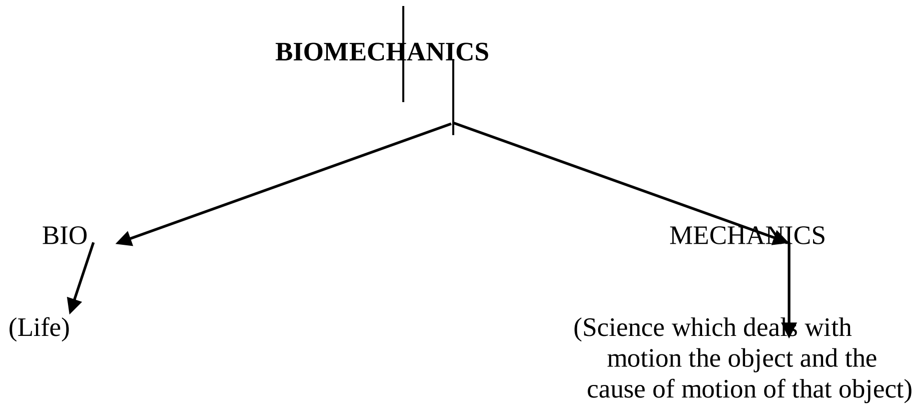
Biomechanics and its relation to other Sciences

By: Abu Tareq



DEFINATION:

Sports biomechanics is one of the important branches of sports science.

Biomechanics is the study of forces (Internal & External) and their effect on living system (human & animals).
Biomechanics investigates the movements of the living beings (Men & Animals) from the aspects of laws of mechanics.
Or
Biomechanics is the science, which deals with the application of mechanical laws to the living structures specifically to the loco motor system of the human body

Sports Biomechanics:

Sports Biomechanics is the Science, which deals with the application of laws of mechanics to study the human motion during sports activities & in sports environment.

Biomechanics is multidisciplinary field knowledge from a variety of fields including human anatomy & physiology, mechanics & mathematics is utilized in biomechanics.

Sports basically goal oriented movement activities. Sports Biomechanics is the science of sports movement. Laws and principles of mechanics regulate all the physical movements during sports participation. Sports biomechanics deals what & how of sports movement and help to achieve goal. Thus the fundamental purposes of Sports Science to know the nature of sports performance and to improve the sports performance depend on Sports Biomechanics. Sports Biomechanics helps to sportspersons, sports trainer, sports official and even the sports organizer to be more efficient in their respective job. The function of Sports Biomechanics in game and sports can be summarized in the different heading.

1.Improvement of sports techniques
2.Improvement of sports training.

3.Improvement of sports equipment and facilities.
4.Devlopment of methods of analysis of sports movement.
5.Prevention of sports injuries (Technique & Equipment)

Biomechanics teaches us about maintaining equilibrium, explaining the causes of linear and angular motion. It covers the details of fluid (air and water) mechanics and the effect of water and air in regard to relative motion.

There are many more examples when talented athletes had to leave the sport prematurely due to poor performance or sport injury, which could have been easily improved or avoided with the guidance of biomechanics expert.

Relation of SBM with other sciences

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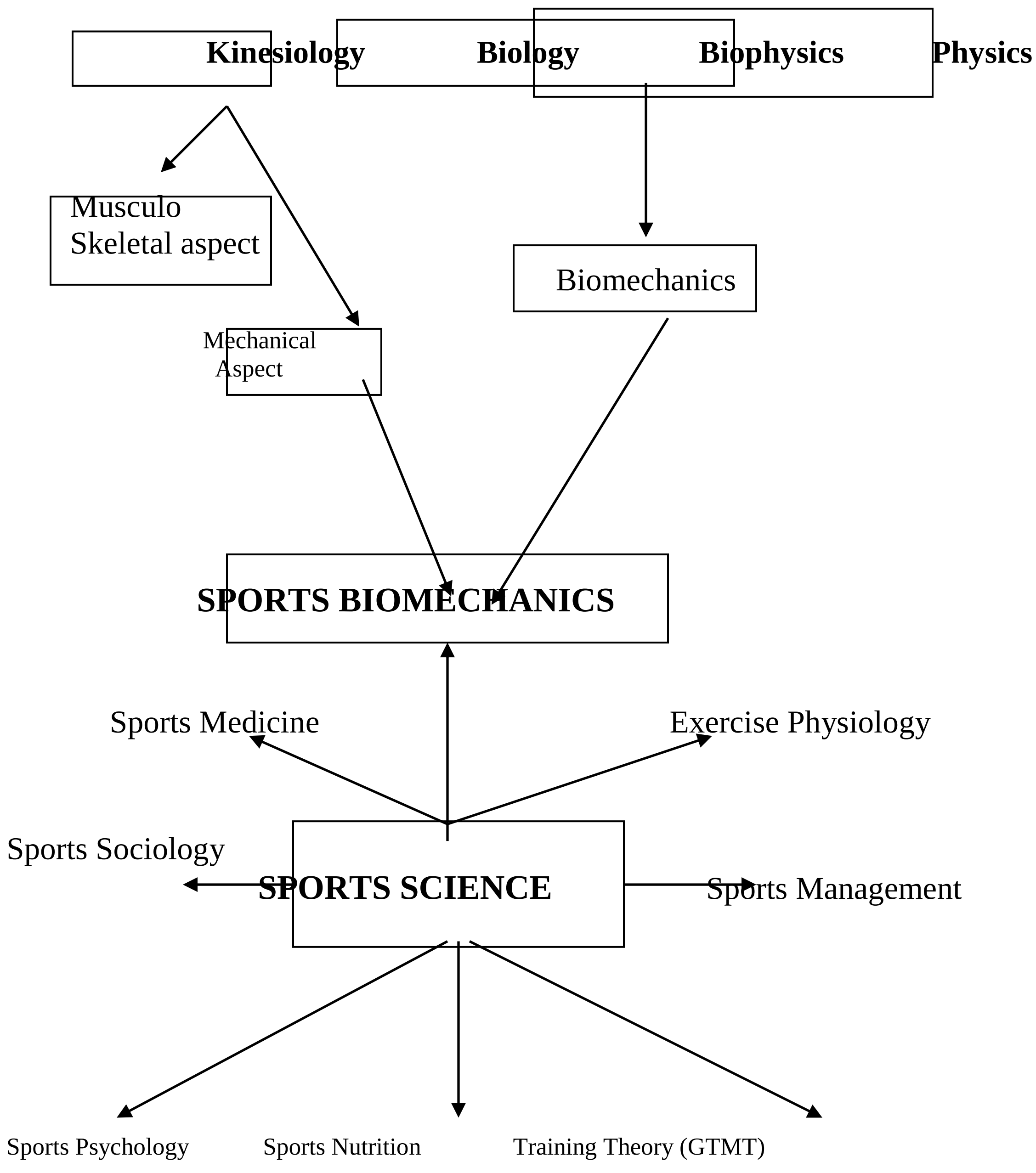
Sports biomechanics is not an independent area of study. Rather it has in inter disciplinary link with many other scientific fields. This relationship is shown in the figure below.



IMPORTANCE OF SPORTS BIOMECHANICS

By: Abu Tareq

1. **It gives sound base of knowledge to the physical education teachers and Coaches to impart teaching training and coaching.**
2. **It helps the coaches and physical education teachers to find out the technical and general execution errors during teaching and training of sports skills of different sports disciplines.**
3. **Sports Biomechanics helps in evaluation the sports performances form biomechanical points of view. (Kinematics and kinetic)**
4. **It helps to analyze the sports movements qualitatively and quantitatively.**
   (Videography, Cinematography and Dynamography etc.)
5. **It helps in measuring various motor abilities.**
   (Maximum strength, speed & endurance etc.)
6. **It helps in developing new and appropriate sports techniques (Improving old sports techniques and Developing new sports techniques)**
7. **Knowledge of Sports Biomechanics helps in developing new sports implements, equipments & exercises. (Equip. Shoe, ware guards and gloves etc,)**
8. **It helps in developing safety majors to the sports men/women.**
   (Some injuries fall catching, throwing, jumping, landing etc.)
9. **It helps in generalizing the Biomechanical principles, which are used in different situations of different games and sports.**

Generalized facts –Based principles (Natural-Mechanical and Biological)

1.Biomechanical principle for initial force.
2.Biomechanical principle for optimum path of acceleration.
3.Biomechanical principle for optimum tendency of course of acceleration.
(Ascending and Descending)
4.Biomechanical principle of conservation of angular momentum.
5.Biomechanical principle of reaction.

1, 2 & 3 are Mechanical
4 & 5 are Biological &mechanical

IMPORTANCE OF BIOMECHANICS

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Bio-mechanics helps in improving sports performance in the following ways:

1. Help for coaches and players

Main task of coaching is to identify faults of the players in technique. Most of times coach finds difficulties to locate faults with necked eyes. In bio-mechanics the movement of the players is recorded by high speed movie camera/video camera. Later on the recorded movements are shown to the coaches and players in slow motion or in freeze frame condition. This helps to locate faults of the players in technique. By using appropriate soft ware, for digitization it is possible to measure the movement parameters (speed, velocity, acceleration, angle, position of CG correctly. Comparing these parameters with those of successful performers of national and international levels, the coaches can be helped to understand where there are possibilities of improvement for a particular athlete and accordingly the training programme can be planned.

2. Force measurement

Force is the main factor for any kind of sports movement. Measurement of force can be done in bio-mechanics with the help of force platform and force transducers. These equipments measure force applied by a player during the movement.

3. Modification of technique

Bio-mechanics can help the coach in modifying the standard technique of a sportspersons keeping in mind the strong and week points. The technique of a player can be modified keeping in mind his special characteristics.

4. Prevention of injuries

5. Fabrication of equipment

Analysis of Movements

By:Abu Tareq

All coaches are concerned, at one time or the other, with movement analysis and some of the more practical applications of bio-mechanics. Occasionally the focus is on observing a good performance so as to determine what makes it good. More often, the coaches concern is with poor execution and the means by which faults may be corrected. The results of analysis may be utilized in planning execution of skills in a manner so that superior performances can be created.

Types of Analysis

1. Kinesiological Analysis

A kinesiological analysis seeks to identify the joints, muscles and bone levers used in a skill as well as the sequence and degree of their involvement. This kind of information might come from published electromyographic studies that have been done on the skills. To do this analysis efficiently the coach should be well familiar with the knowledge of kinesiology. With the help of this analysis the coach can suggest exercises for the development of muscles related to a particular sport. This is also useful to improve sportspersons joint flexibility.

2. Mechanical Analysis

Mechanical analysis helps coaches to know sports more fully, can make them more confident about their practices and can extend their knowledge beyond the techniques involved in the sports to the underlying scientific reasons for doing a particular movement in a given way.

It helps in analyzing sports skills with the help of laws of physics particularly those pertaining to the principles of mechanics. Where the performance conforms to the principles of mechanics, optimum results are obtained i. e. one can jump higher, kick football farther, run or swim faster with less exertion, throw a ball or an implement farther, catch an object with greater ease, should with greater accuracy and so on.

Mechanical analysis helps to familiarize one with the mechanical principles involved in a particular technique, to analyze the basic action involved in specific technique and to determine the basic principles to be applied and how they should be applied in order to obtain optimum results.

3. Bio-mechanical Analysis

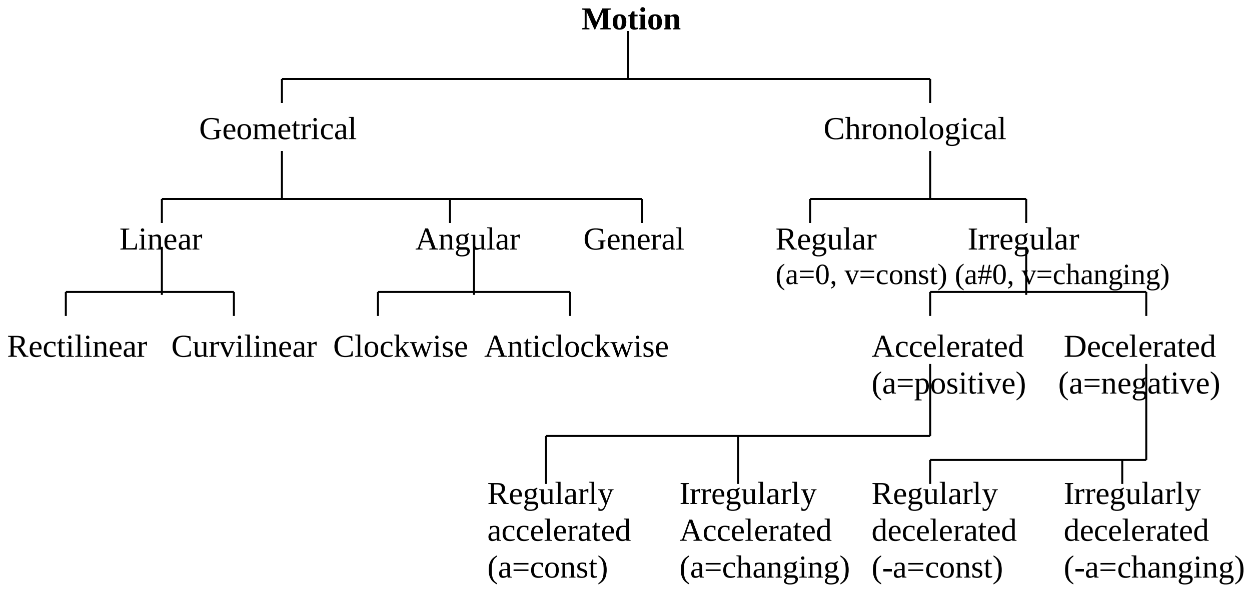
This analysis provides the only sound and logical basis upon which to evaluate the sports techniques that might be used in a given case and to connect observed effects with their underlying causes. This knowledge equips coaches to make sound judgments concerning methods of instruction, length of frequency and nature of practice so as to choose appropriate techniques and to detect the root causes of faults that may arise in their use.

Motion and its Classification

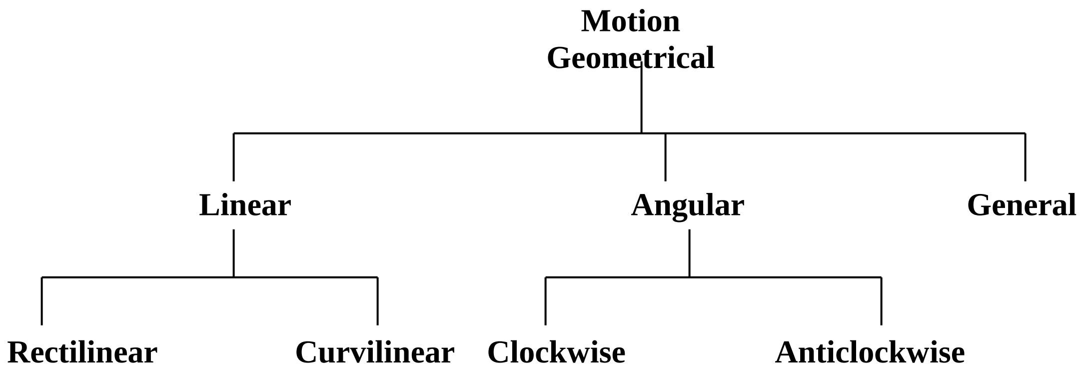
Rest and Motion-Rest and motion are the state of two fundamental positions of a body which indicate whether the body changes its position or remains in the same position with respect of time and environment. The concept of motion is just opposite to that of rest. A body will be said to be at rest when it does not change its position with respect to time. Motion is a state which indicates that the body is changing its position with respect to time and environment.

Types of motion-There is a large variety of motion even in the field of games and sports. They are classified sometimes on the basis of their geometry of covered path and sometimes on the basis of their chronology of motion. Accordingly, we differentiate geometrical classification of motion and chronological classification of motion.

Classification of Motion-Geometrically and Chronologically



Geometrical Classification of Motion



Linear Motion-Different parts of the body changes its position in same direction in same time through same distance. Example-Motion of Cg during walking. Running etc.

Rectilinear Motion-Linear motion in a straight line path. Example-motion of a body during free fall

Curvilinear motion-Linear motion in a curve path. Example-Motion of a body during air bone position.

Angular motion-Different parts of the body changes its position in same direction in same time through same angle. Example-Motion of the limbs of human body, Giant circle movement.

Clockwise angular motion-In angular motion when a body moves in clockwise direction. Example-When a gymnast swinging his leg in clockwise direction (negative angular motion)

Anticlockwise angular motion-In angular motion when a body moves in anticlockwise direction. Example-When a gymnast swinging his leg in anticlockwise direction (positive angular motion).

General Motion-It is the combined from of linear and angular motion of a human body during walking, running, cycling etc.

Muscles

By: Abu Tareq

Muscles provide the required force for movement of human body parts. They are attached to the bones across the joints. So with their contraction they help the part to move.

Types of Muscles: There are three types of muscles-

(i) Skeletal muscles
(ii) Smooth muscles
(i) Cardiac muscles.
(ii)

Among them the skeletal muscle are voluntary muscles. In addition, they are constructed of bundles of striated muscles, which differ in both structure and function from the highly specialized cardiac muscles & from the smooth muscles at blood vessels digestive organ & uragential organs.

Muscles Attachments:
One end of the skeletal muscle is usually attached to a relatively fixed part and the other end is connected to a movable part. The immovable end is called origin of the movable is called 'insertion'. When muscle contract, its insertion in pulled towards the origin.

Line of Pull:
The line joining the origin with insertion by a straight line provides the line at pull. The movement of the segment is determined by the nature of joint as well as by the line of pull.

Roles of Muscles:

Different muscles have different roles during the movement of a body part. According to the role played, the muscles are designated as Mover or Agonists, Antagonists & Synergists, A mover is a muscles that is directly responsible for the movement. They are may be prime moves and Instant moves. Antagonists are the muscles that have an effect opposite to that at the moves. They are located on the opposite of the joint from the mover. Synergists co-operate the muscle functioning as stabilizers or neutralizers. Stabilizers contract statistically support some part of the body against the pull of the contracting muscles, gravity or against the effect of momentum leg. Trunk must be supported against the grisly while hand or foot or head move. Neutralizes are muscles that act to present an undersize action of one of the movers trapezius alone adducts scapula and rotates it upward. Rhomboid alone adducts scapula and rotates it downward. (Together trapezius and rhomboid adduct the scapula withthout moving up or downward).

Group Action of Muscles:

Skeletal muscle almost always function in a group rather than singly. During this group action the different muscles play their role in a coordinated manes. When the agonists contract antagonists relax and allow the agonists to contract. As a results of this smooth movement become possible.

Nature of Muscles Contraction:

Muscle contraction may be of different types of muscles.

1. Static or isometric contraction
2. Dynamic contraction
   (i) Concentric (2) Eccentric (3) Isotonic (4) Isokinetic

Liner Kinematics

By. Abu Tareq

What is Kinematics?

Kinematics is a branch of dynamics and it deals with the description of motion. The parameters which are used for this purpose are known as kinematics parameters. Linear Kinematics is the study of description of linear motion. The linear kinematics parameters are: (i) duration of motion, (ii) distance covered (iii) displacement (iv) speed of motion (v) velocity and (vi) acceleration.

Duration of motion: This parameter describes how long the motion continues. It is generally known as the time of motion and is denoted by ‘t’ it is measured in second, minute or hour unit.

Distance: It is the length of path covered by a body during its motion. It is denoted by ‘1’ is expressed in meter unit. It entirely depends on the path of motion and is a scalar quantity.

Displacement: It is the change of position or perpendicular distance between initial and final positions of the body due to motion. It is denoted by ‘d’ it depends on the initial and final positions and not on the path of motion. It is measured in meter unit and is a vector quantity.

Speed: Speed is the rate of distance covered or distance covered per unit time. It is expressed as: speed=distance/time. It is denoted by ‘s’ and expressed in meter/second unit. It is a scalar quantity.

Velocity: Velocity is rate of change of position or rate of displacement or displacement covered per unit time. It is expressed as: velocity=displacement/time. It is denoted by ‘v’ and is also expressed in meter/second unit. It is a vector quantity.

Acceleration: Acceleration is the rate of change of velocity, it is expressed as: Acceleration= (final velocity-initial velocity)/time. It is expressed as ‘a’ or ‘f’. It is measured in meter/second unit. It is a vector quantity.

Relation among kinematics parameters: Kinematics parameters possess very specific relations among themselves. These relations are very useful finding out one of them with the knowledge of others; these relations are termed as equation of motion.

They are as follows:

(a) Equations for regular motion (Acceleration=0, velocity=constant)

Distance=speed x time/displacement =velocity x time, or speed = distance/time //velocity=displacement/time or time=distance/speed ‘time=displacement/velocity.

(b) Equations for irregular motion (acceleration # 0, velocity =changing):

Final velocity = initial velocity $\pm$ acceleration x time $v = u \pm at$
Total distance = initial velocity x time $\pm$ ½ acceleration x time^2: $s=ut \pm \frac{1}{2} a \times t^2$

Final velocity ^{2} = initial velocity^2 $\pm$ acceleration x total distance: $v^2 = u^2 \pm 2a \times s$

Relation between Linear & Angular Velocities & its Implication in Game and Sports

By. Abu Tareq

When a body processes both linear (curvilinear) & angular motion simultaneously, there exists a definite relationship between its linear motion parameters and angular motion parameters.This relation can be expressed in general as follows: Linear motion parameter=radius x angular motion parameter --- (1). This relationship can be represented for different parameters as following for displacement d = **θ** x r (2) where is expressed in radian unit.ωσ

Or $\theta = d/r$ (3)

Or $r = d/\theta$ (4)

For velocity,

$N = \omega \times r$ (5)

Or $\omega = v/r$ (6)

Or $r = v/\omega$ (7)

For acceleration

$A = \sigma \times r$ (8)

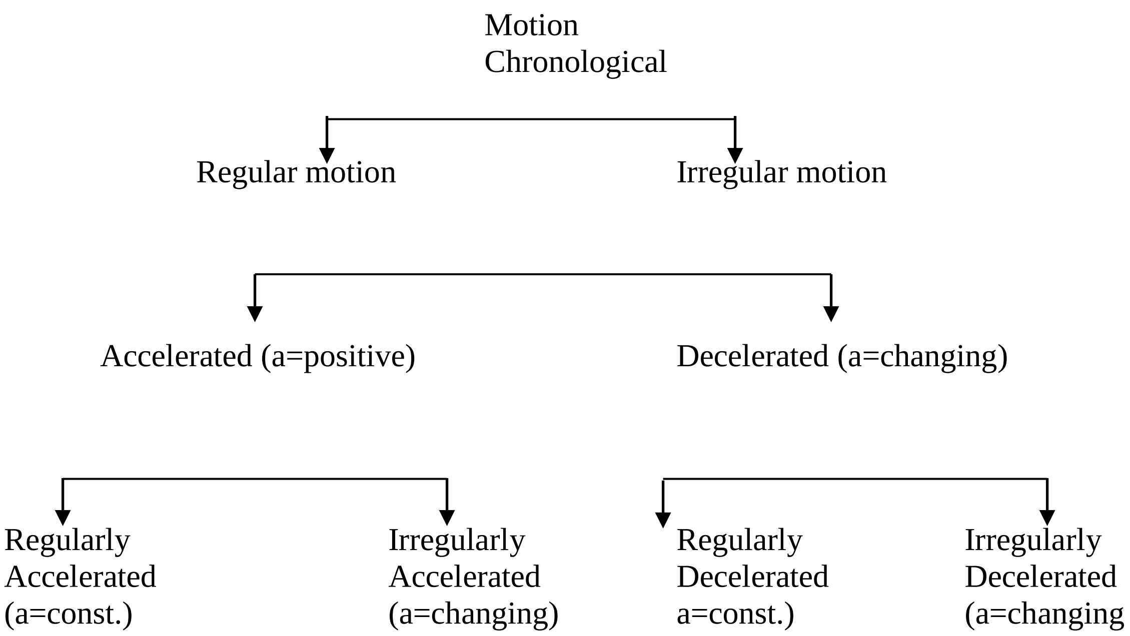
Or $\sigma = a/r$ (9)

Or $r = a/\sigma$ (10)

Implications at this relationship in sports: There relation have great implications in game and sports. They suggest important dues for correct execution of many techniques. They specially help to understand where & how the radius of rotation should be (i) increased (ii) decreased & (iii) alternately decreased & increased for better results during rotational motion. For example, let us consider the eases of equation nos. (5 & 6). From equation nos 5 it is seen that the linear velocity of the body depends on both the angular velocity & radius of rotation. So for increasing the linear velocity both of the qualities should be increased. In this connections it should be kept in mind that among the two, the angular velocity needs to be increased at first and at the end the radius of rotation should be increased. Kicking a soccer ball, something a volley ball, badminton in the examples of these types of execution.

Again from equation nos 6 it is seen that the angular velocity depends directly upon linear velocity & depends directly upon linear velocity & indirectly upon the radius of rotation. There fore when the aim of execution is to increase the angular velocity at the end, the linear velocity should be increased and the radius of rotation should be decreased. This principle is followed during somersault in gymnastics and diving. For increasing angular velocity the radius of rotation is decreased for arm & leg movement during fast running.

Chronological Classification of motion



In chronological classification, we categorize motion into different types on the basis of chronology of motion. This classification of motion is shown bellows.

Regular Motion-When a body moves with constant velocity (50 to 70m in 100m race).

Irregular motion-When a body moves with changing velocity. There may be two situations. Acceleration may be positive or negative (100m race).

Accelerated motion-When a body moves with positive acceleration there may be two situations acceleration may be constant or changing (first 30m to 60m in 100m race)

Regularly accelerated-When body moves with constant acceleration (downward motion of a body from free fall).

Irregularly accelerated-When the body moves with changing acceleration (acceleration part of a sprinter in 100m race). 30 to 60m in 100m race.

Decelerated motion-When body moves with negative acceleration or deceleration or retardation. There may be two different situations-deceleration may be constant or changing (motion of a runner after maximum speed phase in a 100m race). Finishing part of 100m race.

Regularly decelerated-The body moves with constant deceleration (upward motion of a body against gravity).

Irregularly decelerated-The body moves with changing deceleration (finishing part of a 100m race).

Kinematic parameter-The parameter which are related to the motion. That means (i) time (ii) distance (iii) displacement (iv) speed (v) velocity (vi) acceleration.

FUNDAMENTAL MOVEMENTS

The basic movements possible at difference joints of human body are technically known s fundamental movements.

Flexion:

Bending part at a joint so that the angle between them is decreased and the part come closer together. Flexion takes place around transverse axis in a sagittal plane.

Extension:

Straightening parts at a joint so that the angle between them is increased and the parts move further apart. Extension takes place around transverse axis in a sagittal plane.

Hyperextension:

Excessive extension of the parts at a joint beyond the anatomical position. Hyperextension takes place around transverse axis in a sagittal plane.

Dorsi-flexion:

Flexing the foot at the ankle. Dorsi flexion takes place around transverse axis in a sagittal plane.

Planter flexion:

Extending the foot at the ankle. Planter flexion takes place around transverse axis in a sagittal plane.

Abduction:

Moving a part away from the midline. Abduction takes place around sagittal axis in a frontal plane.

Adduction:

Moving a part towards the midline. Adduction takes place around sagittal axis in a frontal plane.

Rotation:

Moving a part around a longitudinal axis. Rotation takes place around longitudinal axis in a transverse plane.

Circumduction:

Moving a part so that its ends follow a circular path. Circumduction is a combination of movement.

Supination:

Turning the hand so the palm is upward or turning the foot so that the medial margin is raised. Supination takes place around longitudinal axis in a transverse plane.

Pronation:

Turning the hand so that the plam is downward or turning the foot so that the medial line is lowered. Pronation takes place around longitudinal axis in a transverse plane.

Eversion:

Turning the foot so that the sole is outward. Eversion takes place around the longitudinal axis in a transverse plane.

Inversion:

Turning the foot so that the sole is inward. Inversion takes place around the longitudinal axis in a transverse plane.

Protraction:

Moving a part forward.

Retraction:

Moving a part backward.

Elevation:

Raising a part (shrugging the shoulders)

Depression:

Lowering a part (dropping the shoulders)

CLASSIFICATION OF BONES

Bones may be classified in a number of different ways.

- **Long-e. g. Femur, Tibia, Ulna**
- **Short-e. g. Tarsals, Carpals**
- **Flat-e. g. Scapula, Ribs, Hip Bone**
- **Irregular-e. g. Vertebrae**

CLASSIFICATION OF MUSCLES

Muscles may be classified in a number of different ways. They may be divided according to:

- **Shape**
- **Location**
- **Action**
- **Role**
- **Number**

Shape

Classification is based on the shape and appearance of the muscle, e. g. deltoid, rhomboid.

Location

Classification is made according to the location of the muscle, e. g. Rectus Abdominis

Action

Muscles performing similar actions may be grouped together, e. g. flexors, rotators.

Role

Muscles may be classified according to the role that they perform, e. g. agonist, synergist.

Number

Muscles may be classified according to their number, e.g. Quadriceps

ROLE OF MUSCLES

Muscles act to produce a given movement, often working together. Depending on the movement required, a muscle would act in a certain role. The roles of muscles are:

- **agonist / prime mover**
- **antagonist**
- **fixator/stabilizer**
- **synergist.**

Agonist / prime mover

An agonist is the main muscle responsible for carrying out a given movement at a joint, e. g. quadriceps acting as a prime mover while putting the shot.

Antagonist

An antagonist produce the opposite effect to the agonist, or prime mover, relaxing reciprocally during the contraction of the prime mover, e. g. hamstrings are the antagonist in the above example.

Fixator / stabilizer

The muscle works to position a bone to provide a base from which the prime mover can act. They act to provide a fixed attachment for another muscle, e. g. when deltoid abducts the upper arm, the muscles of the shoulder girdle contract to stabilize the shoulder to allow deltoid to act from a fixed base.

Synergist

The muscle acts in conjunction with another, to produce a movement neither could produce on its own (conjoint synergist). They may act as a helping synergist, e. g. in flexion of the wrist the

agonists will be flexor carpi radialis and ulnaris, but may be assisted by the flexors of the fingers acting as synergists.

Classification of Muscles

Slow Twitch (Red)-Slow twitch units are involved in relatively low tension, slow moving and enduring exercises.

Fast Twitch (White)-Fast twitch units are more involved in fast, powerful, and relatively short term types of activities.

JOINTS

A joint connects one component of a structure with one or more other components. The exact design of a joint will vary with its primary function, so that a joint that has a primary role of providing stability will be of a different design to one whose primary function is mobility. They may be broadly categorized as synovial joints (diarthroses) and non-synovial joints (synarthroses). Within each of these categories there will be further sub-classifications.

Synovial joints (diarthroses)

In a synovial joint the bones are linked together by a fibrous capsule, together with accessory ligaments, which may be inside or outside of this, so that the bone surfaces are in contact with each other but not in continuity (Williams and Warwick, 1980) (Figure2.2). All synovial joints share certain characteristic features:

- **joint capsule of fibrous tissue**
- **joint surfaces covered by articular cartilage**
- **capsule lined with a synovial membrane**
- **joint surfaces bathed in synovial fluid.**

Synovial joints may further be divided based on shape into seven different varieties.

<u>Hinge joint</u>

These are uniaxal, allowing movement in one plane only. Examples include the inter-phalangeal joints which allow movement (flexion and extension) in the sagittal plane.

<u>Pivot joint</u>

These are uniaxial, comprising one component which acts as a central bony pivot and one that forms an osteoligamentous ring. Movement is restricted to a rotation around a longitudinal axis through the centre of the pivot.

<u>Bicondylar joint</u>

The principal movement occurs in one plane, but a small amount of rotation can occur about a second axis perpendicular to the first. e. g. the knee joint.

<u>Saddle joint</u>

These are biaxial, in which opposing surfaces are concavoconvex, i..e they are convex in one plane and concace in the other. Examples include joint of the thumb, which allows extension and abduction/adduction.

<u>Ellipsoid (condyloid) joint</u>

These are biaxial and have joint surfaces shaped so that the concave surface of one bony component slides over the convex surface of the other component in two directions. Examples include the metacarpo-phalangeal joints.

<u>Plane joint</u>

These are multiaxial, formed by the apposition of fairly flat articular surfaces, producing gliding movements between the bones. Examples include the carpal bones.

<u>Ball and Socket joint</u>

A ball-like convex surface articulates with a concave socket, allowing movement in all three planes. For example, the hip joint.

Non-synovial joint (synarthroses)

In these the bony components are connected by connective tissue

Cartilaginous

a) **Symphyses (e. g. symphysis pubis)**
b) **Synchondroses – These are usually temporary cartilaginous joints where the bony components are joined by cartilage in the immature skeleton.**

Fibrous

Fibrous tissue joins the two bones.

a) **Suture joint (e. g. skull)**
b) **Gomphosis (Peg and socket joint. g. teeth in the mandible)**
c) **Syndesmosis (e. g. shafts of the tibia and fibula are bound together by a membrane)**

HUMAN MOTION

Motion is the prime element in all spots. They either involve motion or resistance against effort to move. Motion consists of movement of the body as a whole, movement of the some part of the body or movement of some object or implement by the body. This motion is a function of direction and speed. It may be in a horizontal direction, a vertical direction, at angle with the horizontal or vertical or it may consist of circular motion about some joint as a centre of rotation. Speed is indicated by the terms velocity and acceleration.

Linear Motion

It takes place when a body (may be inanimate i. e. sports equipment or animate- human body or part there of) moves so that all parts of it travel exactly the same distance in the direction in the same time. e. g. Tabogganing, 100m run (ignoring rotational movements of arms, legs and trunk.

Angular Motion (Rotation)

It takes place when a body moves along a circular path about some line in space so that all parts of the body travel through same angle, in the same direction, in the same time. This point of rotation (line may or may not pass through the body itself and is known as axis or rotation and lies at right angles to the plane of motion. Motion of body e. g. raising legs from lying position, swinging on horizontal bar.

Difference between Linear and Angular Motion

In angular motion, one part of the object-the axis-remains fixed (e. g. rotation of arm around the shoulder joint) but in linear motion every particle of the object travels the same distance simultaneously, moving from one location to another.

General Motion

It is a combination of linear and rotary motion. In sports angular motion is more common as compare to linear motion, and general motion is much more common as compare to both e. g. Cyclist-upper body moves linearly, leg performs rotary motion, wheel-its axis of rotation moves in a straight line but wheel rotates in rotary motion. In pole carry while performing pole vault, legs perform angular motion but pole moves linearly. In sports for better performance both linear and rotary motions are combined.

Uniform Motion

When equal distances are covered in equal times.

Non-Uniform Motion

When unequal distances are covered in equal times

LINEAR KINEMATICS

It is that branch of Bio-mechanics that is concerned with describing the motion of bodies. It deals with such things as, how far a body moves, how fast it moves, and how consistently it moves. It is not concerned with what causes the body to move (Kinetics).

Distance and Displacement

These two quantities are commonly used to describe the extent of a body's motion.

Distance

Distance traveled by a body when it moves from one place to another i. e. the distance through which it moves is simply the length of the path it follows.

Displacement

The displacement, the body undergoes in the course of the same motion is the length of the straight line joining the initial and final position and noting the direction that this line takes.

When a body moves in a straight-line i. e. as in 100m sprint, the distance and displacement have the same magnitude i. e. 100m run. Distance only has magnitude whereas displacement has both magnitude and direction. Thus a 100m runner running in northern direction covers a distance of 100m, but undergoes a displacement of 100m North.

When an athlete runs a distance of 400m on the track, the distance covered by the athlete is 400m however the displacement is 0m.

The distance of Marathon race is 42.195 km. In Boston Marathon the displacement of the runner is 38.6km. ENE. In 1976 Olympic Games the displacement of the runner was 0km. because the Marathon race was started from the track and also finished at the track.

SPEED AND VELOCITY

The rate at which a body moves from one location to another is usually described with reference to its speed or velocity-the two quantities, which people thinks are alike but they are different.

Speed

Distance covered per unit time

$$\text{Average speed} = \frac{\text{Distance covered}}{\text{Time taken.}}$$

$$\text{or} \quad s = \frac{l}{t}$$

where l is the length of distance covered and t is the time taken to cover that distance.

Speed has only magnitude and is therefore a scalar quantity.

Velocity

It is defined as displacement per unit time. It has both magnitude and direction and it is therefore a vector quantity.

It is also defined as rate of change of position in a given direction.

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Time}}$$

$$\text{or} \quad v = \frac{d}{t}$$

where d is displacement and t is the time taken

When a person runs 100m sprint, the magnitude of average speed and average velocity are equal. Whereas in running 400m, the average speed and velocity differ markedly. If the distance is run in 54 sec. **then:**

$$\text{Average speed} = \frac{400m}{54s} = 7.4m\ /s$$

$$\text{Average velocity} = \frac{0m}{54s} = 0m\ /s$$

Thus while breaking records, greater average speeds are required. The average velocities generally remain unaltered at 0m/s.

ACCELERATION

It is defined as the rate at which the velocity changes with respect to time.

$$\text{Average acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

$$= \frac{\text{Final Velocity} - \text{Initial Velocity}}{\text{Time taken}}$$

$$a = \frac{v_f - v_i}{t}$$

The velocity of a body often changes during the course of motion e. g. when a sprinter sprints 100m, it seems that he is running at an even pace but in reality, the velocity changes.

In acceleration the unit of time is stated twice, once as a unit to describe change in velocity and once as a unit to describe the length of time involved.

FORCE

Force is the cause of motion. It is the effort which one body exerts on another. Force and motion are closely associated. It is only through force that motion is created. There may be force without motion, but not motion without force.

A push (or pull) that alters or tends to alter the state of motion of a body is called force. If a body is at rest, a force exerted by another body will set it in motion or at least will tend to do so. Similarly if the body is moving in a straight line, a force exerted by another body will change or tend to change the velocity at which it is moving.

Force is a concept that cannot be seen, although its effect can be felt, e. g. by squeezing a rubber ball. It is an agent that tends to produce change in the state of rest or motion of an object (Enoka, 1988). Force can be designated as applied force (contact), inertial force (motion) and gravitational force (weight). In all cases force cannot exist on its own and there must be a balance to maintain a state of equilibrium. Brancazio (1984) categorizes force as either contact or non-contact force. Contact force are pushes and pulls exerted by one object in direct contact with another, e. g. friction, muscle forces and ground reaction forces. Non-contact forces refer to effects not due to direct contact, such as gravity and the attraction and repulsion of electrically charged particles.

Force is a vector, having both magnitude and direction. A force vector is a line drawn to scale of a certain length to represent the magnitude, at some inclination to represent the direction and in a particular position relative to the body to identify the point of application. An arrow head will provide the direction of the force (Le Veau, 1977).

Forces are vector quantities-they have both magnitude and direction and can be added or resolved using the parallelogram of vectors and are measured in Newtons (N).

In the analysis of human motions, it is customary to regard the human body as a system of bones, muscles and ligaments and the forces exerted by one on another as for example, when a muscle contracts and exerts force on the bones to which it is attached-an internal force. Conversely forces exerted on the body from outside the system-by gravity or contact with some other body are regarded as external forces. The major external forces, which influence sports performance are, ground friction, air and water resistance, gravity, buoyant force, elastic force etc.

Force can put a body at rest, in motion and it can stop the motion of a body or it can change the direction of motion of a moving body. It also can initiate change in shape and size of the body.

Factors of force

1. The direction of force
2. Point of application of the available force
3. Proper sequence in the application of generated forces
4. The resultant effect of the forces applied
5. The time of application of forces

These factors are more important than the mere presence of “brute force”

Effects of forces

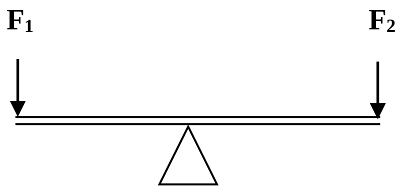
Forces will act together to produce an effect. The effects of forces can be used to analyse human movement by determining the net effect of several forces acting upon the body and the functional effect of that force, e. g. rotation or stabilization.

Linear Force System

When forces act along the same straight line of action they are said to be collinear in a linear system of forces. This is the simplest combination of forces. They may act in the same direction or opposite to each other.

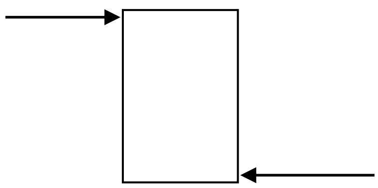
Parallel Force System

When the action lines of the forces under consideration are parallel to each other and lie in the same plane they form a parallel force system. The forces do not have the same line of action and tend to produce a rotatory effect if they are not in equilibrium.



Force couple

This is a specialized example of a parallel force system, which occurs when two forces of equal magnitude act at a distance from each other and in opposite directions. Under these circumstances they will produce a turning effect. As long as the two forces are equal and opposite there will be no linear displacement or acceleration and the resultant of the two forces will be zero, but the object still turns. In the human body, there is no true example of a force couple, but the body may act to form one, e. g. the force couple formed by the thumb and index finger in unscrewing a lid from a jar.



Parallel force systems in equilibrium

In many cases forces will be in parallel and lie in the same plane, but also be in equilibrium. This effect can be utilized therapeutically, especially in the application of orthotics. Most bracing works upon the principle of three-point pressure. The supporting forces of the orthosis are arranged so that two forces pressing against the trunk or limb are opposed be a third acting between them. The third force must be equal in magnitude to the two forces acting in the same direction. For example, in a Milwaukee brace to correct spinal mal-alignment, a three-point pressure system with forces acting in a parallel force system is seen.

Concurrent Force System

When forces action lines meet at a point they are said to operate in a concurrent force system. The forces may be applied from several different angles so that projections of their lines of action will cross. This intersection may occur inside or outside the body. For example, if one views the right hand side of the body, in standing, the line of gravity falls anterior to the ankle joint so that gravitational forces pull the body in a clockwise direction; forces produced by the tension of the posterior tibia muscles act in an anticlockwise direction to maintain an erect stance (Gowitzke and Milner, 1988).

Resultant of forces

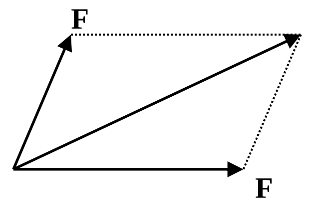
Where many forces are acting on an object, the resultant force, or the final effect will need to be calculated. The resultant is the single force obtained by combining all of the given forces. If all forces acting on the body produce a resultant force of zero, the body is in equilibrium.

Analysis of forces

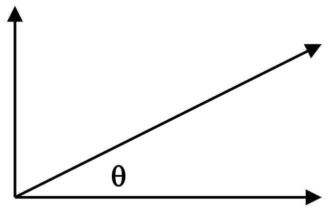
Force may be analysed to find the resultant effect of several forces (composition). Alternatively, the resultant may be analysed to find its component forces (resolution). The analysis may be done by graphic means or trigonometry.

Composition of forces-parallelogram method

The rule of parallelogram of forces states that if two forces act on a body at the same point from two different directions, the body will move in a direction which will be the diagonal of a parallelogram drawn form the point of application of the forces.



Resultant
Direction of movement



$$\cos\theta = \frac{\textbf{Adjacent}}{\textbf{Hypotenuse}} = \frac{H}{R} \quad \therefore \textbf{Horizontal force = resultant } \cos\theta$$

$$\sin\theta = \frac{\textbf{Opposite}}{\textbf{Hypotenuse}} = \frac{V}{R} \quad \therefore \textbf{Vertical force = resultant } \sin\theta$$

Units of Force

Newton (N) It is defined in terms of acceleration it produces. A force of 1N is the force that will produce acceleration of $1m / s^2$ in a body of 1kg mass.
or

A mass of 1kg is a mass that when acted upon by a force of 1N, will have an acceleration of $1m / s^2$

Sources of Force

Forces can be classified according to their effects and according to their sources. According to the effects, forces may be propulsive and resistive. The propulsive force causes motion while resistive force opposes motion. According to the source, forces may be internal and external. The internal forces are developed within the system while the external forces are applied from outside on the system. Considering human body as a system, the muscular force is internal and air resistance is external. For games and sports the external forces of the environment influence the performance to a great extent. Some of such forces are body weight (gravity), frictional force, centrifugal force, elastic force, air resistance, water resistance etc.

Vector property

Force is a vector quantity. For its complete expression it needs magnitude as well as direction. Three factors of a force must be accurately described in the study of human motion are magnitude, direction and the point of application. A straight line drawn from a dot on a sheet of paper can represent a force. The dot indicates the pint of application and the length of the line as the magnitude of force. The sign of an arrow is attached with the line indicate the direction of force. Change in any one of these three factors also changes the effect of force.

ANGULAR KINEMATICS

The basis concepts involved in angular kinematics (angular motion) are closely related to those encountered in the description of linear motion.

Angular distance and Angular displacement

Angular distance

The angular distance through which a rotating body moves is the angle between the initial and final positions measured following the path followed by the body. For example, a gymnast swings her legs forward through 120^0 and then backward through 150^0 so that she can move from sitting position to standing position on the beam, moves her legs through an angular distance of $(120^0+150^0)=270^0$

Angular displacement

The angular displacement through which a rotating body moves is equal in magnitude to the smaller of the two angles between the initial and final positions. The direction of angular displacement is usually indicated by the word clockwise or counterclockwise or even more commonly by the use of plus and minus signs. The counterclockwise is considered positive and clockwise direction negative. For example, a gymnast performing a forward giant circle on the horizontal bar:

Distance=350^0

Displacement=10 clockwise or -10^0

Angular speed and Angular velocity

Angular Speed

The average angular speed of a rotating body is found by dividing the angular distance through which it has moved by the time taken.

$$\text{Average angular speed} = \frac{\text{Angular distance}}{\text{Time taken}}$$

$$\sigma = \frac{\phi}{t}$$

When σ = average angular speed, ϕ = angular distance and t is time taken

$$\text{Average angular velocity} = \frac{\text{Angular displacement}}{\text{Time taken}}$$

$$\omega = \frac{\theta}{t}$$

Where ω is average angular velocity, θ is angular displacement and t is time taken.

In the above example if the girl takes 1.5 sec. to swing her legs forward (from initial position) and then backward (to the final position) the average angular speed is $(270^0/1.5) = 180^0$ /sand the angular velocity is $(-30^0/1.5) = -20^0/s$.

Angular Acceleration

The rate at which angular velocity of a body changes with respect to time

$\omega_f - \omega_i$ change of angular velocity

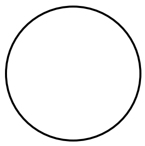
$$\alpha = \frac{\quad}{t} = \frac{\quad}{\text{time taken}}$$

Velocity and Angular Velocity

Cricket players, Volleyball players, boxers and many other sportspersons often seek to have some part of their bodies, or some piece of equipment they are having, moving of maximum possible velocity at the moment it makes contact with the second body. The velocity of the part that makes contact with the second body is in variably the result of either a simple angular motion or a complex general motion that involves a combination of several angular motions. Consider for example a volleyball player executing under arm service. In the case, the velocity of the ball will depend on the velocity of the player's hand at the time contact. The relationship between velocity v and the angular velocity ω is summarized in the equation v=ωr where r is the radius i. e. distance between the axis of rotation and the point of contact. This relationship suggests that there are only two ways in which the contact velocity or a rotating velocity can be increased-by increasing its angular velocity and / or by increasing the radius. If the player is having difficulty in crossing the ball over the net, he should concentrate on swinging his arm hard (maximize ω) and keeping arm straight (maximize r).

Units in Angular Kinematics.
Three units are commonly used

a) Revolution (rev) = one and half somersault body takes 1 ½ rev. about horizontal axis.
b) Degree = (1/360 rev)
c) Radian = 1 rad = 57.3^0



If PQ is equal to length of radius of circle then angle POQ formed by radius joining the ends of the arc to the centre of circle is equal to 1 rad.

LINEAR KINETICS

Kinetics is that branch of mechanics that a deal with what causes a body to move in the way that it does.

Inertia

When a body is lying at rest, it is reluctant to do any thing other than to remain at rest. A heavy barbell lying on the floor of a weight training room shows these reluctance by the resistance it provides when attempts are made to move it. A body in motion is similarly reluctant to change what it is doing, as any one who has thrust out a bare hand to stop a hard driven ball in cricket and testify. This characteristic of a body (its reluctance to change what ever it is doing) is known as its inertia (the tendency of a body to maintain its state). Inertia of a motionless body is called 'inertia of rest' and the inertia of a moving body is called 'inertia of motion'. Mass is the measure of inertia.

Mass

The quantity of matter of which a body is composed is called its mass and it is a direct measure of inertia that the body possesses. Thus a lighter barbell is easier to lift than a heavier one. Similarly it is easier to change the motion of an object which is lighter than it is to effect the same alteration in the motion of heavier object.

Force

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Factors of force

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These factors are more important than the mere presence of "brute force"

Momentum

Momentum is the quantity of motion of a body and is equal to the product of body's mass and velocity.

Momentum = mass x velocity

M = mv

m = 70kg v = 30m/s

M = 2100kg-m/s

90kg (mass) man runs 100m in 10. 0 sec.

M = 90 x 100/10 = 900kg m/s

Momentum of a body is of little importance in sports unless that body becomes involved in collision with another body. Then the result depends upon how much momentum each body had before collision. The greater the momentum of the body, more pronounced the effect that it produces on the other bodies in its path. Two bowlers bowling at same velocity-mass will make a difference. If mass is same, then velocity will make a difference.

Units of Linear Kinetics

Mass-kg.

Force-Newton (N) It is defined in terms of acceleration it produces. A force of 1N is the force that will produce acceleration of $1m / s^2$ in a body of 1kg mass.
or
A mass of 1kg is a mass that when acted upon by a force of 1N, will have an acceleration of $1m / s^2$

Momentum-kg -m / s   Mass in kg, distance in meters and time in sec.

Centrifugal and Centripetal forces and their influence on sports performance

Centrifugal force

It is that force which tends to cause a rotating body to fly off at a tangent to its circle of movement or away from the centre of rotation. It can be quantified using the following formula:

$Cf = Wv^2/ gr$ OR mv^2/r
where Cf =centrifugal force
W = weight of the body
v = velocity in m/s
r = radius of circle
g = force of gravity.

Centrifugal force is assumed to be the reaction force of centripetal force. From Newton's III law we know that action and reaction and reaction are equal in magnitude and opposite in direction. So centrifugal force of a rotating body is same as centripetal force and it is directed away from the center. The line of action for both the forces is same but the direction is opposite.

Centripetal force
It is a force, which tends to cause a rotating body to move towards the center of rotation. It is a center seeking force. This force develops only when a body moves in a circular path. Let us consider the example of an athlete spinning with a hammer. According to Newton's law motion the thrower must apply force to keep the hammer moving in a nearly circular path. He exerts force by pulling the hammer towards the center of rotation. This pulling force is the centripetal force. Since this force prevents the moving objects to fly away, its magnitude is equal to centrifugal force and therefore can be quantified using the same formula i. e. $Cf = Wv^2 / gr$ OR mv^2 / r).

In many games and sports situations centripetal and centrifugal forces influence the performance as external forces. In most of the cases the centrifugal force creates problem during rotational motion and the athlete requires a conscious adjustment in technique to overcome its ill effects. He counters this effect by applying equal amount of centripetal force. Moving on the curve in sprint running and cycling are the examples of such situations. The problem increases with the increase of speed and decrease of curve radius. The sportspersons leans inward to adjust the problem sometimes, the problem of centrifugal force is overcome by providing artificial banking. There are numerous situations, where the sportspersons manipulate the centrifugal force for increasing performance. Rotational movements in discus and hammer throw, curve running in Fosbury Flop and swing movements in gymnastics on parallel bars and horizontal bar are the examples of such situations.

Factors determining centrifugal and centripetal force: As seen form the equations, both these forces depend directly upon the mass and square of the velocity of the body and indirectly upon the radius of rotation.

Centrifugal and Centripetal forces depend upon
1. Directly upon mass
2. Directly upon square of the velocity of the body
3. Indirectly upon the radius of rotation
4. Directly upon the square of angular velocity

In view of the above:
- a) A 16 lb hammer is pulled in with twice the force of a 8lb hammer
- b) If the hammer's speed is doubled, the centripetal force increases four fold
- c) The centripetal force varies inversely with the radius of rotation. Examples are seen when track sprinters and cyclists negotiating a bend on the track

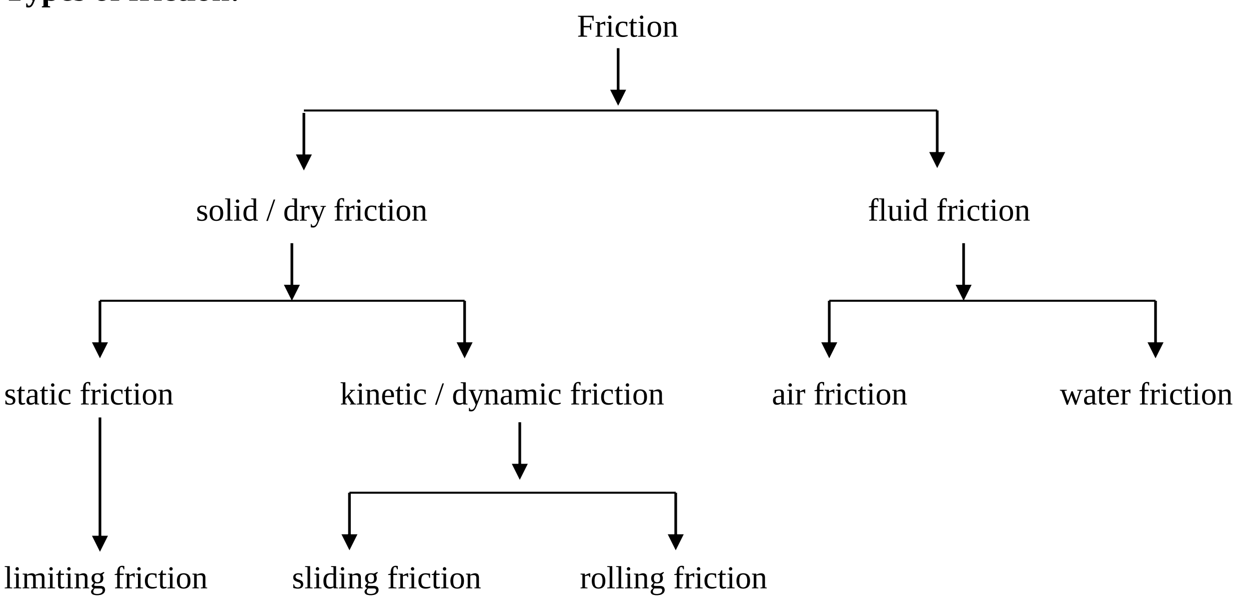
Difference between centripetal and centrifugal forces:

Centripetal force	Centrifugal force
1. The word 'centripetal' has been derived from Latin root 'petere' means to "seek". So the centripetal force is defined as the centre seeking force.	1. The word centrifugal has been derived from Latin root 'Fugere' means 'to flee'. Thus the centrifugal force is defined as the 'centre fleeing force'.
2. Centripetal force is directed towards the centre of rotation of any rotating body	2. Centrifugal force is directed away from the centre of rotation of any rotating body.
3. Centripetal force produces acceleration towards the centre.	3. Centrifugal force is the reaction force.

Friction and its influence in sports performance

When two surfaces in contact tend to exhibit relative motion between them, a force develops at the junction of the surfaces parallel to them in the opposite direction of intended motion. this phenomenon is called friction and the force developed due to friction is called as the frictional course.

Types of friction:



The magnitude of friction varies in a rather unusual way. Consider the following example

A point at which the flock is still at rest, but the friction has reached a limit beyond which it is incapable of increasing further, this value is called limiting friction and it is equal in magnitude to the applied load at that time. If further weight is added, the block begins to slide. The opposing friction becomes less than its limiting value.

Ground friction

Ground friction is in the group of solid of friction. It is the friction between two solid surfaces: the ground and the sole of the shoe during games and sports. There may be three types of ground friction: Limiting friction, sliding friction and rolling friction. Limiting friction is the highest value of static friction. It occurs when the body is about to move from static position. The friction during sliding is called the sliding friction and the friction during rolling is called roll friction. In magnitude static friction is greater than sliding friction and sliding friction is greater than rolling friction.

Sliding friction

This friction acts only when the body is in motion or has a tendency to start moving across the surface of another body. A barbell disc lying on the floor is acted upon by two forces; one its weight (w) and other (R) an upward supporting force exerted by the floor. Under the action of these forces, the disc has no tendency to slide across the floor and thus there is no friction acting to oppose this tendency. If a person gives push to the disc, the disc will tend to slide. Only the friction (F) will act in opposition to this tendency. Another important characteristic of friction is that, until sliding actually commences, the magnitude of friction is exactly equal to that of the force tending to cause the body to slide. Once the friction has reached its upper limit in magnitude (limiting friction) sliding is about to commence.

There are many situations in which sportspersons increase the friction (or grip) between two surfaces in order to prevent sliding.

1. Use of magnesium chalk by gymnast
2. Use of resin by table tennis player
3. Use of spray or vanice turpentine by pole vaulters.

There are also examples where sportspersons make effort to reduce friction – Skiing.

From these examples it is apparent that there are two ways in which friction between bodies can be modified:

a) By altering the nature of the bearing surfaces.
b) By changing the forces that hold these surfaces together.

Law of friction:

For two dry surfaces, the limiting friction is equal to the normal reaction multiplied by a constant, the value of this constant depending only on the nature of surfaces.
That is

$F = \mu R$
where F = Limiting friction
R = Normal reaction
μ (Mu) = The constant known as the coefficient of limiting friction.

Rolling Friction
The friction that opposes the motion of the ball when it rolls across the playing surface is called rolling friction.

Experienced golfers carefully study the approach, the path that the ball will follow, before making a putt, they look closely at the length of the grass and the way it is lying. They also see whether grass is wet or dry because all these things have influence on the movement of the ball. Hockey, Cricket and Football players also study the conditions of the playing surface carefully. They know that the movement of the ball depends upon how hard, smooth and dry it is.

The magnitude of rolling friction depends upon:

1. The nature of the ball and the surface involved.
2. The normal reaction.
3. The diameter of the ball.

In sports only the first i. e. nature of the ball and the surface are more important and the sportspersons can not do any thing against these. The nature of the ball and surface is fixed as per rules. The best thing they can do is to check the prevailing conditions and adjust accordingly if playing surface is heavily grassed, soft and wet, the rolling friction will he high. The player will have to use more force than usual to offset the effect of high rolling friction.
Friction is resistance to motion created by contact between two surfaces. The magnitude of this resistance depends upon four factors:

a) The materials that make up two bodies.
b) The irregularity of their surfaces.
c) The force with which the surfaces are pressed together.
d) Relative action between the surfaces.

A measure of friction is the amount of force applied to the body parallel to the surface of contact that is necessary to just start movement or slipping between the surfaces. It has been found that this forces is proportional to the force that presses against the two surfaces. Most interesting and significant from the sports point of view is the fact that the force pressing against the surfaces may be concentrated at one point or spread over a large area. The proportional relationship for all practical purposes does not change. If the force pressing the two surfaces together is represented by W, and the force necessary to start the movement by P, this relation may be shown as a ratio:

$P/W = c$ where c is the coefficient of friction between the surfaces.

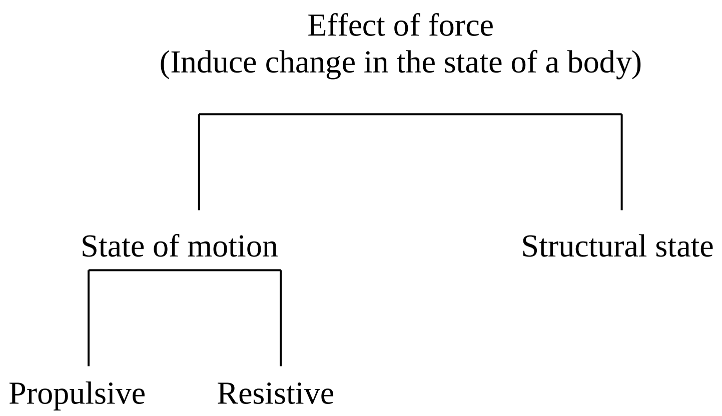
Force: Concept, Vector property, Effect, Source and System

Concept of force: Concept of force is derived from Newton's I law of motion. It is a factor, an effort that tends to initiate change in the positional state of a body. It compels a body at rest to start motion and a body in motion to stop motion or change the magnitude or direction of motion.

Vector property: Force is a vector quantity. For its complete expression it needs magnitude as well as direction. In fact, three factors of a force must be described in the study of human motion are magnitude, direction and the point of application. A straight line drawn from a dot on a sheet of paper can represent a force. The dot indicates the point of application and the length of the line as the magnitude of force. The sign of an arrow is attached with the line to indicate the direction of force. Change in any one of these three factors also changes the effect of force.

Unit of force: The unit of force in S. l. unit is Newton. It is the quantity of force that produces an acceleration of $1 m/s^2$ when applied on a body of mass 1 Kg. the smaller unit of force in CGS system is dyne (A forec that gives a body of mass of 1 gm an acceleration of $1 cm/sec^2$. one Newton = 10^5 erg.) The gravitational unit of force is kilopound (kp) which acts on a mass of one kilogram at normal acceleration of gravity (1kp=9.8 Newtons).

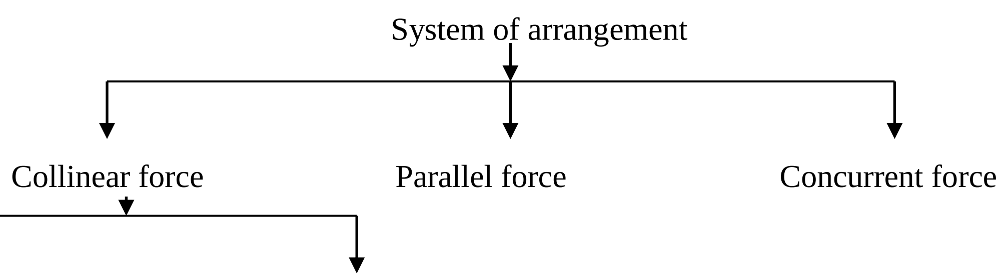
Effect of force : Effect of force has been shown if following fig.



Propulsive force helps the body to propel from one place to another, whereas the resistive force opposes motion. In games and sports the interaction between propulsive and resistive forces goes on everywhere. Structural state indicates the shape and size of the body. External force tends to produce changes in these aspects also.

Source: According to the source forces may be internal and external. The internal forces are developed within the system while the external forces are applied from outside on the system. In games and sports human body is considered to be a system. The internal force in this case is produced by muscle contraction. The external forces that influences sports performances are gravity, friction, centripetal & centrifugal forces, elastic force, buoyant force etc.

Force Systems:



Unidirectional Opposite directional

Collinear forces: When two forces act in the same line and in the same direction, the magnitude of the resultant will be: $F_1+F_2=R$; but if the direction of the forces become opposite, the magnitude of the resultant will be: $F_1+(-F_2) = R$ or $R=F_1-F_2$

Parallel forces: When two or more forces acting on a body are parallel to one another. The resultant will be $R=F_1+R_2$ (the direction will be same as that of the forces.

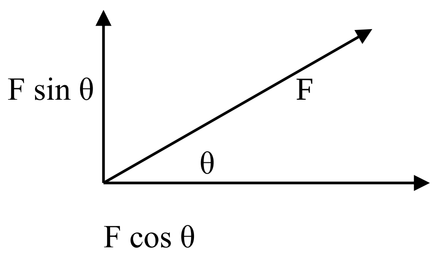
Concurrent forces: When two or more forces are acting on a same point. For two concurrent forces the magnitude will be $R= \sqrt{(F_1^2+F_2^2+2F_1F_2\cos\theta)}$

Resolution of forces: A single force can be resolved into two mutually perpendicular directions.

By using mathematical method

The resolved components of a force F will be F cosθ in horizontal direction and F sin θ in vertical direction where θ is the angle between the force F and the horizontal direction.

By using geometrical method



PRESSURE

When a gymnast performs a one-handed handstand, she supports her weight on the palm of her hand. If she weighs 500N and the area of her palm in contact with the floor is 100 cm^2, the average load supported per unit area-i.e. the average pressure is:

Pressure = Force / Area
= $500N / 100cm^2 = 5N /cm^2$

If regular handstand with both hands is done, the area of hands in contact with the floor is 200 cm^2, the average pressure is decreased ($500N / 200cm^2 = 2.5N / cm^2$). If he performance head stand, the area of head and hands in contact with the floor increases to $250cm^2$, the average pressure is reduced further i. e. $500N /250cm^2 = 2N / cm^2$.

The pressure to which any given part of the body can be exposed without it suffering damage is limited. It is therefore essential that from the safety point of view sports activities should not involve greater pressure than the body is capable of withstanding.

Many sports involve use of helmets, shin guards, pads, gloves etc. so as to distribute the pressure over a large area. Some sports involve use of special techniques to spread the forces, especially impact forces over a large area. Judo involves use of break falls to reduce pressure exerted on the body during the landing following the throw.

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PRESSURE

When a gymnast performs a one-handed handstand, she supports her weight on the palm of her hand. If she weighs 500N and the area of her palm in contact with the floor is $100cm^2$, the average load supported per unit area-i.e. the average pressure is :

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$= \frac{500N}{100\ cm^2} = 5N / cm^2$$

If regular handstand with both hands is done the area of the hands in contact with the floor is 200 cm^2, the average pressure is decreased.

$$\frac{500N}{200cm^2} = 2.5N / cm^2$$

If she performs head stand, the area of head and hands in contact with the floor increases to 250 cm^2, the average pressure is reduced further i.e. $500N / 250cm^2 = 2N / cm^2$.

The pressure to which any given part of the body can be exposed without it suffering damage is limited. It is therefore essential that from the safety points of view sports activities should not involve greater pressure than the body is capable of withstanding. Many sports involve use of helmets, shin guards, pads, gloves so as to distribute the pressure over a large area. Some sports involve use of special techniques to spread the forces, especially impact forces over a large area. Judo involves use of break falls to reduce pressure exerted on the body during the landing following the throw. If a sportspersons falls, he is advised to roll in order to reduce the injury. The roll distributes the pressure of fall over a bigger area.

MOMENTUM

Momentum is the quantity of motion of a body and is equal to the product of body's mass and velocity.

Momentum = mass / velocity

M = mv

If m= 70kg and v=30m/s then M=2100kg m/s
If 90kg man runs 100m in 10.0 sec. then M=90 x 100/ 10 = 900kg m / s.

Momentum of a body is of little importance in sports unless that body becomes involved in collision with another body. Then the result depends upon how much momentum each body had before collision. The greater the momentum of the body, more pronounced the effect it produces on other bodies in its path. Two bowlers bowling at the same velocity-mass will make a difference. If mass is same, then velocity will make a difference.

MOMENT OF FORCE

It is the tendency of a force to rotate a body to which it is applied about its axis of rotation.

The moment is equal to the force when directed at right angle to the force arm multiplied by the length of the force arm.

$M = F / x$ where M is the moment of force, x is the moment arm and F is the force.

In sports, axis of rotation may be the centre of gravity of body e. g. gymnast doing somersault. It may be a point of support e. g. hands when doing handstand or feet in lifting. It may be median line of body e. g. discus throw or batting in cricket. It may be a joint e.g. hip joint in kicking or shoulder joint in golf. It may be a bar e. g. giant swing in gymnastics.

If one is over coming moment of force or holding it to minimum, he should keep the moment arm (the distance from the point of application of force to the axis of rotation) as short as possible. If lifter is closed to the bar, he does not have to overcome any handicap. If lifter is 10cms away from the bar, the moment of force is increased 10 times.

There are also situations when it is advantageous e. g. Giant Swing in Gymnastics. Batting in cricket or hitting in hockey. More linear speed is created at the end which contacts the ball.

LEVERS

The body movements are produced through a system of levers. The bones of the body act as levers. They are acted upon by a force that is produced by the contraction of muscles. The Principle of lever has its application outside the body also i. e. in games and sports. The techniques of wrestling are largely based on the principles of levers and leverage.

A lever is a mechanical device designed to produce turning motion about an axis. It consists of fulcrum, which is the centre or axis of rotation, a power arm which is the distance from the fulcrum to the point where the force is applied and the weight arm which is the distance from the fulcrum to the weight upon which the force is acting.

Levers are of three types

(1) First Class - Fulcrum is between power and resistance
(2) Second Class - Resistance is between fulcrum and power
(3) Third Class - Power is between fulcrum and resistance

Levers create mechanical advantage for producing either strength or speed unless they are first class or balancing type. The functions or levers are two fold.

(1) Strength
(2) Speed

Increase Speed		Increase Force	
P △ R	P △ R	P △ R	First Class
		△ ↓R ▲P	Second Class
▽ ▲P R▼			Third Class
Force arm is smaller than resistance arm	Force arm is = Resistance arm	Force arm is greater than resistance arm	

WORK

It is defined as the product of force applied to the body and the distance through which the body moves in the direction in which the force acts.

Work = force x distance or W= F x d

This definition leads to confusion. There are several situations in which work is done but body do not move a distance. For example bench-press when arms are held straight. This is called mechanical work. This may be positive, zero or negative. Positive work is done when barbell is lifted. Zero work is done when barbell is held with stretched arms. Negative work is done when barbell is lowered.

POWER

The rate at which mechanical work is performed is determined by dividing the work done by the time taken.

Power = work done / time taken or P = W / t

ENERGY

In any physical activity work in performed and energy is consumed. The amount of energy possessed by each individual for performing work is limited. Therefore, it is of considerable importance from a competitive standpoint to know the energy requirement for the performance in terms of the method used. The effectiveness of technique is determined in terms of both the results accomplished and the energy expanded.

Energy exists in many forms i. e. mechanical, chemical, electrical, heat and sound. Mechanical energy is the only form considered here. It is the energy that a body has because of its motion, because of its position relative to surface of earth or because it has been pushed or pulled out of shape.

Kinetic Energy

It is defined as the energy that a body possesses because of it is in motion.
Linear motion-kinetic energy of translation
Angular motion –kinetic energy of rotation

$KE = ½ mv^2$

Potential Energy

It is defined as the energy that a body possesses because it is some distance above the level of earth's surface and can thus do work in returning to that level.

PE = mgh or wh.

Work-Energy Relationship

Work done = Kinetic Energy
$F \times d = ½ mv^2$
$v_f^2 = v_i^2 + 2ad$
$a = v_f^2 – v_i^2 / 2d$

or $a = v_f^2 / 2d$ (initial velocity is zero)
$F = ma$
$F = m v_f^2 / 2d$ or $Fd = ½ mv^2$

EXPERIMENT NO.7 DETERMINATION OF AVERAGE VELOCITY

Principle:

Velocity is defined as the distance covered by the body per unit time. Average velocity is calculated by the ratio of total running distance and the total time taken.

Mathematically

Average velocity $\overline{v}$ = distance (s) / time (t) where '$\overline{v}$' in the average velocity. 's' is the total distance covered and 't' is the time taken.

Equipment's, Instruments and tools:

For measuring average velocity the following equipment's, instruments and tools were used:

(a) A 400m standard track as a course of running
(b) Three electronic stopwatches, capable of measuring $1/100^{th}$ part of a second were used to measure the time taken to complete the race.
(c) A starting device (whistle)
(d) Finish posts, kept in line with the finish line.

Procedure:

(1) At first the subject was allowed to complete his warm up before the start of the race
(2) Then he was instructed to fix the starting block for the race.
(3) The finish posts were placed on the finish line.
(4) The starter was placed at the suitable place with the whistle.
(5) The timekeeper was ready with stopwatch for recording time.
(6) The starter started the race by blowing the whistle.
(7) The time keepers started the watch with the start of the race and recorded the time up to the point of touching the "torso" with the vertical plane of the inner side of the finish line.

Subject (2), (3), (4) and (5) were tested similarly.

Results:

The time taken to complete 400m by the subjects and their average velocities are shown in Table 1

Table 1

Average velocity of the subjects in 400m race.

Subject No.	Distance rum (m) s (m)	Time taken				Average velocity $\overline{v}$=s/t m-s^1
		Watch-I	Watch-II	Watch-III	Official time	
1.	400	57.43	57.90	57.50	57.50	6.956
2.	400	57.40	57.49	57.53	57.49	6.957
3.	400	59.10	60.19	60.30	60.19	6.645
4.	400	57.50	58.10	57.79	57.79	6.921

Conclusion:

From Table values it is seen that subject No. 1 completed 400m race with an official time of 57.50 and an average velocity of 6.956m /s. Subject No. 2 completed 400m race with an official time of 57.49 and an average velocity of 6.957 m /s. Subject No. 3 completed 400m race with an official time of 60.19 and an average velocity of 6.645 m/s. Subject No. 4 completed 400m race with an official time of 57.79 and an average velocity of 6.921 m/s.

So among the subjects, No. 2 is first, No. 1 is second, No. 4 is third and No. 3 is fourth.

FREE FALLING BODIES AND PROJECTILES

Free Falling Bodies

Concept of Free Falling Body: When a body moves through air only under the influence of gravitational pull as an external force, it is considered as a free falling body. During the motion of such a body, the effect of air resistance is ignored. When a ball is thrown upward, its upward velocity gradually slows down and finally it stops its upward motion at a particular height, thereafter, it starts falling downward motion is considered as free fall.

By nature free fall is a regularly irregular motion where the body moves with a constant acceleration ($g = 9.8\ m/s^2$). This motion is also governed by the equations of motion with constant acceleration. In this case the equations are as follows.

$v = u + gt$ .... (1)
$h = ut + \frac{1}{2} gt^2$....................... (2)
$v^2 = u^2 + 2gh$.......................... (3)

In these equations, 'h' denotes the vertical height, 'g' the acceleration due to gravity, 'u' the initial velocity and 'v' the final velocity.

Projectile

Many sports involve projection of a body in to the air. In football, tennis discus the body projected is an inanimate object. In diving, gymnastics and jumping events the projectile is animate i. e. the performer. In all these sports and in many others the quality of performance depends largely on performer's ability to control and / or predict the outcome of projectile motion involved.

Projectile Motion

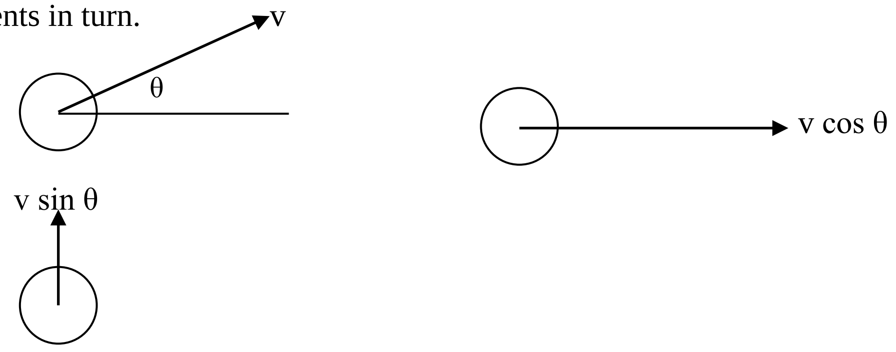
The motion of bodies that have been projected in to the air

It is important for the coaches to have knowledge of the mechanical factors that govern such motions. When a body is projected in to air, two things act to change its motion.

(1) Gravity-It pulls the body downward towards the earth with a constant acceleration of $9.80 m/s^2$
(2) Air resistance-It may retard its forward motion or in certain circumstances cause it to be lifted.

For discussion the effect of air is neglected.

For the purpose of analysis, the horizontal and vertical components of projectile are considered separately for e. g. when a stationary ball is kicked up field, the velocity imparted to the ball acts in a direction at some angle θ to the horizontal. If this velocity is resolved in to horizontal and vertical components, the effect of kick can be studied by considering each of these components in turn.



The horizontal velocity of the ball at the instance it is projected into air is v cos θ, since nothing tends to change the rate at which it is moving (ignoring air resistance) it maintains same horizontal velocity throughout. Therefore the average horizontal velocity of the ball during flight is also v cos θ.

$d = \bar{v}\, t$
$d_H = v \cos \theta \times t$
$R = v \cos \theta \times T$ where T = time of flight

Time of flight is important.

Example of cricket (Range is important)
Example of gymnastics e. g. somersault (both range and time of flight are important)

Vertical Motion

The lifting of the ball is due to vertical velocity imparted to it prior to release. The time of flight also depends on the vertical velocity at release.

$T = t_{up} + t_{down}$
$t_{up} = v \sin \theta / g$
$t_{down} = v \sin \theta / g$

When release and landing is at same level, it takes projectile same time to go up and for it to come down.

$T = t_{up} + t_{down}$
$= v \sin \theta / g + v \sin \theta / g$
$= 2v \sin \theta / g$

If projectile is released at height above or below the level at which it lands.

$$T = \frac{v \sin \theta + \sqrt{(v \sin \theta)^2 + 2gh}}{g}$$

Range of Projectile

$R = v \cos \theta \times T$
$R = c \cos \theta \times 2v \sin \theta / g$
$= v^2\, 2 \sin \theta \cos \theta / g$

According to trignometrical identity
$\sin 2\theta = 2 \sin \theta \cos \theta$
$R = v^2 \sin 2\theta / g$

When release point is higher than landing point (shot put)

$$R = \frac{v^2 \sin \theta \cos \theta + v \cos \theta \sqrt{(v \sin \theta)^2 + 2gh}}{g}$$

v = initial velocity
θ = angle of projection with horizontal
g = acceleration due to gravity
h = height of release

Long Jump

$$R_1+R_2+R_3 = \frac{v2 \sin\theta \cos\theta + v \cos\theta \sqrt{v^2 \sin^2\theta + 2g\,(h-c \sin\alpha)}}{g} + c \sin\alpha + c \cos\beta$$

θ = angle of projection of C. G.
v = velocity of C. G. at take off
h = vertical distance of C. G. at take off
g = acceleration due to gravity
c = distance from foot to C. G. at take off
β = angle of lean with vertical at take off
α = angle of legs at the moment of alighting with horizontal

Guiding Principles

(1) The optimum angle of release is always less than 45^0
(2) For any height of release, the greater the speed release, the more closely the angle approaches 45^0
(3) For any given speed of release, the greater the height of release the less is the optimum angle.
(4) In jumping, throwing and kicking activities, where horizontal distance is the goal, the body or object should be projected at an angle of not greater than 45^0.
(5) If the body takes off or an object is released at a height above the point of landing, the angle of projection will be less than 45^0.
(6) In throwing activities in which time is a factor in reaching a specific distance, the object should be projected at a lowest possible angle from which the distance can be reached.
(7) If maximum horizontal distance is the goal, the body should remain in the air for as long as possible without sacrificing distance.
(8) If time is a factor, the body should be kept in the air for as short time as possible.
(9) In order to gain maximum distance in jumping, throwing and kicking activities, their must be careful integration between development of velocity (speed of movement) and height of projection.

EQUILIBRIUM

When the sum of forces and the sum of moments acting upon a body are both equal to zero, the body is said to be in equilibrium. The equilibrium is of two types:

Static Equilibrium-when a body is static

Dynamic Equilibrium-when a body is moving with linear or rotary motion.

The static equilibrium may be of three types depending upon the degree of stability-(1) stable, (2) unstable and (3) neutral. In stable equilibrium the degree of stability is more and the body does not want to move away from that position. In case the body is forced to move away, it tries to come back to the position again. In unstable equilibrium the degree of stability is less and the body does not want to remain in that position. With slightest provocation it moves away from that position to the stable equilibrium position. Once displaced it does not have the tendency to come back to the initial position. In neutral equilibrium position the degree of stability does not change with the change of position. So the body does not show any tendency either to move away or to come back to the initial position after being displaced.

In sports equilibrium is called balance, poise, position or stance. Actually, body positions or movements of any kind involved some aspect of equilibrium. For example sitting or rising from the chair involves some of the principles of equilibrium. Waking is nothing more than interrupted falling, which consists of upsetting and regaining balance.

Equilibrium is a state of rest of a body. If a high degree of immobility is desired, then a position that will provide great stability-a position from which it will be difficult to move or dislodge the individual-must be assumed. The wrestler on defense is an example. If a delicate degree of stability is desired, a position that will permit upsetting equilibrium easily will be assumed. The starting position of a swimmer or an athlete is an example. In many sports a position is desired that will permit the participant to start quickly in any direction while at the same time protecting him from being dislodged. In these case the equilibrium is between stable and unstable equilibrium.

The degree of stability depends upon following five factors:

(1) Equilibrium is directly proportional to the area of the base on which the body rests.

(2) Equilibrium is indirectly proportional to the distance of centre of gravity of the body above the base.

The C. G. of a body is a point from which the body can be suspended in perfect balance. As the various members of the body change position, the C. G. also may change.

(3) For equilibrium to exist, the centre of gravity of the body must fall within its base.

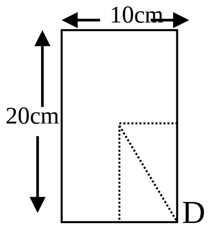
The C. G. must be kept within the boundaries of the base e. g. Hand stand-C. G. to be kept between hands.

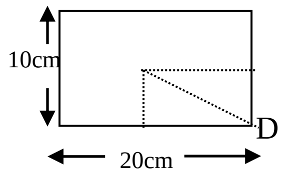
(4) Equilibrium in a given direction is directly proportional to the horizontal distance of the C. G. from the edge of the base towards the given direction of movement.

A basketball player when rapidly stops, he has to shift his C.G. on the rear foot. He is less likely to fall forward.

(5) Equilibrium is directly proportional to weight of the body.

The above principles can be best illustrated with the help of two wooden blocks each weighing 5 kg. and the size of each block is 20x10x10 cms.





Block A stands on 10x10 cms base and block B rests on 20x10 cms. Both blocks are homogeneous and the C. G. is at centre of each. The C. G. block A is 10cms above base and that of B is 5cms above base. Both blocks are in a state of rest or equilibrium. To upset the equilibrium it is necessary to move the blocks so that their C. G. falls outside the bases. To do this it will be necessary to tip the blocks. Point D is chosen as axis of rotation for tilting the blocks. The length of C D is approximately found to be 11.18cms.

In block A C. G. is raised by 1.18 cms. and in block B by 6.18cms. i. e. the C. G. of this block was raised 5cms higher than C. G. of block A. Since both blocks weigh 5 kg the block B require (5x.05m) more force as compared to block A. Even if the weight of block A is raised to 10kg, the block B is till more stable.

IMPACT AND ELASTICITY

IMPACT

There is a large number of sports in which one body collides (or impacts) with another and in which the success of a participant depends very largely on his (or her) ability to predict the outcome of such impact. In squash the player are continually called upon to predict where the ball will go following the impact with a wall, the floor and even the racket and to position themselves ready for their next shot in accordance with his prediction. If they misjudge the outcome of the impact, they are very likely to find themselves in a position from which it is difficult, perhaps impossible to make a suitable return shot. When players do position themselves correctly, their next task is to play the ball in such a manner as to obtain the best results. In other games i. e. football, volleyball and the like it is important to consider the factors that influence the outcome when two bodies collide.

ELASTICITY

When two bodies come in contact, they either remain in contact or they bounce apart. In the first case the bodies tend to become one body e. g. when a shot falls on a soggy field and the impact is said to be inelastic. In the second case, both the bodies involved in the impact are first deformed and then due to the springy nature of the materials of which they are made, are restored to their original shape. Such impacts are said to be elastic.

The property of a body that causes it to return to its original shape after being deformed in an impact is called its elasticity, a property possessed by most of the bodies that are involved in the impact.

Coefficient of Restitution- The tendency of a body to return to its normal shape once it has been deformed, differs from one body to another. Some return very quickly to their original hsape, but others do so much less quickly.

Sir Isaac Newton investigated the properties of elastic bodies and the result of impacts between them and formulated the following emperical law (Newton's Law of Impact). If two bodies move towards each other along the same straight line, the difference between their velocities immediately after impact bears a constant relationship to the difference between their velocities at the moment of impact.

$$\frac{\text{Velocity of separation}}{\text{Velocity of impact}} = -e$$

or

$$\frac{v_1 - v_2}{u_1 - u_2} = -e$$ where e is the coefficient of restitution

or

$$e = -\frac{v_1 - v_2}{u_1 - u_2}$$

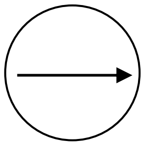
When a ball is dropped under the influence of gravity on to a fixed horizontal surface (one body involves in impact is at rest) and if its height of rebound is measured, the coefficient of restitution can be measured using the following equation.

$$e = \frac{h_b}{h_d}$$ This formula does not apply to situation in which both bodies are free to move

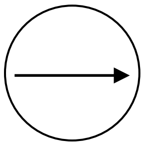
SPIN

Spin is the application of off center force. A ball may spin (turn) around an axis which passes through the center of the ball horizontal to the ground (horizontal axis) or an axis that is vertical to the ground (vertical axis).

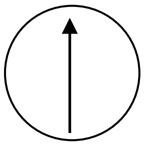
Top Spin: When a ball is spinning around horizontal axis in such a way that the top of the ball is moving forward (in the same direction the ball is moving), the ball is said to have topspin or forward spin.



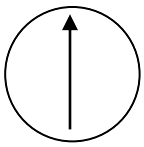
Back Spin: When a ball is spinning around the horizontal axis in such a way that the top of the ball is moving backward (away from the direction of flight) it be said to have backspin.



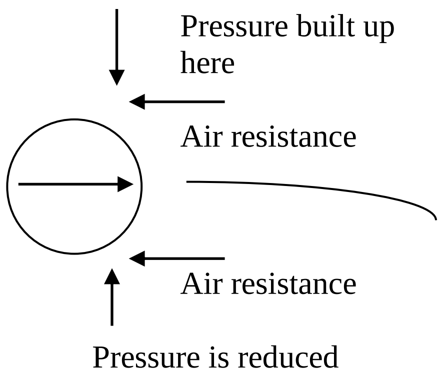
Right Spin: When the ball is spinning around vertical axis so that the front of the ball (the side facing the direction of flight) is moving to the right, the ball is said to have right spin.



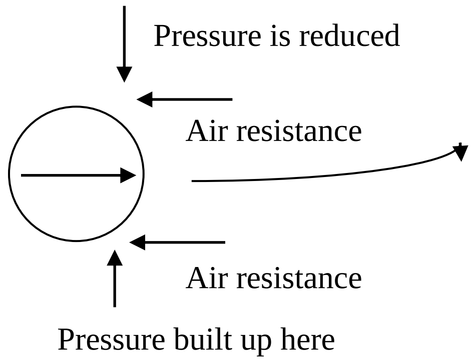
Left Spin: When the ball is spinning around vertical axis so that the front of the ball (the side facing the direction of flight) is moving to the left, the ball is said to have right spin.



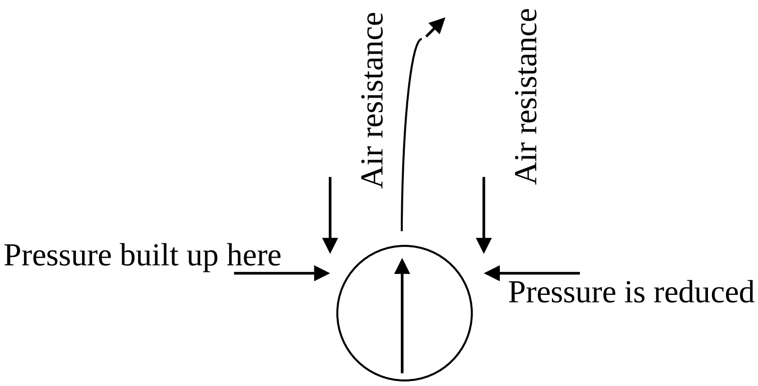
TOPSPIN



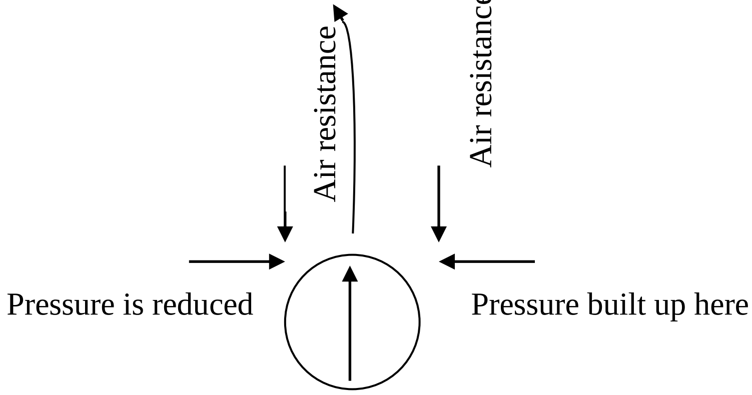
BACKSPIN

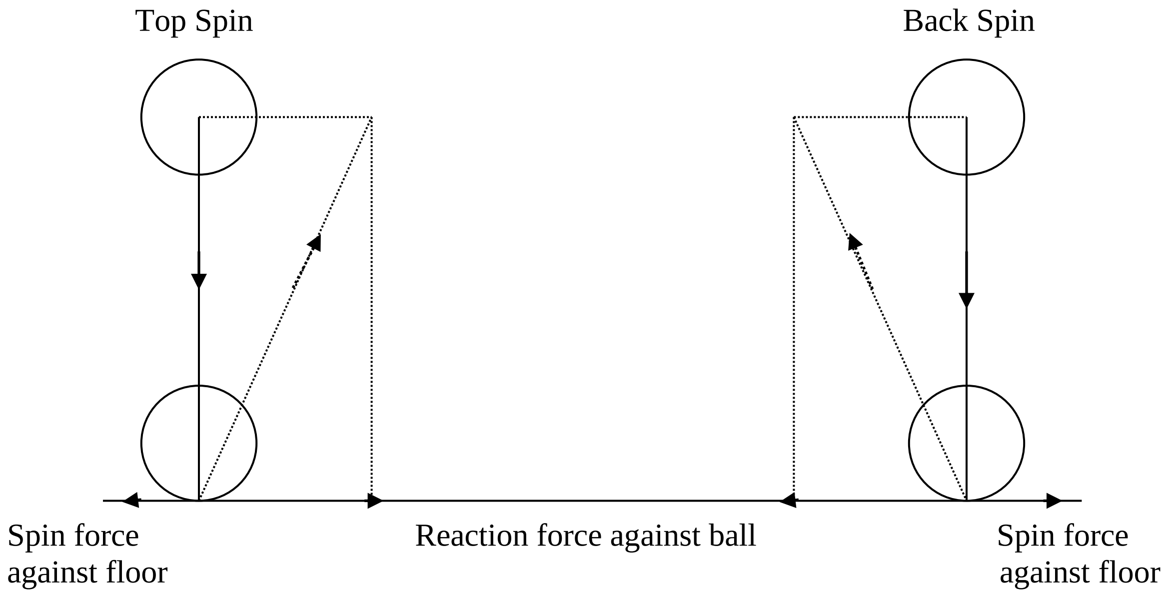


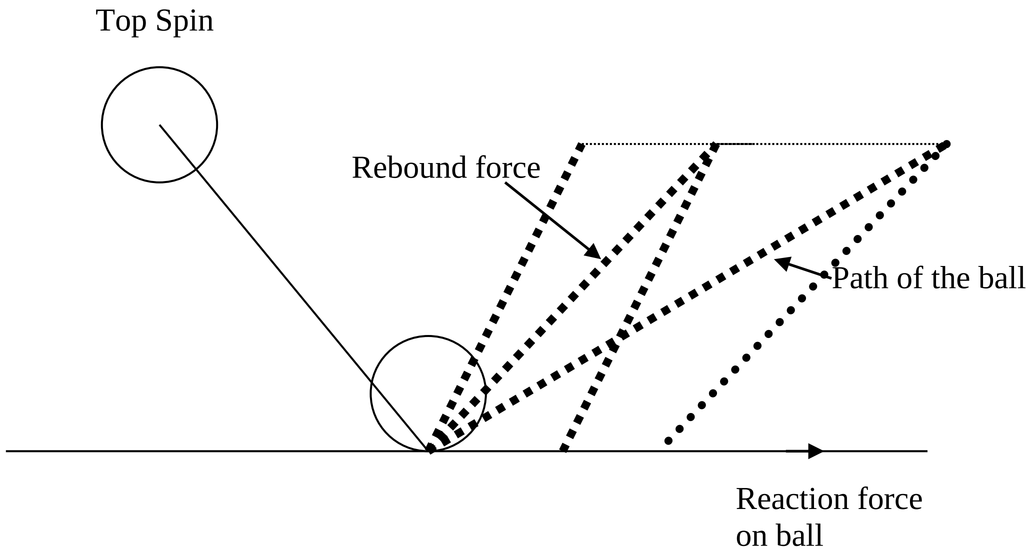
RIGHTSPIN

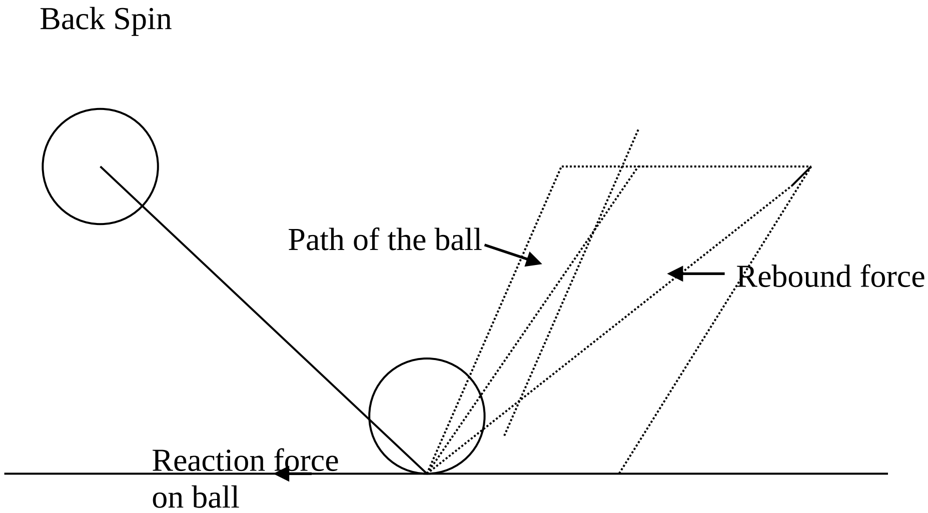


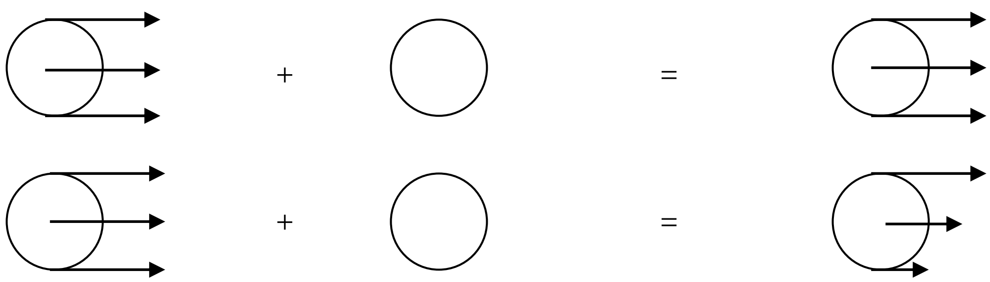
LEFTSPIN




Top Spin
Back Spin
Spin force
against floor
Reaction force against ball
Spin force
against floor


Top Spin
Rebound force
Path of the ball
Reaction force
on ball


Back Spin
Path of the ball
Rebound force
Reaction force
on ball


+
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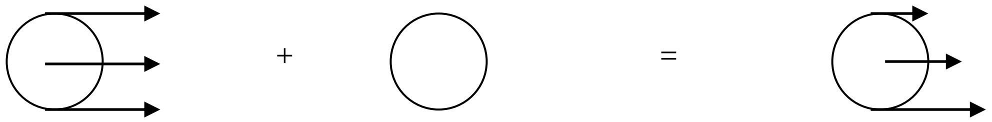
When topspin is given, horizontal velocity after contact increases



When backspin is given, horizontal velocity after contact reduces

FLUID MECHANICS

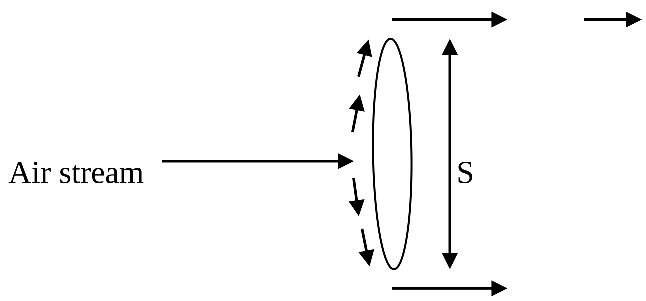
All motions in sports are influenced by the environment in which they take place. The surrounding air, their particular fluid environment (air) slows a basketball player, when he dribbles down a little. Skin divers are affected even more by fluid environment (water) is which they operate. Swimmers compete in two different environments i. e. air and water and their motion is influenced by both.

In many sports the effect of fluid environment is so small that they are disregarded. But in several sports its effect is so pronounced that due consideration has to be given.

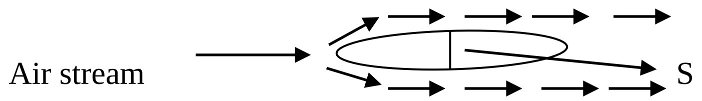
Air Resistance

Air resistance plays a vital part in many sporting activities. The principles of aerodynamics are important to be recognized for determining best methods of performance so that we combat its effect or take advantage of air resistance.

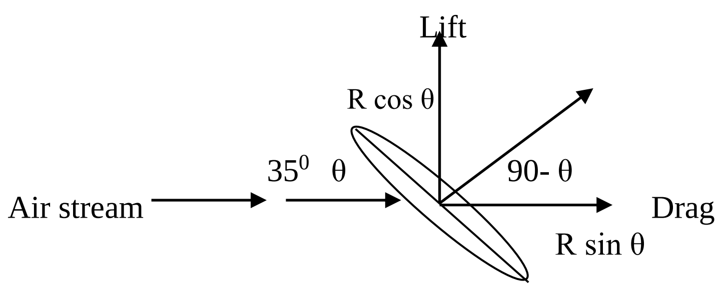
(1)



(2)



(3)



The reaction resulting form the diversion of air stream about a moving air born object may expressed by the equation

$$R = \frac{Cp\ SV^2}{2}$$

Where R = Resulting reaction.

C = A numerical, non dimensional coefficient depending on the shape of the body and its attitude to the air stream.

p = pressure of the air (15 lb/in^2 at sea level).

V = velocity of air stream with respect to body.

(1) Surface at right angle to the air stream. The whole reaction R will be in one direction, along the line of stream. The Y component of R will be zero. The drag will be large per unit area because of greater change in the direction of air particles.

(2) If edge of the discus is presented to the air stream, the drag effect will be almost negligible because the change of air particles is slight and only few are involved. R is still wholly in the direction of air stream, with its Y component being zero.

(3) If discus is presented at on angle to air stream, an intermediate value of R would be obtained. Its magnitude would depend upon the angle. Air is considered as a fluid, so the reaction R will be at right angle to the discus. If the leading edge is above the trailing edge, lifting effect will be produce. The Y component of R is the lift and it is directed upward in opposition to force of gravity. The X component is the drag and It is parallel to the air stream and opposed to direction of discus. The ratio of lift to drag (L/D) is the index of lifting efficiency of the body, which is acted upon by the air stream.

In a wind tunnel a discus was projected at an angle of 35^0. Head wind velocity not exceeding 14 mph gave good results. Head wind of 7 to 8 mph was the most advantageous. Head wind of 14.5 mph was detrimental as it increased the lift effect to much and thus reduced the total horizontal distance. When tail wind was played upon the discuss, the lift effect was reduced (vacuum-tail suction behind the discus was very much less than it was in the case of head wind). So loss of vacuum drives the discuss sooner to the ground, even though the speed of the discus becomes higher.

Therefore, if the head wind is more than 14.5 mph, the discus should be thrown with a flat angle of inclination. In case of tail wind, throw the discus with a more angle of inclination.

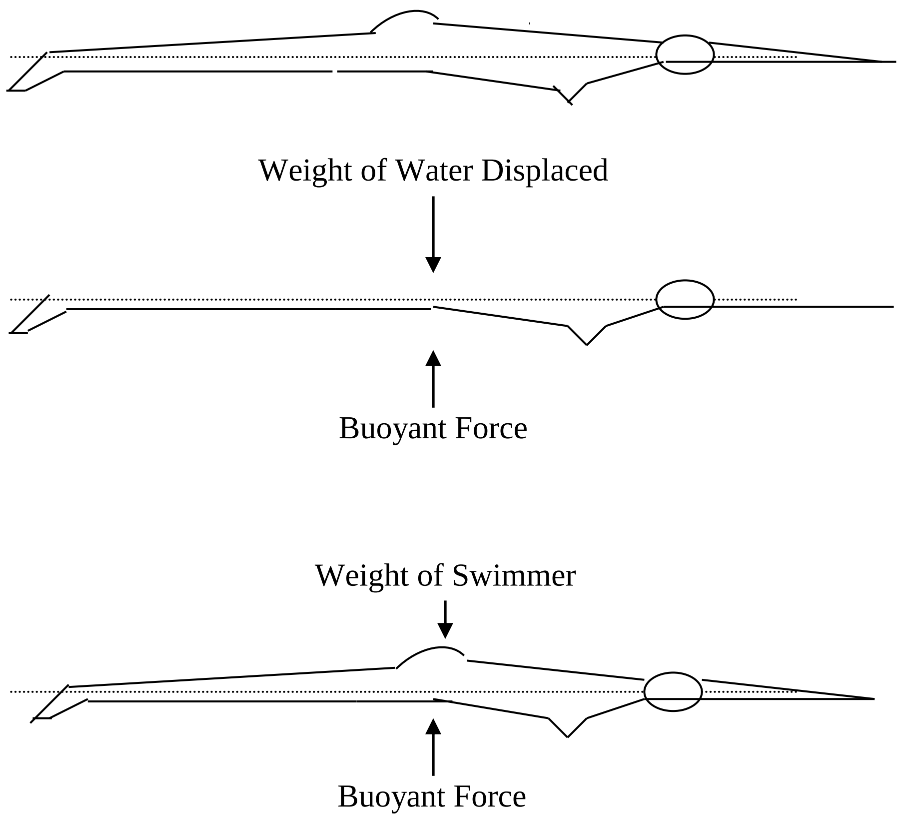
FLOATATION

The ability of a body to float (i. e. to maintain a stationary position at the surface of water) is of some importance in most aquatic sports. In swimming, for instance, a persons floating ability can influence success at both beginner and championship levels. Logically a person who is able to float with ease is likely to learn how to swim more readily than one who floats with difficulty or not at all. At the other of the performance scale, a champion swimmer who floats high in the water is likely to encounter less resistance to forward motion than one who cannot float as well. While ability to float has decided advantage in swimming, its importance should not be overrated. Many people who cannot float have learnt how to swim and some of them have even broken records and won in Olympic Games.

Buoyant Force

It is the upward force exerted by the water.

The swimmer in the following figure is floating horizontally on the surface of water. Because she is in a state of equilibrium in this situation, the sum of forces acting on her body in any direction must be equal to zero. In vertical direction (and this is important in determining whether a body floats on the surface or sinks below it) The only forces acting are her weight and whatever vertical forces the water exerts on her.



The resultant of this upward vertical force (the so-called buoyant force) that the water exerts must be equal in magnitude to her body weight. This decides whether the body will float or sink. If the weight of the body is more than the buoyant force that the water can provide, the body will sink. If it is not, the body will float. Expressing in mathematical terms, a body will float only if:

The weight of the body $\leq$ the maximum buoyant force
(Archimedes Principle-Buoyant force is equal to the weight of the water displaced).

Water Resistance

Water resistance is a particular problem in swimming. The resistance to motion of a solid through a liquid increases with its velocity. When a force a given value is applied to a body to move it through a liquid, the velocity of the body will gradually increase until it reaches a certain limiting value at which the resistance due to friction is equal to applied force. After that value has been reached, the velocity will remain constant as long as the force is applied. Thus a body following through water will have a constant velocity after it has fallen a certain distance.

The following eight factors cause loss of force in swimming:

(1) Waves: Wave making is probably the foremost of the resistance factors. The force that makes waves does not propel the body, but rather becomes resistance. Avoiding up and down movements or rolling during the stroke largely eliminates Wave making. It should be pointed out in this connection that, the so-called butterfly stroke presently used in the breaststroke cassias considerable wave making. However, the force produced is relatively so much greater than the resistance that greater speed is obtained. There is considerable increases in the energy is used.

(2) Eddies: Eddies are evidences of dissipated force is merely moving water or in changing stroke. A clash of eddies cause a loss of speed. In order to reduce or eliminate this factor, it is customary to plug up the scum gutters of pools, which have them to raise the water to the level of the gutter. The result is that the water of the pool is quieted. There is no return eddy when the water hits the back of the gutter, as there is when it hits the side of the pool and rebounds back into the pool.

(3) Cavitation: Cavitation is a loss of suction. It is caused when propelling member is pulled through the water so fast that a cavity is formed. When this happens there is nothing but space for propelling member to push against. By newton’s third law it is obvious that there would be reduced forward movement. The action may be linked to slipping, which causes a loss of force for propelling purposes.

(4) Skin Friction: There is a little scientific information on the study of the reduction of skin friction. The smooth the surface, the less the friction. The hairy body has been shaved to make the surface smoother. Oils of various kinds have been applied to the skin. It has been discovered that silk made swimming suits cause less friction than wool suits.

(5) Force: Force used at unproductive angles cases resistance and may be opposed to the intended direction of motion. For example, in the crawl stoke, when the arm is down in a vertical direction, it is most productive of propelling force. When it is straight out in front of the body, it is least productive. If the stroke begins at this point, the force exerted serves only to lift the body from the water, thus producing waves. If the hand is brought to across the median line of the body in front of the head and the stroke begins at this point, the force directs the body sideways instead of forward.

If in the breaststroke, the hands are brought together out in front of the head and the stroke begun at this point, the force is directed at right angles to the direction of movement. If the legs are thrashed up and down, motion will be produced.

(6) Starting and Stopping: Starting, stopping and lack of smooth progress create resistance. The added effort necessary to overcome inertia dissipates force that might be used in developing speed. The breaststroke is the best example of this factor. However, the introduction of the butterfly stroke has cut down the glide time measurably. Last, as a result of this, the time in the breaststroke races has been reduced surprisingly.

(7) Internal Resistance: That the effect of tenseness is probably more apparent in swimming than any other sport is observed clearly in most beginning swimmers. Their tenseness is usually caused by fear. The aim therefore should be to learn to relax in all situations. It has been well said “an individual, who has implicit confidence in his instructor so that he has no fear and can relax, can be taught to swim in 15 minutes”.

(8) Resistance due to physical features: Resistance is proportional to the greatest cross-sectional area of the body. If the width of the leg stroke is kept within this cross sectional area, resistance will be cut down. Very heavy glutii muscles, which cause the buttocks to protrude, will tend to create greater water resistance. There is also resistance when the head is kept between the arms on the plunge. It was found that greater distance was attained in this way.

CINEMATOGRAPHIC EQUIPMENT AND USE

The art of photographing human movement known as cinematography is widely employed in bio-mechanics as a means of recording the events associated with muscular action. In the larger context, it provides a pictorial record of events that occur so rapidly that careful analysis is impossible by observation alone. The human eye is a notoriously poor recorder; account of the same action by several observers frequently results in discrepancies. With the use of special photographic equipment, a record can be obtained of the movement that can be use later for detailed analysis.

The filming of action is probably the least time consuming part of cinematography; more time is required to handle the host of other details surrounding such things as:

(a) Selection of equipment
(b) Calibration of camera
(c) Setting up of proper protocol
(d) Analysis of data

(a) <u>Selection of equipment</u>

Ample consideration should be given to purchase a proper cinematographic equipment, including cameras and accessories, stroboscopic equipment, flood lights and various tripods. The expenditure of money for high quality material will pay important dividends in the quality of research produced and will also tend to serve for a long time without difficulty or loss of accuracy. Inferior quality may cause a premature lack of accuracy and render the equipment useless for research at an early date. Thought should also be given to the manner in which the film is to be processed and for this a darkroom and equipment for developing film will be required. Such facility will provide greater flexibility to the investigator and he can try different methods of processing film and also try out various camera settings and lighting techniques. Generally commercial processing is expensive and time consuming and invariably when the film is received you find that it is too dark or too light.

It the past, requirement for cinematographic research was to employ two cameras, one placed in front and another facing his or her side. Thus a two-dimentional view is obtained, and analysis is movement in two planes is accomplished. The growing need is to have three-dimentional photography which will require three cameras-the third to be placed directly over-head. In doing so, the three cardinal planes can be viewed simultaneously and all the portions of the movement accounted for.

Film size and shutter speed are also important. 16mm film with camera capable of operating at 64 to 128 frames per sec (spring driven cameras, Electronically driven cameras have speed of more than 1000 frames per sec. If filming is to be done indoors, tripods and flood light are important.

(b) <u>Calibration of Cameras</u>

The cameras should be properly calibrated to ensure that they record required number of frames per second. Speed of camera frames is required at the time of conversion of data. If camera is electronically driven no problem is experienced but if it is spring driven, its calibration can be checked using following methods.

(iii) Photographing and object (ball) falling from a known height thus time may be calculated according to the formula $S= ½ gt^2$ where S is distance, g is acceleration due to gravity. The amount of film elapsing during the time of fall can be converted into frames per sec. For accuracy, the procedure is to be repeated several times because the ball may contact between two frames.

(iv) Second method is to be photograph the sweep hand of 100^{th} second timer and than counting the number of frames elapsing between seconds. It is more accurate.

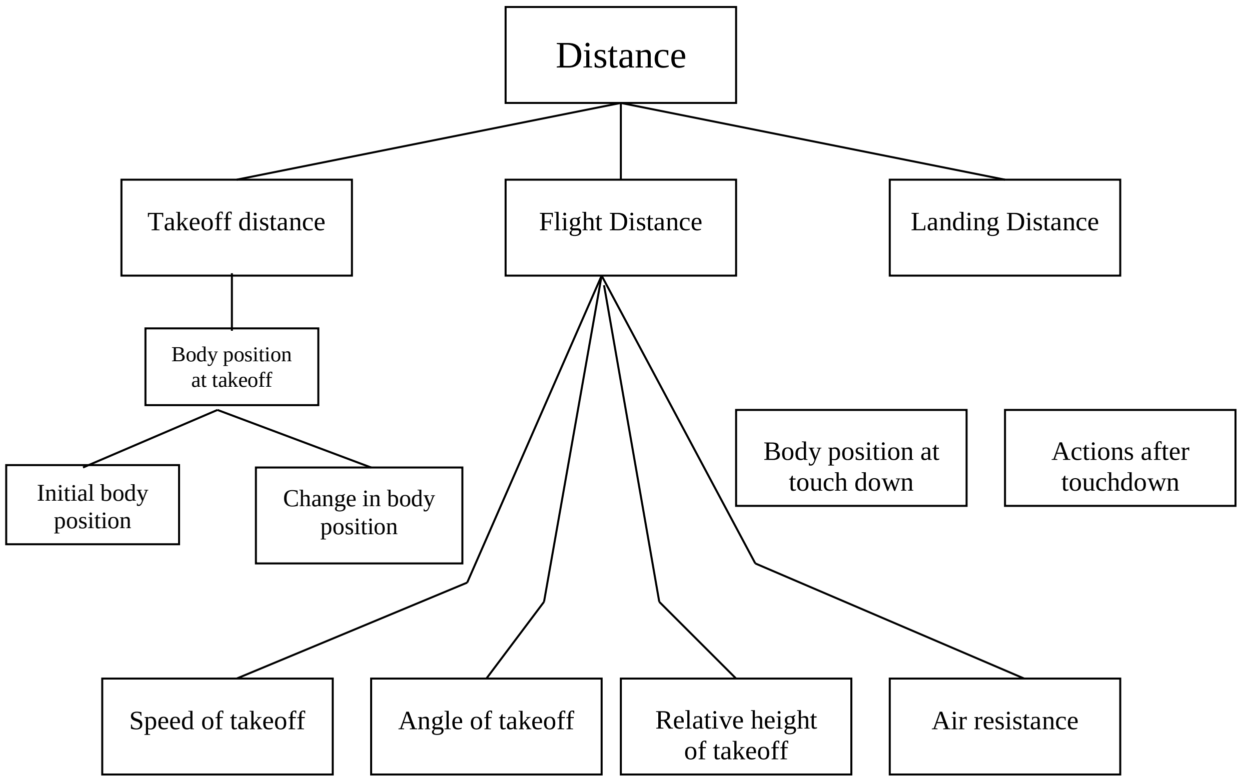
(c) Experimental Protocol

Decide whether photography is to be done outdoors or indoors. If to be done indoors, flood light would be required. Background is important so that the photograph stands out clearly. Outdoors if there are many trees in the background, photograph is not clear and thus creates problem while analyzing. Use a grid at an average subject position from the camera so as to have actual distance of the subject from the camera. Decision to be taken whether two cameras (two-dimensional) or three cameras (three-dimensional) photography is needed.

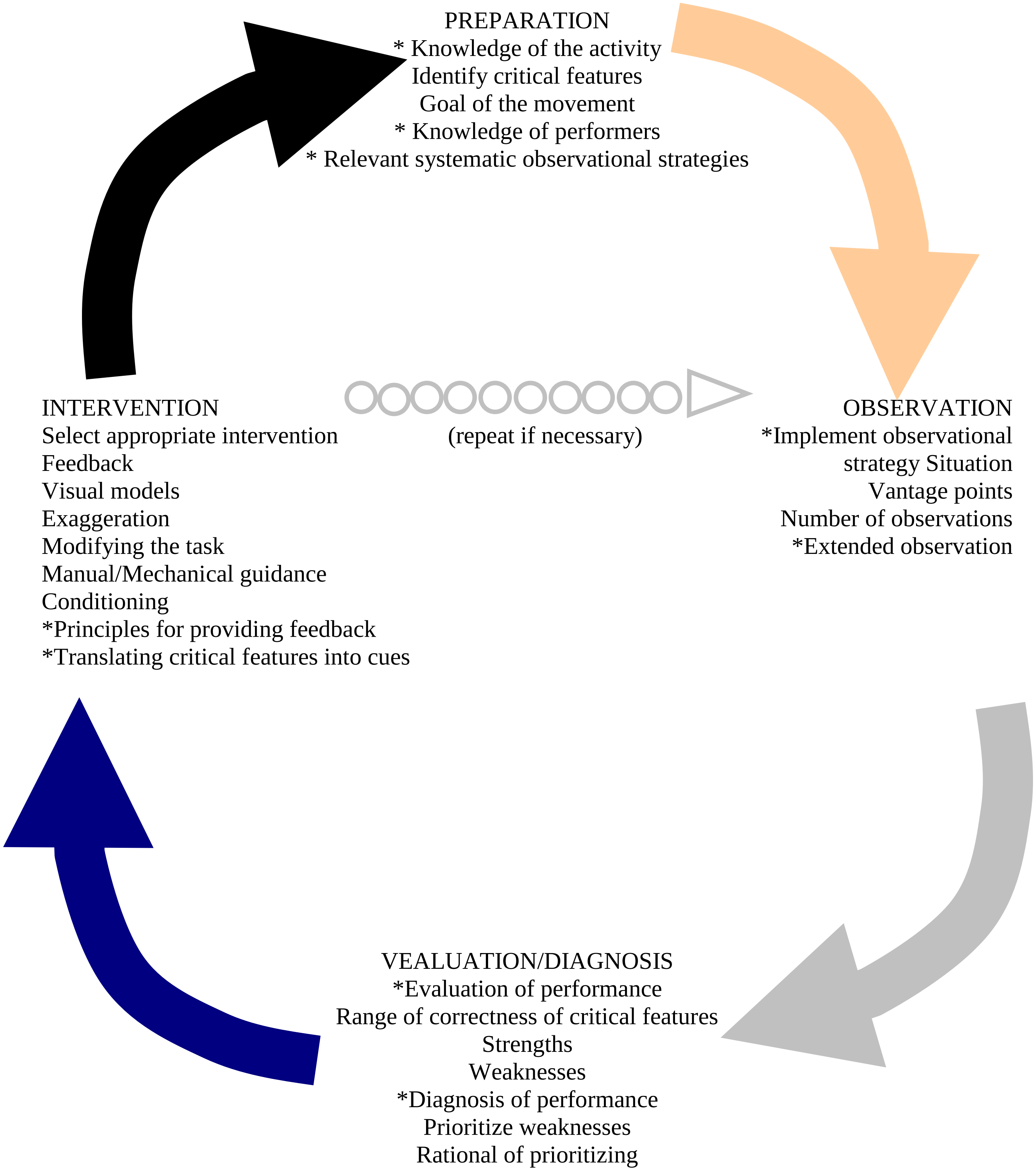
Preparation of subjects is also important. To identify specific body parts, black tape can be fixed to have marking. Generally few subjects are used otherwise with more subjects it becomes quite expensive.

(d) Analysis of Data

First decide which frames are to be used for analysis of data. For this, first see the whole film and decide. Use a film reader (Digitizer and Projector) to display x-y coordinates. Digitizers can also be connected to computers to directly get the scores of x and y coordinates.



Deterministic model of a long jump used in preparing for qualitative analysis.


PREPARATION
* Knowledge of the activity
Identify critical features
Goal of the movement
* Knowledge of performers
* Relevant systematic observational strategies
INTERVENTION
Select appropriate intervention
Feedback
Visual models
Exaggeration
Modifying the task
Manual/Mechanical guidance
Conditioning
*Principles for providing feedback
*Translating critical features into cues
(repeat if necessary)
OBSERVATION
*Implement observational
strategy Situation
Vantage points
Number of observations
*Extended observation
VEALUATION/DIAGNOSIS
*Evaluation of performance
Range of correctness of critical features
Strengths
Weaknesses
*Diagnosis of performance
Prioritize weaknesses
Rational of prioritizing

Sports Biomechanics

Qualitative analysis of motor Skills

Second type of analysis of motor skills may be the Biomechanical analysis. Again, this may be (a) **qualitative mechanical analysis and (b) quantitative mechanical**
analysis, Quality is a characteristic that constitutes the basic nature of a thing. It is the degree of excellence, which a thing possesses. Quantity is the property that can be determined through either counting or measuring. A qualitative analysis involves nominal analysis (identifying the components of the whole) and evaluative analysis (comparing and judging). A quantitative analysis, on other hand, deals with the accurate determination of the amount of various components of a thing.

Qualitative biomechanical analysis of a movement skill is breaking down the total movement into its basic elements and then qualitatively examining those elements from biomechanical perspective. Usually the teachers and coaches perform this analysis to observe the performance of their students and describe the mechanical characteristics of the performance. The sense of visual observation is the basis of most of the qualitative analyses. Comparative descriptors (faster, slower, higher, lower, shorter, longer, larger) may be used to describe the characteristics. The approach may be different depending upon the goal of analysis; the general scheme of qualitative biomechanical involves four steps: (1) **Preparation^!) Observation, (3) Evaluation and (4) Intervention.**

Preparation - It is also known pre planning or pre observation. The purpose is to develop a theoretical model of the most effective technique and to describe it. It includes (a) gathering knowledge of the skill, (b) identification of purpose of the skill and (c) identification of the characteristics of the most effective skill.

For **gathering knowledge** past experience should be used, the experts should be Consulted and the information of the scientific research should be referred. Knowledge of the skill includes the rules of activity, nature of equipment and even the knowledge of the performer.

The second step is to **identify the purpose** and interpret that purpose in mechanical terms. The purpose of some sports is easy to define, for others, it is more difficult. Some sports may have one purpose; others may have more than one. Sometimes identifying the purpose is not very difficult but defining that purpose mechanically may be.

The next step i.s to **identify the characteristics of most effective technique.** For this, the traditional technique should be assessed at first. Thereafter, the model of most effective technique should be developed. The task here is to determine which aspects of the traditional technique are important and which are not. This can be done in two ways. **Firstly,** the execution of the skill by elite performers should be observed as many times as possible. From this the actions that are common to all these athletes should be identified. Then each action should be assessed by asking how it contributes to the mechanically to achieving the purpose of the skill. Those actions that contribute to the achievement to the goal should be included as characteristics of the effective skill. The **second way** is to assess the actions common to the technique as illustrated in most of the coaching materials.

It may be easier to break down the purpose of the skills into part. During assessment of the specific action it should be noted how the action contributes to achieving the specific part or sub-goal.

Observation - The second step in qualitative biomechanical analysis of sports technique is the observation. Visual observation is the primary basis for most of the biomechanical analysis, but the observation needs to be planned in advance considering (i) **whom will you observe? (ii) What conditions will the subjects perform under? Where will you observe the performance? What will you look for? .**

Whom to observe? Observation will depend upon the level of performance of the athlete, For novice athletes the errors (i) will be easily recognised, (ii) may not be repeated, (iii) performance may be variable. So, detailed analysis will be difficult and useless.

For highly skilled athletes, the errors will be minor. So, detailed analysis will be required. As the performance will be less variable in this case, the errors will be repeated in the performance.

What condition? The environment of performance varies from class practice session to the competition. The actual competition may be the best for the athlete; it may not be very suitable for observation because of obstructions of officials and other athletes. The normal class practice session is also not ideal for observation because it may not stimulate for normal performance. However, for the beginners the normal class sessions may be used for observing the performance. For elite athletes it is required to stimulate the normal performance and minimize the distractions.

Where to observe? Where to observe determines what parts of the performance will be visible. If the activity has principal plane of movement, the line of sight should be perpendicular to that plane. Running, long jumping, vaulting in gymnastics, basketball free throw backstroke swimming etc. are the examples of activities whose movements occur in sagittal plane. This sagittal view may be observed either from the right or left side. A closer view is desirable if only a certain aspect of performance is evaluated. On the other hand a more distant view is better for evaluating the performance as a whole.

Activities with multiple planes of motion require multiple viewing positions. In these cases at first the most important part of the skill should be selected.

It is better to videotape the performance from different viewing positions. This .helps to view the same trial again and again with affecting the subject for fatigue. In addition, video record will be useful for giving feedback to the athlete or coach about the performance.

What to look for? Following are some of the distinguishing features to look for during observation.

1. The position of the body or body segments at specific instants. This indicates the direction of force application as well as the range of motion. Examples: instant of release in throwing activities (shot put, Javelin throw, discus throw. Basketball free throw etc.), the instant of take-off in jumping activities (running, hurdling, high jumping, volleyball spiking, diving etc); the instant of contact in striking activities (kicking, serving, hitting in all racket activities, punching in boxing, spiking in volleyball etc.). The instant the mark the beginning of these movements should also be examined (instant of take off contact in jumping, start of initial forward movement in throwing and striking activities).

2. The duration and range of motion of the body and its segments during specific phases of the skill, especially the force producing phases. (For high jumping: the duration of take-off phase and the vertical range of motion of the arms and free leg, propulsion phase during throwing and jumping).
3. The velocity and acceleration of the body segments during specific ' phases of the skill. For high jump: the vertical velocity of the arms and free leg as fast as possible during take-off. It is more useful to assess the acceleration of the limb. Once the forward motion is initiated, it is to be seen whether the throwing or striking limb or implement is continuously accelerated.
4. The timing of body segment motions relative to each other. For high jump: do the arms and free leg swing together in upward direction during take off? For throwing and striking activities, the movement is initiated by larger limbs (the legs) and proceeds in sequence to the smaller throwing or striking limbs. **Evaluation-** This is the third phase of qualitative analysis. This is done in two steps. First, the detection of errors and the second, the evaluation of the errors. Evaluation of errors should be done by comparing the actual performance to the characteristics of most effective technique. After identification of faults they should be evaluated in terms of their cause and effect. Several points should be emphasized here.

1. Does the error expose the performer to the danger or injury^ Such errors should be corrected immediately.
2. Is the error caused by the strength deficiency or is it due to incorrect staring position. Will it take months, weeks days or only one practice session to correct?
3. Is the error s result of another error that occurred earlier? If so, the another error should be the focus of correction.
4. Is the error due to poorly designed equipment?
5. How great the effect does the error have on the performance?

After evaluating each error in light of above concerns, it is to be decided which error to correct in which order. For this the errors should be ranked in three categories: (1) from major to minor in terms of their effect on the performance; (2) from earliest to latest in terms of their chronology during performance; and (3) from easiest to most difficult in terms of the time and effort it will take to correct them. **Intervention-** The purpose of this phase is to correct the errors for improving performance. For this three things should be done. First, the athletes should be communicated what their error was. Second, the athletes should be communicated what should be done for correcting the errors, Third, the athletes should be told how the errors should be corrected.

For communicating the performers verbal explanation or showing the videotape of the performance can be used. It is better to correct one error at a time. During communication the teacher should be positive and patient.

For correction the appropriate means and methods should be developed. The skills along with the drills should be taught as a corrective measure. During this process emphasis should be more on learning the correct movement sequence. Speed of movement should be regulated. The total structure of movement should be taught in parts in proper sequence.

Sports Biomechanics Quantitative Biomechanical Analysis

Quantitative Biomechanical analysis: While qualitative analysis is non numerical analysis of movement, the quantitative analysis is based on numerical measurement of performance. Comprehensive quantitative biomechanical analysis is usually done for the performance of elite athletes. It requires specialised and expensive equipment tor recording and measuring the mechanical variables of interest. It needs biomechanists or trained technicians. It involves analysis of **both kinematic and kinetic factors** of movements executed. **Kinematic analysis** involves the recording of the original movements by high-speed movie camera or video camera and through subsequent projecting the recorded motion in slow motion obtaining the basic (distance -time) information by using motion analyser. From these basic information the other kinematic measures like displacement, velocity, and acceleration - both linear and angular may be obtained. For **kinetic parameters** the force platforms and other such devices are used. For measuring parameters related to the muscle activity, the EMG technique may be used. Most of these equipments are interfaced with computers. In most of the cases the appropriate softwares are available. Like qualitative analysis there may be four steps in quantitative analysis -a) **the preparation; b) the recording; c) analysis and evaluation and d) intervention.** Preparation includes gathering knowledge about the activity and finalising the purpose of analysis. Recording includes either capturing the whole movement structure in original or the measuring the force and other kinetic factors that are responsible for the movement activities. The methods used for quantitative analysis are (1.) Cinematography, (2) Videography and (3) Dynamography.

Cinematography: Cinematography' is a fundamental method for analysing kinematic parameters of sports movements. It refers the whole process of recording of the movement by a movie camera, examining the recorded movement in slow motion or freeze by motion analyser and assessing the mechanical parameters of the movement performance. So, the cinematography has the following phases:

A) Cine filming;
B) Projecting the film;
C) Measuring the data from the projected film; and
D) Analysis of the data obtained.

A. Cine filming

Cine filming is the technique for recording for recording and storing information of human activity. As an experimental method it is a versatile and simple method. It has advantages over other techniques as -

1) it is a non contact method of recording movement;
2) it records all the details of the original movements;
3) it records the movements even without the knowledge of the performer;
4) it can be used successfully both in training as well as competition situations;
5) it is a simple method.

Following factors are very important for scientific filming -

a) Cine cameras Usually 16mm movie cameras are used for most of the scientific analysis. It is better to use motor driven cameras. The frequency of the camera should be 30 to 100 frames per second for carrying out biomechanical studies economically and accurately.

b) The environment of the filming: FOT scientific filming the following facilities are needed;

1) Black back cloth;
2) Distance measuring scale;
3) Horizontal and vertical reference lines; and
4) A timing device for accurate knowledge of the camera frequency.

Back black cloth - Large rolls of matt black paper are available from photographic suppliers. Provide a backing that can be set up and removed within a few minutes. Black curtain is more durable and, if provided with hooks, rings or a supporting rail, is also quickly positioned.
Distance measuring scale - It is necessary that the scaling should be established for relationship between a true length and its apparent length as seen on the projected film. The distance scale may be a straight bar with equal distances marked clearly on it black and white. It is important to place the distance measuring scale in the plane of motion. Reference axes - The vertical and horizontal axes are important as reference lines on the picture from which the coordinates of points on the body will be measured. They should be visible to the camera throughout the filming process. Timing - For determining the camera frequency a clock or other timing device may be placed in the camera's field of view. If possible a digital timer may be filmed directly This will provide a permanent record of the elapsed time on the film itself.

c. Preparing the subject:

In preparing the subject for cine filming, the main concern is to mark the joints (points of interest) on the body as precisely as possible. Black disc markers on the skin or •direct marking with felt pen are the usual methods. Greater contrast may be obtained by whitening the area of skin around the marker. Placing the discs is fairly simple for the ankle and wrist joint but problems may be encountered in locating the knee, hip and shoulder joint markers. If the skin over the hip joint is to be visible to the camera, the subject will have to wear briefs. The elbow and shoulder joints are sometimes not sufficiently well marked by discs, which tend to be reported out of view during arm flexion. A black band may be used in such cases.

d .Cine filming: (Recording the movement)

After completing the required preparations for the subject and the filming environment the filming should be done. The camera should be as far away as from the subject as possible to keep 'obliquity' error ^;i small as possible. It is better to use a tele lens wherever possible. The axis of the camera must be perpendicular to the direction of movement to be recorded. Camera should be started a few seconds earlier than the actual movement to be captured.

B Projecting the film

Processing and initial testing- After filming the film should be chemically processed. It is desirable to have permanent film studio to carry out biomechanical studies., but in case it is not available, the film should be taken to the professional studio for development.

Projection - A first examination of the processed negative or positive copy may be made with a slide projector having filmstrip attachment. The nest stage is projecting the film using a specialised analysing projector. The important feature here should be stationary projection of the single frame A frame counter and push button feed are usually provided and the projector may run at steady low speed for slow viewing.

Screen- The screen for projection will be the surface on which measurements are taken. A cloth screen is not really suitable, A matt a white cleanable panel is the best. .Alternately, white cartridge paper taped firmly to a rigid board may be replaced as necessary. The screen must be accurately set at right angle to the projection axis.

X-Y film analyser- The film is projected on a cabinet mounted back projection screen by a projector with single frame feed. At sides of the screen carry horizontal and vertical sliders with cursor. When the cursor is located at a particular point on the projected picture, a push button system can be used to read off the X and Y coordinated of the point.

,

C. Measurement of the projected film

After projecting a particular frame, it will be informative to draw 'stickman' configurations from the frame and horizontal and vertical reference lines should be included for correct spatial location. Measurement of linear coordinates will be easy on a projection of reasonable size (6-10 inches). A steel ruler should measure the distance. When an angle measurement is required, a protractor is not used in the dark room and it is better to draw lines on the screen to indicate the required limb positions. If much overlapping occurs in the drawing, a new paper sheet screen will be needed for every few frames. Finally, the measurement of the distance scale as it appears on the projector must not be forgotten.

D. Analysis of cine data

The data available will provide the Distance- time information of the movement of a particular body part. This information should be used to present the measured quantities graphically without any intervening calculations. The analysis may be taken to a further stage of difficulty if linear and angular velocities are required. The normal method of differential calculus cannot be used because the displacements are not in algebraic form. The tabulated displacement time- data from film measurement must be put through some form of numerical differentiation to produce values of velocity at each frame. Some smoothing may be incorporated to counter the effects of random errors or noise in the data. . .

Calculation of acceleration is carried out by taking the differentiation procedure one stage further. The estimation of force from film analysis depends upon the reliable . computation of acceleration values.

QUALITATIVE VERSUS QUANTITATIVE ANALYSIS

Qualitative analysis is by nature a subjective judgment call. This does *not* mean that it is unorganized, vague, or arbitrary in nature. In fact, we will see that qualitative analysis requires extensive information from many disciplines, planning, and systematic steps to be most effective.

Figure 1.1 illustrates a continuum of human movement analysis. Any analysis of human movement can be located somewhere along the continuum from qualitative to quantitative. Analyses of baseball pitching can vary from broad statements by television color commentators to statistical breakdowns of pitches and their locations to radar measurements of ball speed. The qualitative end of the continuum involves the nonnumerical analysis of movement data or a judgment on the quality of an aspect of movement.

Quantitative analysis, however, is based on some *measurement* of performance. If performance can be expressed in numbers, then the analysis is based on quantified data. Quantification of data (in seconds, feet, meters, degrees per second) moves the analysis further to the right on the continuum. But even research measurements (quantification of a very controlled nature) cannot be purely objective. There is some subjectivity in deciding where to place the tape measure or where to take a skinfold measurement. Quantification does not automatically ensure validity and reliability, and the lack of quantification in a qualitative analysis does not automatically mean the assessment is less valid or reliable.

Information from traditional qualitative analysis in kinesiology falls near the left side of the analysis continuum. Most teachers or coaches use qualitative analysis in everyday practice situations to diagnose and correct errors. Other movement analyses are midway along the continuum. Evaluation of skill or developmental level using a rating scale or timing a 40-yard dash is at the beginning of quantified performance.

The highest levels of quantitative analyses in sport sciences, such as biomechanics and exercise physiology, are primarily being performed in university research settings or at the Olympic Training Centers for elite athletes. Biomechanists measure instantaneous values of velocity, acceleration, or force for various parts of the body. Physiologists measure oxygen consumption, body fat, or amounts of lactic acid in the blood. Generally, these measurements of human movement have been too expensive for widespread use in teaching and coaching settings.

A situation where a qualitative analysis would be helpful is illustrated in figure 1.2, where an athlete has missed a fly ball during outfield practice. A good qualitative analysis of this situation would include specific feedback to the performer to help improve subsequent performance. Many teachers might attempt to correct the hand position, which is clearly not the best hand position for fielding balls above the waist. The real question is whether a qualitative analysis integrating all sources of information would suggest

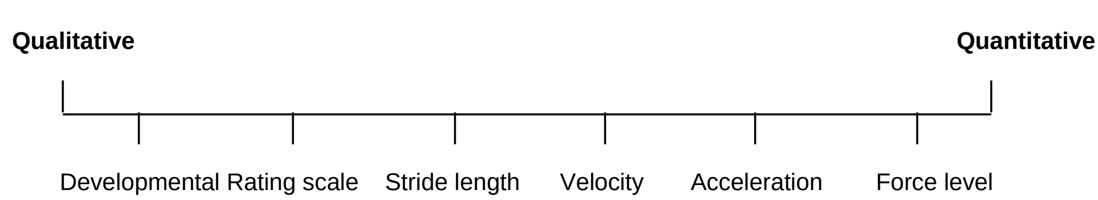


Figure 1.1 Sample continuum of human movement analysis for analyzing running.

**Video graphic analysis Videography-
possibilities and limitations**

Recently, video graphic technique has begun to replace conventional cinematographic technique for motion analysis. The advantage of this technique over the cinematographic technique are:

1. Videotape is erasable and reusable,
2. Videotape does not require developing;
3. Videotape is more economical than film;
4. The recorder is inexpensive and portable;
5. The recorder is simple to operate and permit immediate play back.

With all these advantages video graphic technique is very appropriate for teaching, coaching and qualitative analysis. But it is not generally suitable for research of a quantitative nature. The image on the video recorder is formed by an electron beam impinging upon a fluorescent screen. The beam scans the face of the cathode ray tube at a rate of 30 fps. While the videotape is acceptable for viewing purpose, it is not of sufficient resolution and linearity to permit fine measurement. In addition, the image tends to deteriorate }f the types are stored for extended period of time.

Video technology

Video images are limited representations of reality because those are made up of a **2-D array of dots.** These dots that comprise each picture.are called **pixels** (short of picture elements). Each picture element is given a shade on the gray scale (from black to white) for a black and white video picture. Color video is made up of pixels that have been given an intensity or mix of red, green and blue light. A video picture is called a **frame** and is made up of two **halves, or fields.** One field is odd numbered, horizontal number of pixels and the other field is even-numbered horizontal lines. The number and size of the pixels determine the quality, of the video picture.

Video picture format is determined by broadcasting conventions that vary around the world. **National Television Standards Committee** (NSTC) standards are used in North America and Japan. The United Kingdom and European countries use **Phase Alteration Line (PAL)** video format, while the French and Russians use **Sequential Conleur a Memorie** (SECAM) video NSTC has 30 **frames** per second while PAL and SECAM have 25 **frames** per second.

The resolution of a **paused video** image becomes worse because of flickering of picture. **Flicker** is caused when there is motion between two halves of the video frame. Careful set up and procedural techniques are needed to collect images and to **digitize,** scale and make calculations from video data. Many of the video systems are based on digital video that break the video signal into each field and use sophisticated image processing to create sub pixel resolution. Stereo photogrammetric techniques and computers are needed to generate 3-D data from synchronised multiple camera images. At present, necessary softwares have been developed to **Capture** (transfer of analog video to disk). **Digitise** (automated video analysis). **Filter** (smoothing and filtering of random noise). **Transform** (computation of 3-D kinematic data based on video analysis), **Trim** (synchronise different video views), and **Display** (complete presentation for biomechanical analysis).

Experiment No. 1 Identification of Coordinal Axes and Planes for Human Body Motion

Principle: From the standpoint of science, human body is a solid tri (three) dimensional rigid object. So, it has three dimensions, viz, length, breadth, and height. For explaining the orientation of the body, mention of these three directions is needed. The movements of human body as a whole or in parts also take place around three axes in three planes. These axes are intersecting and mutually, perpendicular to one another. Similarly, the planes are also intersecting and mutually perpendicular to one another. The line of intersection between two planes indicates an axis. These planes and axes are termed as "cardinal" or "primary" when the pass through c.g. of the body.

Axes: Axis is an imaginary line around which the body segment rotates. The three mutually perpendicular axes are identified for human body motion such as sagittal axes or anterio-posterior axis, transverse axis or medial-lateral axis, and longitudinal axis. When these axes pass through the center of gravity of the body, they become the primary axis. When these axes pass through the joint of any other limb these axes become secondary axes. Sagittal axes passe the body from front to back. The movements like abduction and adduction take place around this axis. Transverse axis passes from side to side. Flexion and extension take place around this axis. Longitudinal axis passes from top to bottom along the length of the body part that rotates. Circumduction and rotation take place around this axis.

Planes: Planes are basically the geometrical figures with two dimensions-length and breadth. When a body part rotates around on axis, it forms a plane during its path of motion. Like axes there are three planes for human body motion. These are sagittal plane, frontal plane and transverse plane. Sagittal plane divides the body into left and right halves. The frontal plane divides the body into front and back halves and the transverse plane divides the body into upper and lower halves.

Abduction and adduction takes place around sagittal axis but in frontal plane. In fact, sagittal axis is perpendicular to frontal plane. Flexion and extension take place around transverse axis but in sagittal plane. In fact, the transverse axis is perpendicular to sagittal plane. Circumduction and rotation take place around longitudinal axis but in the transverse plane. In fact, the longitudinal axis is perpendicular to transverse plane.

Experiment No. 2 Study on Fundamental Movements of Human Body

Principle:

Human body is complex machine. Inspite of its biological limitations, it can produce movements with infinite variations and with supreme accuracy. Human body movements are the result of combination of the simple basic movements of various joints. These movements vary from one another in respect of direction, planes and axes, range etc. The basic movements possible at difference joints of human body are technically known s fundamental movements.

Flexion:

Bending part at a joint so that the angle between them is decreased and the part come closer together. Flexion takes place around transverse axis in a sagittal plane.

Extension:

Straightening parts at a joint so that the angle between them is increased and the parts move further apart. Extension takes place around transverse axis in a sagittal plane.

Hyperextension:

Excessive extension of the parts at a joint beyond the anatomical position. Hyperextension takes place around transverse axis in a sagittal plane.

Dorsi-flexion:

Flexing the foot at the ankle. Dorsi flexion takes place around transverse axis in a sagittal plane.

Planter flexion:

Extending the foot at the ankle. Planter flexion takes place around transverse axis in a sagittal plane.

Abduction:

Moving a part away from the midline. Abduction takes place around sagittal axis in a frontal plane.

Adduction:

Moving a part towards the midline. Adduction takes place around sagittal axis in a frontal plane.

Rotation:

Moving a part around a longitudinal axis. Rotation takes place around longitudinal axis in a transverse plane.

Circumduction:

Moving a part so that its ends follow a circular path. Circumduction is a combination of movements.

Supination:

Turning the hand so the palm is upward or turning the foot so that the medial margin is raised. Supination takes place around longitudinal axis in a transverse plane.

Pronation:

Turning the hand so that the palm is downward or turning the foot so that the medial line is lowered. Pronation takes place around longitudinal axis in a transverse plane.

Eversion:

Turning the foot so that the sole is outward. Eversion takes place around the longitudinal axis in a transverse plane.

Inversion:

Turning the foot so that the sole is inward. Inversion takes place around the longitudinal axis in a transverse plane.

Protraction:

Moving a part forward.

Retraction:

Moving a part backward.

Elevation:

Raising a part (shrugging the shoulders)

Depression:

Lowering a part (dropping the shoulders)

Experiment No. 3 Study of the Muscle of Shoulder Joint and their Action

Anatomy of the Shoulder Joints:

The shoulder joint is a ball and socket joint that consists of the rounded head of the humerus and the shallow glenoid cavity of the scapula. The coracoid and acromion processes of the scapula protect these parts above. They are held together by various connective tissues and muscles.

The joint capsule of the shoulder is attached along the circumference of the glenoid cavity and the anatomical neck of the humerus. Although it completely envelops the joint, the capsule is very loose and by itself is unable to keep the bones of the joint in close contact. However the capsule is surrounded and reinforced by muscles and tendons and these structures are largely responsible for keeping the articulating parts of the shoulder together.

The ligaments that help prevent displacement of the articulating surfaces of the shoulder joint include coracohumeral ligament, glenohumeral ligament, transverse humeral ligament and glenoidal labrum.

The muscles and their origin, insertion and action

Sl. No.	Muscle	Origin	Insertion	Action
1.	Coracobrachialis	Coracoidprocess of scapula	Shaft-of humerus	Flexion and Adduction
2.	Pectoralis Major	Clavicle, sternum and coastal cartilages	Intertubercular groove of humerus	Flexion Adduction rotation
3.	Teres major	Lateral border of scapula	Intertubercular groove of humerus	Extension, adduction rotation
4.	Latissimus dorsi	Spine of sacral, lumber and lower thoracic vertebrae	Intertubercular groove of humerus	Extension, adduction, rotation and downward pull.
5.	Supraspinatus	Posterior surface of scapula	Greater tubercle of humerus	Abduction
6.	Deltoid	Acromion process of scapula, clavicle.	Deltoid tuberosity of humerus	Abduction, extension, or flexion.
7.	Subscapularis	Anterior surface of scapula	Lesser tubercle of humerus	Medial rotation.
8.	Infraspinatus	Posterior surface of scapula	Greater tubercle of humerus	Lateral rotation
9.	Teres minor	Lateral border of scapula	Greater tubercle of humerus	Lateral rotation.

Experiment No. 4. Study on the Muscles of Elbow Joint and their Action

Anatomy of the elbow joint

The elbow in a complex structure that includes two articulations a hinge joint between the trochlea of humeras and the trochlear notch of the ulna, and a gliding joint between the capitulum (foves) on the head of the radius. These unions are completely enclosed and held together by a joint capsule, whose sides are thickened by ulner and radial collateral ligaments and whose anterior sutitace is reinforced by fibers from a muscle (brachialis) in the upper arm.

The ulner collateral ligament, which consists of athick band of fibrous connective tissue, is lorated in the medial wall of the capsule. The anterior portion of this ligament connects the medial epicondyle of the humerus to the medial margin of the coronoid process of the ulna. Its posterior part is attached to the medial epicondyle of the humerus and to the olecranon process of the ulna. The radial collateral ligament, which strengthens the lateral wal of the joint capsule, is composed of a fibrows band extending between the lateral cpicondyle of the humerus and the annular ligament of the radius. The annular ligament is attached to the margin of the trachlear notch of the ulna, and it encircles the head of the radius, functioning to keep the head in contact with radial notch of the ulna. the synovial membrane that forms the inner lining of the elbow capsule projects into the joint cavity between the radius and ulna and partially humerus radial portions.

The muscles of this joint and their actions are as follows

Muscle	Origin	Insertion	Action
1. Bicepsbrachi	Coracoid process and tubercle above glenoid cavity	redial tuberosity of vadius	Flexion lateral rotation
2. Brachialis	Anterior shaft of humers	Coronoid Process of ulna	Flexion
3. Brachio radialis	Distal lateral end of humerus	lateral surface of radius above styloid proces	Flexion
4. Triceps brachii	Tubercle below glenoid covity and lateral and medial surface of humerus	Olecranon process o9f ulna	Extension
5. Supinator	Lateral condyle of humerus and crest of ulna.	Lateral Surface of radius	Laleral rotation
6. Pronator teres	Medial epicondyle of humerus and coronoid process of ulna	Lateral surface of radius	medial rotation
7. Pronator quadratus	Anterior distal end of ulna.	Anterio distal end of radius	Medial rotation

Experiment No. 5 Study of the Muscle of Hip Joint and their Action

Anatomy of the hip joint:

A hip joint is a ball and socket joint that consists of the head of the femur and the cup-shaped acctabulum of the coxal bone. A ligament (ligament capitis) is attached to a pit (fovea capitis) on the head of the femur and to connective tissue within the acetabulum. This attachment deems to have little importance in holding the articulating bones together. Instead, it serves to carry blood vessels to the head of the femur. A horseshoe shaped ring of fibrocartilage at the rim of the acetabulum deepens the cabity of the acetabulum. It encloses the head.

The muscles of this joint and their functions are as follows:

Muscle	Origin	Insertion	Action
1. Psas major	Lumber interver tibral disksi bodies and transverse processes of lumber vertebrae	Lesser trochanter of femur	Flexion
2. Lliacus	lliace fossa of ilium	Lessertrochanter of feur.	flexion
3. Gluteus maximus	Sacrum, Coccyx and posterior surface of Ilium.	posterior surface of femur and fascia of thingh	Extension
4. Gluteus Medius	Lateral Surface of llium	Greater tronhanter of femur	Abduction rotation (medially)
5. Gluteus minimus	lateral surface of llium	Greater trochanter of femur	Abduction rotation (medially)
6. Tensor fasciae latae	Anterior iliac crest	Fascia of thigh	Abduction flexion rotation (medially)
7. Adductor longus	Pubic bone near	Posterior of femur	Adduction flexion rotation (lateral)
8. Adductor magnus	Ischial tuberosity	Posterior surface of femur	Adduction extension rotation (lateral)
9. Gracilis	Lower edge of symphysis pubis	Medial surface of tibia	Abduction (lhigh) flexion (leg)

Experiment No. 6 Study on the Muscle of Knee Joint and their Action

Anatomy of the knee joint:

Knee joint is the largest and most complex synovial joint. It consists of the medial and lateral condyles at the distal ends of the femur, and the medial and lateral condyles at the proxial end of the tibia. In addition, the femur articulates anteriorly with the patella. Although the knee is sometimes considered a modified hinge joint, the articulations between the femur and tibia are condyloid, and the joint between the femur and patella is a gliding joint.

The joint capsule of the knee joint is relatively thin, built greatly strengthened by ligaments and the tendons of several muscles. Anteriorly the capsule is covered by the fused tendons of several muscles is the thigh. Fibers from these tendon depends to the patella, partially enclose it, and continue down word to the tibia. The capsule is attached to the margins of the femoral and tibia condyles as well as to the areas between these condyles.

The ligaments associated with the joint capsule that help keep the articulating surface of the knee joint in contact include patleller ligament, obligue popliteal ligament, arcuate popliteal ligament, tibia collateral ligament, fibular collateral ligament. In addition to the ligaments that strengthen the joint capsule, two ligaments within the joint, called cruciate ligaments, help prevent displacement of the articulating surface. These strong bands of fibrous tissue stretch upward between the tibia and the femur, crossing each other on the way. They are named according to their positions of attachment to the tibia. Thus, the anterior cruciate ligament originates from the anterior inter condylar area of the tibia and extends to the lateral condyle of the femur. The posterior cruciate ligament connects the posterior intercondylar area of the tibia to the medial condyle of the femur.

Separating the articulating surface of the femur and tibia are two fibrocartilaginous menisci. Each miniscus is roughly C-shaped, with a thickrim and a thinner centre, and is attached to the head of the tibia. The medial and lateral minisci for depressions that fit the corresponding condyles os the femur, thus compensating for the differences in shapes between the surface of the femur and tibia.

The Muscles of the knee joint and their function are as follows:

Muscle	Origin	Insertion	Action
1. Biceps-femurs	Ischial tubero sity and linea aspera of femur	Head of tibia and lateral condyle of tibia.	Flexion and rotation of leg and extension of thigh.
2. Semitendinosus	Ischial tuberosity	Medial surface of tibia	Flexion, rotation (medially) of leg extension of thigh
3. Semimembranosus	Ischial tuberosity	Medial condyle of tibia	Flexion, rotation (medially) of leg, extension of thigh.
4. Sartorius	Anterior superior iliac spine	Medial surface of tibia	Flexion (leg thigh); abduction and rotation laterally of thigh.
Quadriceps femoris 5. Rectus femoris	Spine of ilium and margin of acctabulum	Patella by common tendon	Extention of knee
6. Vastus lateralis	Greater trachanter and posterior surface of femur.	Patella by common tendon.	Extension of knee
7. Vastusmedialis	Medial surface of femur	Patella by common ten don	Extension of knee
8. Vastus intermedius	Anterior and lateral surface of femur	Patella by common tendon	Extension of knee.

Experiment No. 7 Determination of Average Velocity

Principle: Velocity is defined as the distance covered by the body per unit time. Average velocity is calculated by the ratio of total running distance and the total time taken. Mathematically

Average Velocity $\overline{v}$ = distance (s) /time (t) where '$\overline{v}$' is the average velocity, 's' is the total distance covered and 't' is the time taken.

Equipments, Instruments and Tools

For measuring average velocity the following equipments, instruments and tools were used:

a) A 400m standard track, as a course of running
b) Three electronic stop watches, capable of measuring to 1/100th par to a second were used to measure the time taken by the subject to complete the race.
c) A starting device (clapper)
d) Finish post, kept in line with the finish line

Procedure

1. At first the subject was allowed to complete his warm up before the race.
2. Then he was instructed to fix the starting block for the race
3. The finish posts were placed on the finish line
4. The starter was stationed at the suitable place with the clapper
5. The time keepers were ready with the stop watch for recording time and were placed in line with the finishing line.
6. The starter started the race by sounding the clapper.
7. The time keepers started the watches with the start of the race and recorded the time up to the point of touching of the 'torso' with the vertical plane of the inner side of the finish line.

All the subjects (4) were tested as per the procedure explained above

Results

The time taken to finish the race (400m) by each subject as well as their average velocities are shown in the following table.

Table 1
Average Velocity of the Subjects in the 400m Race

Subject No.	Distance run (m)	Time taken (t) sec.				Average Velocity v=s/t m/s
		Watch-1	Watch-2	Watch-3	Official Time	
1	400	57.43	57.90	57.50	57.50	6.956
2	400	57.40	57.49	57.53	57.49	6.957
3	400	59.10	60.19	60.30	60.19	6.645
4	400	57.50	58.10	57.79	57.79	6.921

Conclusion

From the table values it is seen that subject no. 1 completed 400m race with an official time of 57.50 and average velocity of 6.956m/s. Subject no. 2 completed 400m race with an official time of 57.49 and average velocity of 6.957 m/s. Subject no. 3 completed 400m race with official time of 60.19 and average velocity of 6.645. The subject no. 4 completed 400m race with an official time of 57.79 and an average velocity of 6.921 m/s. So among the subjects, no 2 is first, no. 1 is second, no. 4 is third and no. 3 is fourth.

Experiment No. 8 Determination of Instantaneous Velocity

Principle: While velocity is defined as the rate of displacement, instantaneous velocity is considered to be the velocity at a particular moment or velocity at a particular time.

Mathematically v=ds/dt

So instantaneous velocity is defined as the rate of change of position for a very small duration of time within the course of movement of the body.

Equipments, Instruments and Tools

In the present experiment the following equipments, instruments and tools are used.

a) A 400m standard track.
b) Ten electronic stop watches, capable of measuring to 1/100th par to a second were used to measure the time taken by the subject to complete the race.
c) A starting device (clapper)
d) Finish post, kept in line with the finish line
e) Starting block for start

Procedure

Before starting the race the subject was instructed to warm up properly. The subject ran a distance of 100m. Ten time keepers were used to record the elapsed time at intervals of ten meters each. The starter used the clapper to start the race. The command used was 'on your marks', 'set' and 'go'. With the command 'go' the clapper was sounded. As soon as both the arms of the clapper came together, all the ten time keepers simultaneously started their watches. As the subject's torso touch the 10m , 20m, 30m and so on up to the finishing point, the concerned time keepers stopped their watches.

Subsequently with the help of distance-time (d-t) data, the distance-time curve was drawn on a graph paper. From this distance-time (d-t) curve instantaneous velocities at a distance of 70m and 90m were found out by tangent method.

Results

Distance-time information at different position of the subject is presented in the following table.

Table 1
The distance-time information at different distances

Distance (m)	10m	20m	30m	40m	50m	60m	70m	80m	90m	100m
Time (sec)	1.83	2.87	3.80	4.66	5.50	6.33	7.17	8.02	8.89	9.79

On the time-distance curve the 70m and 90m points were marked. At both these points tangents were drawn. The instantaneous velocity at each point was calculated by the following formula:

$$V = \frac{y_2 - y_1}{x_2 - x_1}$$

The instantaneous velocities at both points of the curve are presented in table 2.

Table 2
Instantaneous velocities at 70m and 90m points on the (d-t) curve for 100m run

Point	ds (y_2-y_1)m	dt (x_2-x_1) sec	v=ds/dt= y_2-y_1/x_2-x_1
A (v_1)	75-65=10		
B (v_2)	95-85=10		

Conclusion

The instantaneous velocities at point A (70m) was ------------- and at point B (90m) was --------------------.

Experiment No. 9 Determination of Centre of Gravity by Reaction Board Method

Principle: Centre of gravity is the point through which the resultant of all the forces of gravity of the body acts. It is considered as the point of balance. Determination of centre of gravity for a living human being is based on the principle of moment of force. According to this principle the sum of the moments of different parts of a body, in equilibrium is equal to zero.

Equipments and tools

The following equipments and tools were used for carrying out the test.

1. A wooden platform of 2.0 meter by 40cm was used.
2. A weighing machine capable of indicating the body weight to nearest 0.5kg.
3. A wooden scale of 1.00m length graduated in m. m.
4. White papers, marking pencil and other such general materials were used.

Procedure

Following steps were used:

1. The length of the reaction board between two sharp edges was measured by the scale. Let us consider the length was-l
2. The body weight of the subject was measured by weighing machine. Let the weight be – w.
3. The reaction board was placed in such a way that one of its knife edge is on the platform of the weighing machine and the other end on the solid base.
4. The initial zero reading of the scale of weighing machine was adjusted.
5. The level of reaction board was tested by mercury level.
6. The reading of the weighing machine with the reaction board is recorded. Let this reading be Rw.
7. The subject to lay supine on the board with the heel against the foot rest, the end of the board.
8. The reading of the scale is recorded. Let the weight of the subject be Bw.
9. Considering equilibrium position of the board, the clockwise and anticlockwise torques about the point of foot rest is zero.
   So, d x w = (Rw – Bw) x l
   Where d is the distance of centre of gravity from the foot of the subject
   or
   d = (Rw – Bw) x l /w

Result

The position of centre of gravity of the body has been presented in table 1.

Table 1

Determination of position of centre of gravity

Height (m)	Body Weight (kg)	Scale Reading		Length of the Board (l) m	Position of cg.	Percentage
		With Board (kg) Bw	With Subject & Board Rw (kg)			

Conclusion

The position of centre of gravity of the subject is situated at a distance of -------- from the ground which is ------ percent of his body height.

Experiment No. 10- Measurement of Leg Strength by Dynamometer

Principle:

Measurement of force is very important in sports biomechanics. As it is the cause of motion, its measurement helps us to understand the effectiveness of an applied force for any kind of skill execution. Force tends to bring about changes in size and shape of the body or its state of motion. Force causes deformation of an object. Due to the elastic property of matter this deformation becomes proportional to the applied force within elastic limit. So, the applied force can be quantified by measuring the elongation of the matter as a result of force.

In the mechanical dynamometer this elongation is measurable. The principle here is $F \alpha \Delta l$. For increasing accuracy, the deflection of the needle due to the elongation of the material is enlarged by means of lever principle. Finally, the amount of force is found out from the scale indicated by the pointer.

Instruments:

For measuring leg and back strength the following instruments was used:

1. Leg and Back dynamometer

Procedure:

Measurement of Leg Strength
The Leg and Back Dynamometer measured the Leg Strength in the following way:

1. The subject stands erect with the hands on the front of the thighs, fingers extended downward, elbows slightly flexed, knees bent and trunk straight.
2. The tester then hooks the chain so that the bar level remains just below the finger tips of the subject.
3. The subject grasps the handle firmly with the help of fingers, keeping the elbows flexed knees bent and trunk straight.
4. Before pulling the chain the pointer of the dynamometer was kept at the ‘0’ mark.
5. The tester firmly grasps the subject’s hands during the lift.
6. Keeping the elbows flexed and trunk straight, the subject straightens the legs. The head was kept up and the eyes directed straight ahead.
7. As the subject straightened the knees, the pointer of the dynamometer moved across the scale to indicate the strength applied. The reading on the pointer was noted. This reading was the leg strength of the subject.
8. Every subject was given three trials and the mean values were considered as the leg strength of the subject.

Results:

In the present experiment two subjects were tested and the results have been presented in the following table.

Table 1

Leg Strength of Subjects as Measured by Leg and Back Dynamometer

Subject Name	Trial No.	Initial Reading (kg)	Final Reading (kg)	Mean Value (kg)	Rank
Mizan	1 2 3	0	85 100 95	93.33	2
Amin	1 2 3	0	105 120 110	111.67	1

Conclusion:

From the results of the present experiment, the following conclusion is drawn:

1. The leg strength of Amin is more than the leg strength of Mizan.

Experiment No. 11- Measurement of Back Strength by Dynamometer

Principle:

Measurement of force is very important in sports biomechanics. As it is the cause of motion, its measurement helps us to understand the effectiveness of an applied force for any kind of skill execution. Force tends to bring about changes in size and shape of the body or its state of motion. Force causes deformation of an object. Due to the elastic property of matter this deformation becomes proportional to the applied force within elastic limit. So, the applied force can be quantified by measuring the elongation of the matter as a result of force.

In the mechanical dynamometer this elongation is measurable. The principle here is $F \alpha \Delta l$. For increasing accuracy, the deflection of the needle due to the elongation of the material is enlarged by means of lever principle. Finally, the amount of force is found out from the scale indicated by the pointer.

Instruments:

For measuring leg and back strength the following instruments was used:

1. Leg and Back dynamometer

Procedure:

Measurement of Back Strength

The Leg and Back Dynamometer measured the Back Strength in the following way:

1. The subject stands erect with the hands on the front of the thighs, fingers extended downward, elbows and knees straight and trunk slightly flexed at the waist.

2. The tester then hooks the chain so that the bar level remains just below the fingertips of the subject.

3. The subject grasps the handle firmly with the help of fingers, keeping the elbows and knees straight and trunk bent.

4. Before pulling the chain the pointer of the dynamometer was kept at the '0' mark.

5. The tester firmly grasps the subject's hands during the lift.

6. Keeping the elbows straight and trunk flexed, the subject straightens the trunk. The head was kept up and the eyes directed straight ahead.

7. As the subject straightened the trunk, the pointer of the dynamometer moved across the scale to indicate the strength applied. The reading on the pointer was noted. This reading was the leg strength of the subject.

8. Every subject was given three trials and the mean values were considered as the back strength of the subject.

Results:

In the present experiment two subjects were tested and the results have been presented in the following table.

Table 1

Back Strength of Subjects as Measured by Leg and Back Dynamometer

Subject Name	Trial No.	Initial Reading (kg)	Final Reading (kg)	Mean Value (kg)	Rank
Mizan	1 2 3	0	90 105 100	98.33	2
Amin	1 2 3	0	110 125 115	116.67	1

Conclusion:

From the results of the present experiment, the following conclusion is drawn:

1. The back strength of Amin is more than the back strength of Mizan.

Assessment of Kinesiological and Sports Biomechanics variable (Posture) of Bangladeshi young active boys those who were appeared in BKSP admission test in different games and sports (Archery, Cricket, Football, Gymnastics, Hockey and Swimming)