of application and the work done on the material is stored as elastic energy (E_{ES}) given by equation:

$$E_{ES} = 1/2\ k.\ d^2$$

Elasticity

Elasticity describes **the way in which a material deforms and then returns to its original shape**. Materials that do this well are called elastic (e.g., an elastic band or spring). Materials that do this poorly are called inelastic.

Viscoelastic

Viscoelastic means that the stress and strain in a material are dependent on the rate of loading, so the timing of the force application affects the strain response of the material.

Hysteresis

When an object is deformed and then allowed to return to its original state a certain amount of energy is lost. This energy loss is termed **hysteresis**.

Point and area elastic

A special note should be given to sports surfaces. In sports like gymnastics and tumbling the surfaces are described as **area elastic** that is they deform over a large area when jumped on and have good elasticity to aid the performer.

Wooden gymnasium floors that are "sprung" are also area elastic. Surfaces like real or artificial turf are considered **point elastic** hat is they deform in a localized region when jumped on.

Generally point elastic surfaces have poor elasticity. Permanent deformations are referred to as **set**, and describe the **plastic** behavior of materials. Set can be important in some sport materials, for example those used in the midsoles of running shoes. The expanded foam material that is used to provide cushioning as the foot makes contact with the ground gradually permanently deforms through use.

- **Biomechanics of the passive muscle–tendon unit (MTU)**

The mechanical response of the MTU to passive stretching is visco elastic, so the response of the tissue depends on the time or rate of stretch. At a high rate of passive stretch the MTU is stiffer than when it is slowly stretched. This is the primary reason why slow, static stretching exercises are preferred over ballistic stretching techniques.

Slow stretch results in less passive tension in the muscle for a given amount of elongation compared to a faster stretch. The load in an MTU during other movement conditions is even more complicated because the load can vary widely with activation, previous muscle action and kind of muscle action.

Tendon is the connective tissue that links muscle to bone and strongly affects how muscles are used or injured in movement. Tendon is a well-vascularized tissue whose mechanical response is primarily related to the protein fiber *collagen*. The parallel arrangement of collagen fibers in tendon and cross-links between fibers makes tendon about three times stronger in tension than muscle.

The ultimate strength of tendon is usually about 100 MPa (mega Pascal). Even though the diameter of tendons is often smaller than the associated muscle belly, their great tensile strength makes tendon rupture injuries rare.

Acute overloading of the MTU usually results in **strains** (sports medicine term for overstretched muscle, not mechanical strain) and failures at the muscle tendon junction or the tendon/bone interface.

In creating movement, a long tendon can act as an efficient spring in fast bouncing movements because the stiffness of the muscle belly can exceed tendon stiffness in high states of activation. A muscle with a short tendon transfers force to the bone more quickly because there is less slack to be taken out of the tendon.

The intrinsic muscles of the hand are well suited to the fast finger movements of a violinist because of their short tendons. The Achilles tendon provides shock absorption and compliance to smooth out the forces of the large calf muscle group (soleus and gastrocnemius).

- **Muscle Movers**

Agonists (primary movers) Agonists are the main muscle(s) doing the movements. These are usually the larger muscles since they have to be strong.

Assisters: The assister muscles help the primary movers in one of two ways:

1. ***Synergist*** helps the primary mover by moving the same way. If the primary mover is in a concentric contraction, so is the synergist. If the primary mover is in an eccentric contraction, so is the synergist.

2. ***Antagonist*** helps the primary mover by moving opposite. If `the primary mover is in a concentric contraction, the antagonist is in an eccentric contraction.

Stabilizers: These muscles help prevent motion. We usually get hurt when our stabilizers become primary movers, such as in lifting something off the floor by bending at the waist instead of using our legs.

Connective tissue: The function of connective tissue is to support, protect, and connect other tissues. Types of connective tissue relating to the muscular system include tendons, ligaments, and cartilage.

Tendons: Tendons attach muscle to bone (for example, the Achilles tendon attaches the gastro cnemius to the calcaneous).

Ligaments: Ligaments attach bone to bone (for example, the anterior cruciate ligament attaches the femur to the tibia).

Cartilage: Cartilage provides the cushion between bones. An example is the two cartilages between the femur and the tibia of the knee.

Fascia: Fascia is a web of tissue that serves to maintain structural integrity by providing support and protection while acting as a shock absorber.

Bursa (pl. bursae): Bursa is a small fluid-filled sac that provides cushion between bones and tendons and/or muscles around a joint. They are filled with synovial fluid.

- **Biomechanics of bone**

Unlike muscle, the primary loads experienced by most bones are compressive. The mechanical response of bone to compression, tension, and other complex loads depends on the complex structure of bones. Remember that bones are living tissues with blood supplies, made of a high percentage of water (25% of bone mass), and having considerable deposits of calcium salts and other minerals.

The strength of bone depends strongly on its density of mineral deposits and collagen fibers, and is also strongly related to dietary habits and physical activity. The loading of bones in physical activity results in greater osteoblast activity, laying down bone.

Immobilization or inactivity will result in dramatic decreases in bone density, stiffness, and mechanical strength. A German scientist is credited with the discovery that bones remodel (lay down greater mineral deposits) according to the mechanical stress in that area of bone. This laying down of bone where it is stressed and re absorption of bone in the absence of stress is called **Wolff's Law**.

The macroscopic structure of bone shows a dense, external layer called cortical (compact) bone and the less-dense internal cancellous (spongy) bone. The mechanical response of bone is dependent on this “sandwich” construction of cortical and cancellous bone. This design of a strong and stiff material with a weaker and more flexible interior (like fiberglass) results in a composite material that is strong for a given weight. This is much like a surf board constructed of fiberglass bonded over a foam core.

Cortical bone is stiffer (maximum strain about 2%), while cancellous bone is less stiff and can withstand greater strain (7%) before failure. In general, this design results In ultimate strengths of bone of about 200 Mpa in compression, 125 Mpa in tension, and 65 Mpa in shear.

It is also important to understand that the ultimate strength of bone depends on nutritional, hormonal, and physical activity factors. Research done with an elite power lifter found that the ultimate compressive strength of a lumbar vertebral body (more than 36,000 N or 4 tons) estimated from bone mineral measurements was twice that of the previous maximal value. More recent studies of drop jump training in prepubescent children has demonstrated that bone density can be increased, but it is unclear if peak forces, rates of loading, or repetitions are the training stimulus for the increases in bone mass. More research on the osteogenic effects of various kinds of loading and exercise programs could help physical educators design programs that help school children build bone mass.

- **Biomechanics of ligaments**

Ligaments are tough connective tissues that connect bones to guide and limit joint motion, as well as provide important Proprioceptive and kinesthetic afferent signals. Most joints are not perfect hinges with a constant axis of rotation, so they tend to have small accessory motions and moving axes of rotation that stress ligaments in several directions.

The collagen fibers within ligaments are not arranged in parallel like tendons, but in a variety of directions. Normal physiological loading of most ligaments is 2–5% of tensile strain, which corresponds to a load of 500 N in the human anterior cruciate ligament except for “spring” ligaments that have a large percentage of elastin fibers (ligamentum flavum in the spine), which can stretch more than 50% of their resting length. The maximum strain of most ligaments and tendons is about 8–10%. Like bone, ligaments and tendons remodel according to the stresses they are subjected to.

A long-term increase in the mechanical strength of articular cartilage with the loads of regular physical activity has also been observed. Inactivity, however, results in major decreases in the mechanical strength of ligaments and tendon, with reconditioning to regain this strength taking longer than deconditioning.

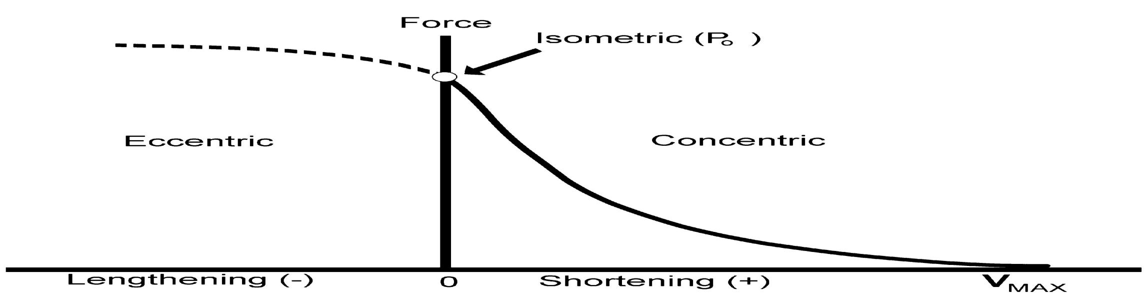
The ability of the musculoskeletal system to adapt tissue mechanical properties to the loads of physical activity does not guarantee a low risk of injury. There is likely a higher risk of tissue overload when deconditioned individuals participate in vigorous activity or when trained individuals push the envelope, training beyond the tissue's ability to adapt during the rest periods between training bouts.

- **Mechanical characteristics of muscle**

The three major mechanical characteristics of muscle that affect the tension skeletal muscles can create are the force–velocity, force–length, and force–time relationships.

1. **Force–Velocity Relationship**

The **Force–Velocity Relationship** explains how the force of fully activated muscle varies with velocity. This may be the most important mechanical characteristic since all three muscle actions (eccentric, isometric, concentric) are applied. In Force–Velocity Relationship of skeletal muscle, the Force–Velocity curve essentially states that the force the muscle can create decreases with increasing velocity of shortening (concentric actions), while the force the muscle can resist increases with increasing velocity of lengthening (eccentric actions).



On the above graph

The force in isometric conditions is labeled P in Hill's equation.

The right side of the graph corresponds to how the tension potential of the muscle rapidly decreases with increases in speed of concentric shortening.

Also note, however, that increasing negative velocities (to the left of isometric) show how muscle tension rises in faster eccentric muscle actions.

In isolated muscle preparations the forces that the muscle can resist in fast eccentric actions can be almost twice the maximum isometric force

2. **Force–Length Relationship**

The length of a muscle also affects the ability of the muscle to create tension. The **Force–Length Relationship** Documents how muscle tension varies at different muscle lengths. The variation in potential muscle tension at different muscle lengths, like the Force–Velocity Relationship, also has a dramatic effect on how movement is created and is influential on the torque a muscle group can make as the geometry (moment arm) of the muscles and joint.

3. **Force–Time Relationship**

Another important mechanical characteristic of muscle is related to the temporal delay in the development of tension. The **Force–Time Relationship** refers to the delay in the development of muscle tension of the whole MTU and can be expressed as the time from the **motor action potential** (electrical signal of depolarization of the fiber that makes of the electromyography or EMG signal) to the rise or peak in muscle tension.

The time delay that represents the Force–Time Relationship can be split into two parts.

The first part of the delay is related to the rise in muscle stimulation some-times called active state or excitation dynamics. In fast and high-force movements the neuromuscular system can be trained to rapidly increase (down to about 20 m/s) muscle stimulation.

The second part of the delay involves the actual build-up of tension that is sometimes called contraction dynamics. The contraction dynamics of different fiber types was about 20 m/s for fast twitching and 120 m/s for slow twitching muscle fibers.

CHAPTER THREE

FORMS OF MOTION

Body motion is produced or started by some action of muscular system. Motion cannot occur without a force. Muscular system is source of force in humans. These are:

1. **Translation (linear motion)-**a straight line path called translatory. Because all moving body travel in the same distance, direction and time. In other word it is a motion along a line. Example: 100m dash.

2. **Rotation (angular motion)-**a circular path or rotatory, curvilinear, parabolic movement. Example: projectile bodies like shot put, javelin, discus, hammer, etc. or it is a rotation around an axis. In the body, the axis of rotation is provided by the various joints.

Linear & angular motions are related. Angular motion of the joints produces the linear motion of walking. Sports exercise cumulative angular motion of the joints imparts linear motion to a thrown object (ball, shot) or to an objects truck with an instrument (bat, racket).

What is human movement?

- √ Human movement is defined as the change in position of the body or body segments in space and time through the application of varying amounts of force or it can be described as either linear or angular types.
- √ The movement of human body through their various environments can be studied from three basic points of view.

1. **Psychological kinesiology**

The movement of nerve inputs started from central nervous system.

2. **Physiological kinesiology**

ATP——> ADP + Pi + Energy Chemical energy into mechanical energy

3. **Mechanical Kinesiology**

Is the study of human motion or a person in motion.

Chapter Four

Kinetics

Linear kinetics

Kinematics or descriptions of motion could be used to provide information for improving human movement. The important laws of kinetics that show how forces overcome inertia and how other forces create human motion.

Studying the causes of linear motion is the branch of mechanics known as **linear kinetics**. Identifying the causes of motion may be the most useful kind of mechanical information for determining what potential changes could be used to improve human movement.

- **NEWTON'S LAWS OF MOTION**

Arguably, some of the most important discoveries of mechanics are the three laws of motion developed by the Englishman, Sir Isaac Newton. Newton is famous for many influential scientific discoveries, including developments in calculus, the Law of Universal Gravitation, and the Laws of motion. The importance of his laws cannot be overemphasized in our context, for they are the keys to understanding how human movement occurs.

Newton's Laws help to explain the relationship between forces and their impact on individual joints, as well as on total body motion. Knowledge of these concepts can help one understand athletic movement, improve athletic function, understand mechanisms of injury, treat and prevent injury.

- ***Forces & Torques***

Force – a push or pull; exerted by one object on another; come in pairs (Newton's 3rd Law); creates acceleration or deformation (Newton's 2nd Law); causes an object to start, stop, change direction, speed up or slow down (Newton's 1st Law).SI Unit of Force is the Newton (N) = force required to accelerate a 1 kg of mass 1 meter per second squared.

Force is described by its size (magnitude) and direction. The angular equivalent of force (F) is Torque (T); a Torque rotates an object about an axis at a distance r. Therefore T = F x moment arm.

Resultant Force – the summation of all forces acting on a body; determines the direction of motion of a body. Internal Forces and Torques – forces or torques that act within the studied object; i.e. the human body, or the object being manipulated by the human; pole vault, soccer ball, etc.

Internal forces can cause movement of body segments at a joint but cannot produce a change in the motion of a body's center of mass.

Muscular force is the primary internal force examined in biomechanics. As the overwhelming majority of motion in the human body is angular, torque is more applicable in biomechanics. The terms Force and Torque will be used interchangeably throughout this course. Essentially, if the term “Force” is used to describe angular motion, "Torque” is implied.

External Forces – forces that act on an object as a result of its interaction with the environment surrounding it. Most External Forces are contact forces, requiring interaction with another object, body or fluid. Some External Forces are non-contact forces; including gravitational, magnetic and electrical force.

The science of biomechanics largely deals with contact forces and gravity (weight), which accelerates objects at 9.8 m/s.

- ***Contact Forces***

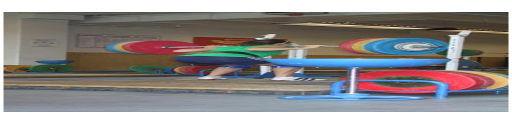
Contact forces can be sub-divided into normal reaction force and friction.

Normal Reaction Force – line of action of the force is perpendicular to the

Surfaces in Contact.

Friction Force – line of action of the force is parallel to the surfaces in

Contact



1. **Newton’s 1st Law – Law of Inertia**

Objects tend to stay at rest or in uniform motion unless acted upon by an unbalanced force. A player sitting and “warming the bench” has just as much inertias a teammate of equal mass running at a constant velocity on the court.

A body remains at rest or in a motion except when compelled by an external force to change its state. A force is required to start, stop, or alter motion. Inertia – the tendency of a body to remain at rest or resist a change in velocity Inertia is directly proportional to its mass. The angular equivalent is Mass Moment of Inertia.

2. **Newton's 2nd Law – Law of Acceleration**

Newton's second law is arguably the mostimportant law of motion because it showshow the forces that create motion (kinetics)are linked to the motion (kinematics). Thesecond law is called the **Law of Momentum**or **Law of Acceleration**,

The acceleration of a body is directly proportional to the F causing it, takes place in the same direction in which the F acts, and is inversely proportional to the mass of the body.

a = change in velocity / time

F = ma (Force = mass x acceleration) (linear)

Angular equivalent of F is Torque (T)

Impulse-Momentum Relationship; from F=ma, we can derive Momentum (p) and Impulse

Impulse = Force x time (Ft)

Momentum = mass x velocity (mv)

Ft= mv (impulse = momentum) If Ft increases, mv increases

Mass is considered constant within biomechanics, therefore, an increase in impulse implies an increase in velocity. Because Mass is constant, and external forces are largely non-modifiable, in the world of sports and exercise, the duration of force application is the most modifiable.

If the Force is not constant, impulse is the avg. force times the duration of that average force. Conversely, if the application of Force happens more rapidly (decreased time), there will be a higher Force (avg. & peak) in order to maintain impulse.

Example: If a football kicked with1000N force and 0.01s calculate the impulse comes from the leg of the player, momentum of the ball and final velocity of the ball. Assume mass of the ball is 450gm.

Work-Energy Relationship -- from F=ma, we can also derive Work (W)

Work = Force x Distance (W = FD) (linear)

Angular equivalent = Torque x Angular displacement (T x degrees)

Measured in Newton meters (Nm)

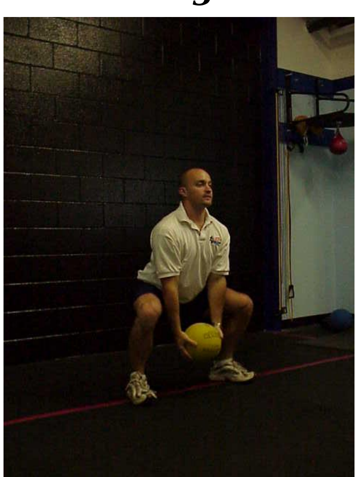
Work is a measure of strength measured by the extent to which a force moves a body over a distance without regard to time

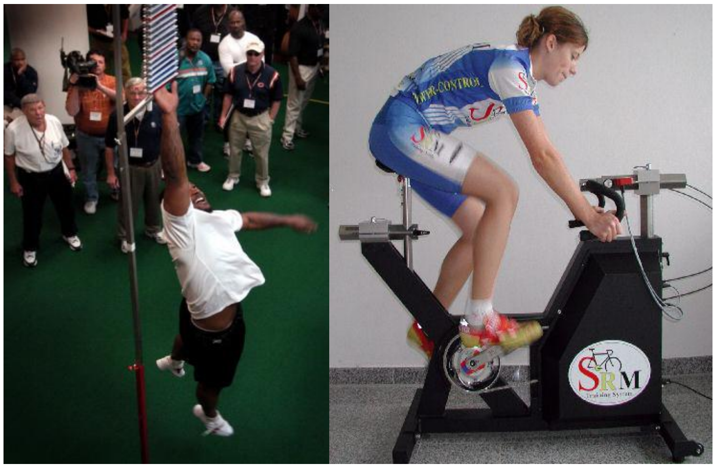
Power (P) – the rate of work; W/time; W/t = F x D/t = F x V (W=FV)

Training power in an athlete requires doing work quickly, or explosively

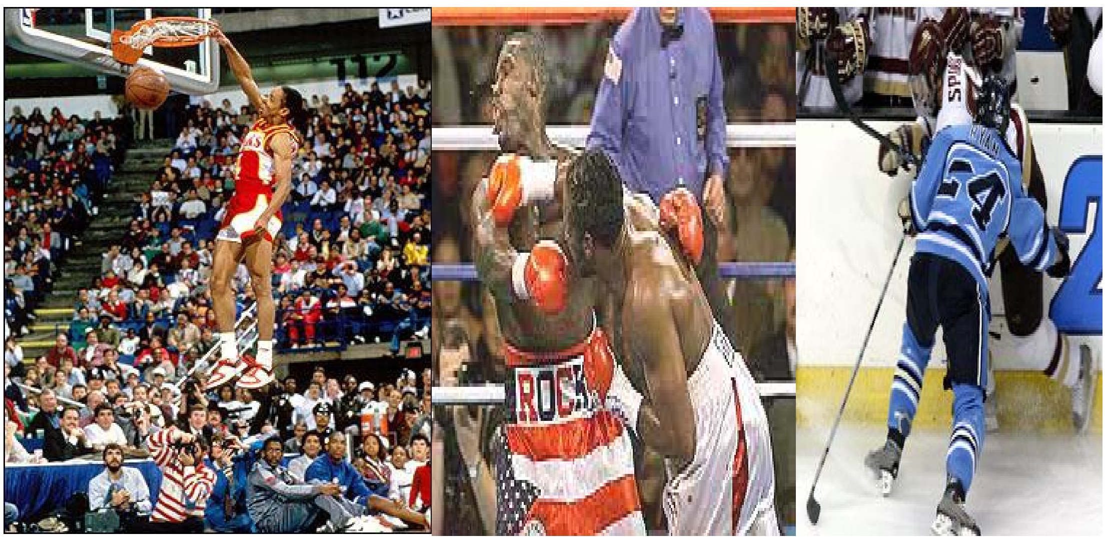
How is Power measured and trained in sport and exercise?

Measuring and Training Power in the Athlete





Power in Sport



3. Newton’s 3rd Law: - – Law of Action-Reaction

Newton's third law of motion is called the **Law of Reaction**, because it is most often translated as: for every action there is an equal and opposite reaction. For every force exerted, there is an equal and opposite force being exerted. If a patient exerts a sideways force of +150 N on an elastic cord, there has to be –150-N reaction force of the cord on the patient's hand.

For every action, there is an equal and opposite reaction the two bodies react at the same time, according to F = ma; each body experiences a different acceleration effect which is dependent on its mass. Examples in swimming, jumping, and starting sprints used reaction force to initiate acceleration in sport world.

- **Class of Lever**

Lever can be classified according to the relative positions of the axis, motive force and resistive force (ARM).

- 1st class Axis is between resistance and motive force.
- 2nd class Resistance force is in between the axis and the motive force.
- 3rd class Motive force is in between the axis and the resistance force.

Humans moves through a system of levers. Levers cannot be changed, but they can be utilized more efficiently– lever - a rigid bar that turns about an *axis* of rotation or a fulcrum– axis - point of rotation about which lever moves.

Levers rotate about an axis as a result of *force* (effort, *E)* being applied to cause its movement against a *resistance* or weight. In the body:

- bones represent the bars
- joints are the axes
- muscles contract to apply force

Resistance can vary from maximal to minimal– May be only the bones or weight of body segment. All lever systems have each of these three components in one of three possible arrangements. Three points determine type of lever &for which kind of motion it is best suited

- Axis *(A)*- fulcrum - the point of rotation
- Point *(F)* of force application (usually muscle insertion) - effort

- Point *(R)* of resistance application (center of gravity of lever) or (location of an external resistance)

1st Class Lever

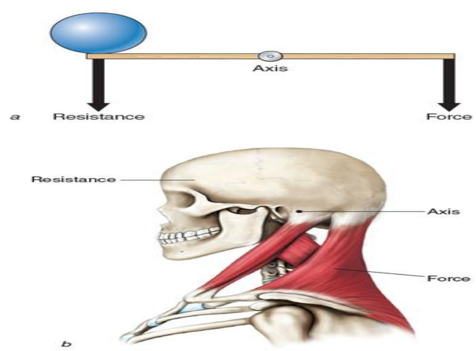
Most versatile lever because it can be used for any type of mechanical advantage.

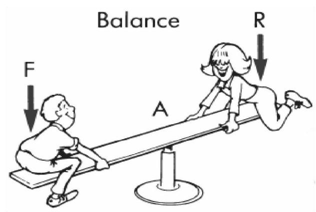
Produce balanced movements when axis is midway between force &resistance (e.g., seesaw)

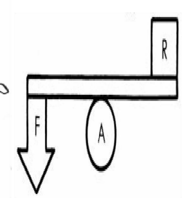
Produce speed & range of motion when axis is close to force, (triceps in elbow extension)

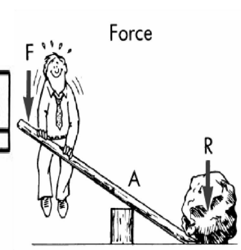
Produce force motion when axis is close to resistance (crowbar)

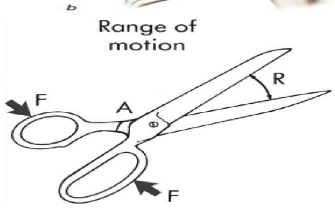
Eg .











2nd Class Lever

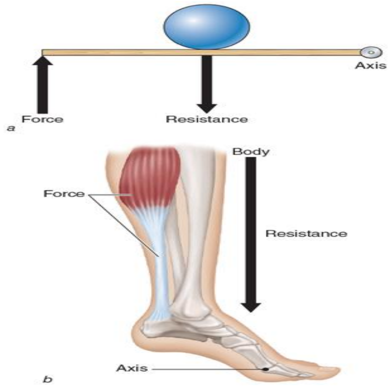
Resistance in middle

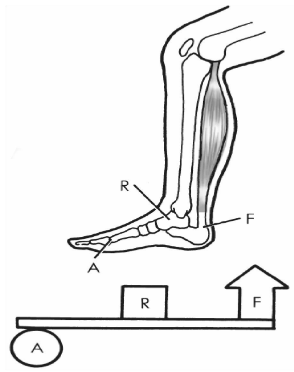
Relatively few 2nd class levers in body Produce force movements, since a large resistance can be moved by a relatively small force.

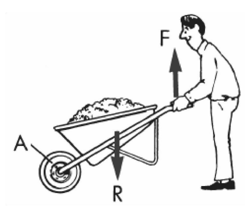
Force advantage usually exists for motive force. For example:

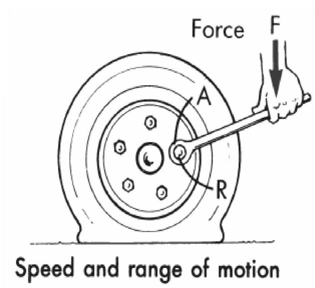
- √ Push-up body is lever, feet are axis, resistance is weight of body and motive is arms.
- √ Plantar flexion of foot to raise the body up on the toes where ball (A) of the foot serves as the axis as ankle plantar flexors

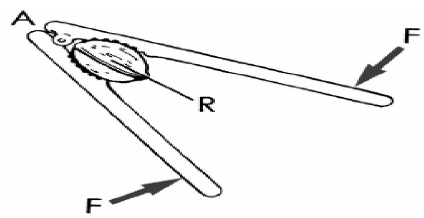
apply force to the calcaneus (F) to lift the resistance of the body at the tibial articulation (R) with the foot











3rd class lever

Motive force in middle

most musculoskeletal arrangements are 3rd class levers

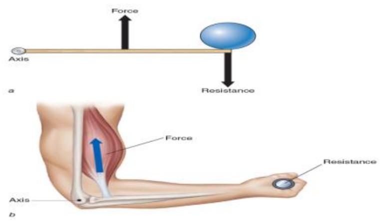
muscle is motive force

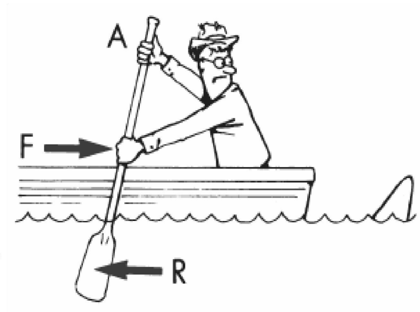
advantage in ROM and speed but disadvantage in F

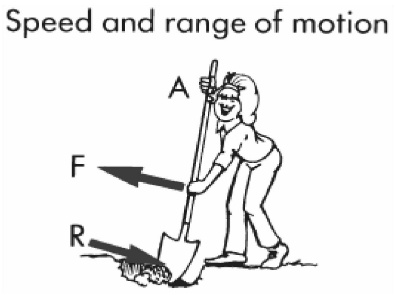
Produce speed & range-of-motion movements

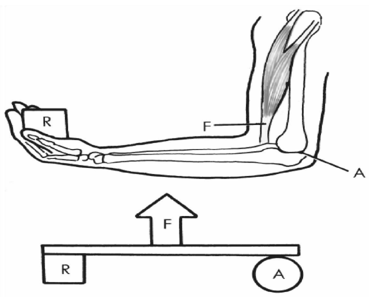
Most common in human body

Requires a great deal of force to move even a small resistance









Factors in use of anatomical levers

- Anatomical leverage system can be used to gain a mechanical advantage
- Improve simple or complex physical movements
- Some habitually use human levers properly
- Some develop habits of improperly using human levers

CHAPTER FIVE
KINEMATICS

- **Linear kinematic motion**

Mechanics is the study of forces and the effects of these forces on living things.A subdivision of mechanics that is concerned with displacement, velocity and acceleration is kinematics and forces that cause or result from motion is kinetics.

Linear motion (translatory motion) is concerned with movement along a line that is either straight or curved and where there is no rotation and all body parts move in the same direction at the same speed. Angular motion involves movement around an axis of rotation.

Scalar quantity a quantity that is represented by magnitude (size) only.

Vector quantity a quantity that is represented by both magnitude and direction.

The term distance is classified as a scalar quantity and is expressed with reference to magnitude only (i.e., 14 miles).

Displacement is the vector quantity and is expressed with both magnitude and direction (i.e., 14 miles north-east).

Speed is the scalar quantity that is used to describe the motion of an object. It is calculated as distance divided by time taken.

Velocity is the vector quantity and it is used to also describe the motion of an object. It is calculated as displacement divided by time taken.

Acceleration is defined as the change in velocity per unit of time.

Average and instantaneous velocity, Average is the usual term for the arithmetic mean. The sample mean is derived by summing all the known observed values and dividing by their number. For example over a 26 mile race the average speed of the athlete was

14 miles per hour (mph). Instantaneous refers to smaller increments of time in which the velocity or acceleration calculations are made.

The smaller the increments of time between successive data points the more the value tends towards an instantaneous value.

- **Kinematics and kinetics**

Linear kinematics is concerned with the quantities that describe the motion of bodies such as distance, displacement, speed, velocity, and acceleration. These quantities can be classified as either scalar or vector quantities.

Scalar quantities are represented by magnitude (size) only, whereas Vector quantities are represented by both magnitude and direction. Hence, vector quantities can be presented mathematically or graphically on paper by scaled straight lines or arrows. For example, speed is defined as the distance traveled per unit of time and as such it is a scalar quantity (i.e., no direction is specified).

$$\text{Speed} = \frac{\text{Distance traveled}}{\text{Time taken}} \qquad V = \frac{S}{T}$$

Ex 1. If an athlete ran 14 miles in 1 hour and 15 minutes what was the athlete's average speed?

1 mile = 1609.344 meters

1 hour = 60 minutes = 60 · 60 minutes = 3600 seconds

11.2 miles = 11.2 · 1609.344 m = 18024.652 m

$$\text{Speed in m/s} = \frac{18024.652\ \text{m}}{3600\ \text{s}} \qquad \text{Speed} = 5.0068\ \text{m/s}$$

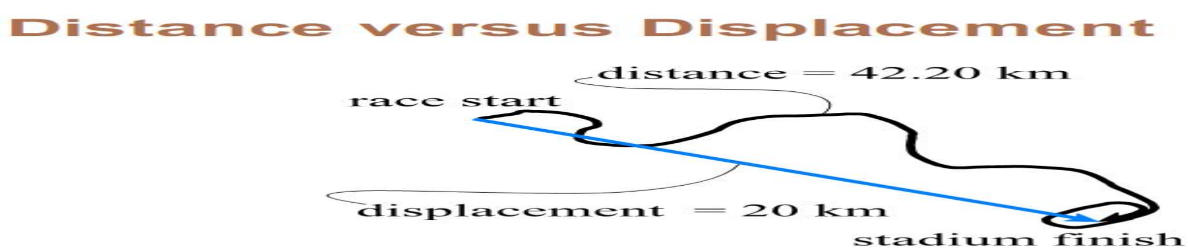
Average speed of 11.2 mph = 5.0 m/s

In the above example we can see that the athlete covered a distance of 14 miles but we do not know whether this was in a straight line, in a series of curves, or indeed in a circle starting and finishing at the same point.In this context the term speed is used because there is no directional component specified. However, if we now re-word this example it is possible to express the solution as a vector quantity such as velocity.

Vector quantities are expressed with reference to both magnitude and direction and in the case of the runner can be restated as follows.

Ex 2if an athlete covered a displacement of 20 km to finish a marathon race of 2 hours and 5 minutes, what would be the athlete's average velocity and speed over this time period?

$\vec{V} = \frac{\vec{D}}{t}$ Where V, implies velocity D, displacement and t, time taken



Often within biomechanics it is useful to be able to express both speed and velocity components. Sometimes it is only the average speed that is of interest (such as, for example, when an athlete runs a marathon race (26.2 miles or 26 miles 385 yards) and the coach is interested in getting a quick and simple measure of how the race was performed overall).As this average speed would be presented over a 26 mile running distance it does not really describe the specific details of the race but it may be useful for training.

Similarly, during the long jump take-off phase it is interesting to be able to know exactly what the vertical and horizontal velocities are at the point of take-off. Such information would allow the coach or scientist to be able to work out the angle of take-off and observe whether the athlete jumped with a ,long trajectory or a high, shorter one. Both these aspects (speed and velocity) are equally important for the under- standing of sport, exercise, and general human movement.

Linear velocity and acceleration are important quantities within biomechanics that are used to describe and analyze the motion of human bodies.

- **Uniformly accelerated and projectile motion**

Equations applied in uniformly accelerated motion

$V_f = V_i + at$ $\qquad$ $S = 1/2(V_i + V_f)t$

$S = V_f + 1/2at^2$ $\qquad$ $V_f^2 = V_i^2 + 2aS$

Where:

s_i = initial position
s_f = final position
v_i = initial velocity
v_f = final velocity
a = constant linear acceleration
t = duration from initial to final positions (i.e., Δt)

For displacement and velocity in the case of uniformly accelerated motion, acceleration is the rate of change of velocity with time.

$a = \frac{V_f - V_i}{t}$ so $at = V_f - V_i$

$V_f = V_i + at$

- **Projectile Motion**

Projectile motion concerns the flight of an object or body after it is free of support. (This includes objects that are dropped.)The flight path of a projectile is called the trajectory. Objects that are continuously being propelled (such as airplanes) aren't considered projectiles. Examples of Projectiles are Football, Javelin , Discus, Long jumper, Diver etc.

A human in flight obeys the same projectile laws as any other object. A human in flight obeys the same projectile laws as any other object.

Factors Affecting the Trajectory of a Projectile are:

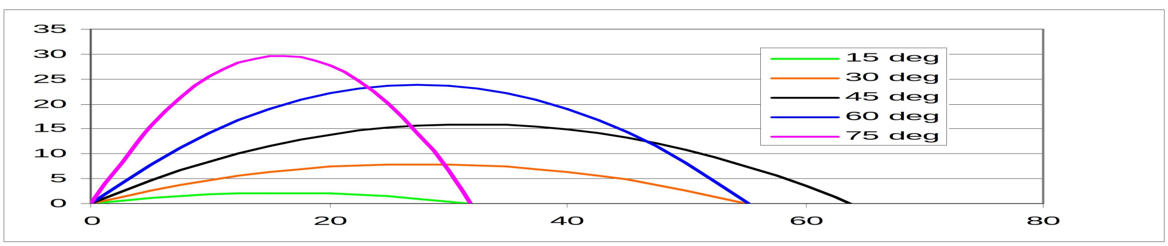
The relative height of projection

The angle of projection (the initial angle of the trajectory relative to horizontal)

The speed of projection (the velocity of the object when it is first released)

Air resistance and wind

Trajectory and range relation for different angle to the horizontal with 25m/s initial velocity



Relative Projection Height

This is the release height compared to the final landing height of the projectile

For example

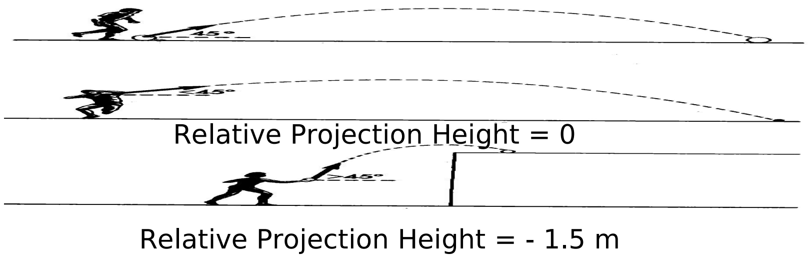
- √ Relative projection height = 0
- √ Relative projection height = 2 m
- √ Relative projection height = -1.5 m

Optimum Angle of Projection (assuming there is no air resistance)

If Relative Projection Height = 0, the optimum angle = 45^0

If Relative Projection Height > 0 , the optimum angle < 45^0

If Relative Projection Height < 0 , the optimum angle > 45^0



CHAPTER SIX

Temperature, Heat and Thermodynamics

Concepts of heat and Temperature

- **Temperature**

Temperature is degree of hotness or coldness or the speed of movement of atoms in a molecule and/or substance. It is also a measure of how warm or cold an objects with respect to some standard. Temperature is related to the random thermal motion of the molecules in a substance.

Temperature is measured by using thermometer and expressed in degree celicius, Farhanait or kelvin

- **Heat**

Heat can be defined as the transfer of energy or the energy transferred between objects due to a temperature difference. It is measured in calorie. one calorie can be defined as the amount of energy transfer required to raise the temperature of 1ml of water by 1^{o}c.

- **Temperature scale**

Kelvin which is one of the seven standard units, is used to measure temperature. It’s conversion to other measurements is described as follows.

0 Kelvin= -273.15 celicius

= -459.67 fahrenheit

- **Thermal expansion**

Thermal expansion is the increase in the size of the material due to the rise of temperature. The bonding force of different materials is different. The solidity or fluidity of a material affects it's thermal expansion. As temperature increases, molecules jiggle faster and move farther apart. Thermal expansion depends of the strength of the bonding force of atoms in a substance.

- In the human body which organ is more responsive to thermal expansion and which one is not?

- **Thermodynamics**

  Thermodynamics is the study of the effects of work heat and energy on a system.

  It relates heat and temperature with energy and work

  The study of energy

- **First law of thermodynamics**

  Energy can be changed from one form to another, but it cannot be created or destroyed.

  The total amount of energy and matter in the Universe remains constant, merely changing from one form to another.

  In this law energy conversion from one form to the other is possible, whereas new energy can't be produced.

- **Second law of thermodynamics**

  In all energy exchanges, if no energy enters or leaves the system, the potential energy of the state will always be less than that of the initial state.

  Entropy is the quantitative measure of disorder in a system. The concept comes out of thermodynamics, which deals with the transfer of heat energy within a system.

Each time a system goes through a thermodynamic process, the system can never completely return to precisely the same state it was in before.

CHAPTERSEVEN

FLUID MECHANICS

Fluid mechanics is concerned with the forces in fluids (liquid sand gasses). A *bio mechanist* would use fluid mechanics to study heart valves, swimming, or adapting sports equipment to minimize air resistance.

Fluid Mechanics deals with the study of all fluids under static and dynamic situations. Fluid mechanics is a branch of continuous mechanics which deals with a relationship between forces, motions, and statical conditions in a continuous material. This study area deals with many and diversified problems such as surface tension, fluid statics, flow in enclose bodies, or flow round bodies (solid or otherwise), flow stability, etc. In fact, almost any action a person is doing involves some kind of a fluid mechanics problem.

The boundary between the solid mechanics and fluid mechanics is some kind of gray shed and not a sharp distinction. The liquid will change its shape to conform to that of the container and will take on the same boundaries as the container up to the maximum depth of the liquid.

Fluid mechanics is the behavior of fluids at rest and in motion. Air Resistance is a major concern in outdoor sports. It has been described in chapter 5 of this course that projectile motions highly affected by the resistance from air. So, it should be highly considered during training and exercise. All in all, as a coach you should work to create adaptation of different environments by your athletes. On the other side, the other fluid, namely, water has a great relationship with the sport.

Swimming sport is totally performed in immersion into water. So, the pressure, the temperature and the density level of the water highly affects the performance of a swimmer. Creating adaptation to adverse conditions while maintain homeostasis is mandatory if we are working to improve the performance of our swimmers.

Fluid Mechanics is the study of forces that develop when an object moves through a fluid medium (water and air).

- ## Fluid forces

In some cases, fluid forces have little effect on an object's motion (e.g., shot put). In other cases, fluid forces are significant (e.g., badminton, baseball, swimming, cycling, etc.). There are three major fluid forces:

1. **Buoyancy**

The vertical, supporting force of fluid is called buoyancy. When an inanimate object is put in a fluid (like water), the vector sum of gravity and the buoyant force determines whether or not the object will float. The **Archimedes Principle** states that the size of the buoyant force is equal to the weight of the fluid displaced by the object.

2. **Drag**

The fluid force resisting motion between an object and a fluid is called **drag**. Or in other words it is a resistive force acting on a body moving through a fluid (air or water). There are two types:

Surface drag: depends mainly on smoothness of surface of the object moving through the fluid.

Form drag: depends mainly on the cross-sectional area of the body presented to the fluid

3. **Lift**

Represents a net force that acts perpendicular to the direction of the relative

Motion of the fluid; Created by different pressures on opposite sides of an object due to fluid flow past the object.

CHAPTER Eight
Biomechanical analysis of sport technique

Biomechanics provides a rationale critical for evaluating technique and prescribing intervention to help young people improve. Biomechanics also allows physical educators to identify exercises and physical activities that contribute to the physical development of various muscle groups and fitness components.

There are seven Principles of Biomechanical Analysis

- **STABILITY**

Principle 1: The lower the center of mass, the larger the bases of support, the closer the center of mass to the base of support and the greater the mass, the more stability increases.

- **MAXIMUM EFFORT**

Principle 2: The production of maximum force requires the use of all possible joint movements that contribute to the task's objective.

- **MAXIMUM VELOCITY**

Principle 3 : The production of maximum velocity requires the use of joints in order from largest to smallest.

- **LINEAR MOTION**

Principle 4: The greater the applied impulse, the greater the increase in velocity.

- **LINEAR MOTION**

Principle 5: Movement usually occurs in the direction opposite that of the applied force.

- **ANGULAR MOTION**

Principle 6: Angular motion is produced by the application of a force acting at some distance from an axis, that is, by torque. The principle is also known as the principle of the production of angular motion

- **ANGULAR MOMENTUM**

Principle 7: Angular momentum is constant when an athlete or object is free in the air. This principle is also known as the principle of conservation of angular momentum, and its key component is the fact that, once an athlete is airborne, he or she will travel with constant angular momentum.