SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – I – BIOMECHANICS – SBMA1403

INTRODUCTION

1.1 Biomechanics

Biomechanics is the study of the structure, function and motion of the mechanical aspects of biological systems, at any level from whole organisms to organs, cells and cell organelles, using the methods of mechanics.

Biomechanics is defined as mechanics applied to biology, and mechanics itself is the response of bodies to forces or displacements.

Biomechanics applies mechanical principles to the human body in order to understand the mechanical influences on bone and joint health.

Developments in the field of biomechanics have improved our understanding of normal and pathologic gait, mechanics of neuromuscular control, and mechanics of growth and form. This knowledge has contributed to the development of medical diagnostic and treatment procedures. It has provided the basis for the design and manufacture of medical implants and orthotic devices and has enhanced rehabilitation therapy practices. Biomechanics has also been used to improve human performance in the workplace and in athletic competition.

1.2 History of Biomechanics

Aristotle

Aristotle was fascinated by anatomy and structure of living things. Aristotle might be considered the first biomechanician. He wrote the first book called "De Motu Animalium" - On the Movement of Animals. He saw animals' bodies as mechanical systems and what causes these movements.

Galen

The second century anatomist, Galen, wrote his monumental work, On the Function of the Parts (meaning the parts of the human body) as the world's standard medical text for the next 1,400 years.

Leonardo Da Vinci

He had an understanding of components of force vectors, friction coefficients, and the acceleration of falling objects, and had a glimmering of Newton's 3rd law. By studying anatomy in the context of mechanics, da Vinci also gained some insight into biomechanics. He analyzed muscle forces as acting along lines connecting origins and insertions and studied joint function.

Da Vinci tended to mimic some animal features in his machines. For example, he studied the flight of birds to find means by which humans could fly; and because horses were the principal source of mechanical power in that time, he studied their muscular systems to design machines that would better benefit from the forces applied by this animal.

Galileo

Galileo , the father of mechanics and part time biomechanic made important contributions to biomechanics. He was particularly aware of the mechanical aspects of bone structure and the basic principles of allometry. Galileo Galilei was interested in the strength of bones and suggested that bones are hollow because this affords maximum strength with minimum weight. He noted that animals' bone masses increased disproportionately to their size.

Borelli

Borelli embraced this idea and studied walking, running, jumping, the flight of birds, the swimming of fish, and even the piston action of the heart within a mechanical framework. He could determine the position of the human center of gravity, calculate and measured inspired and expired air volumes, and showed that inspiration is muscle-driven and expiration is due to tissue elasticity. Borelli was the first to understand that the levers of the musculoskeletal system magnify motion rather than force, so that muscles must produce much larger forces than those resisting the motion.

1.3 Applications of Biomechanics

1. Sports Biomechanics - Subfield of biomechanics where the laws of mechanics are applied in order to gain a greater understanding of athletic performance through mathematical modeling, computer simulation and measurement.
2. Locomotion and Gait- Walking pattern analysis. Locomotion of humans and animals.
3. Fluid Biomechanics- the study of the fundamentals of biological fluid flow, has been recognized to be extremely important for the understanding of how changes in the flow behavior within living tissue maybe affect both the fluid and the tissue.
4. Cardiovascular Biomechanics - The Cardiovascular Biomechanics group performs research in the field of computational and experimental biomechanical analysis of the cardiovascular system.
5. Ergonomics - Ergonomics applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Ergonomics is the study

of people while they use equipment in specific environments to perform certain tasks. Ergonomics seeks to minimize adverse effects of the environment upon people and thus to enable each person to maximize his or her contribution to a given job.

6. Rehabilitation - Rehabilitation biomechanics is a field of study that addresses the impact of disability and the effectiveness of rehabilitation therapies and interventions on human performance. Engineering and physics principles are applied to evaluate and analyze body movement and manipulation.
7. Plant Biomechanics - Interdisciplinary science describing behavior of plants subjected to forces and displacements at the level of molecules, cells, tissues, organs, whole organisms, and ecosystems.
8. Forensics - Forensic biomechanics is the application of biomechanical engineering science to litigation where biomechanical experts determine whether an accident was the cause of an alleged injury.
9. Implant Designing- Designing of orthotic and prosthetic devices, heart valves, etc
10. Biomechatronics - Biomechatronics is an applied interdisciplinary science that aims to integrate biology, mechanics, and electronics. It also encompasses the fields of robotics and neuroscience. Biomechatronic devices encompass a wide range of applications from the development of prosthetic limbs to engineering solutions concerning respiration, vision, and the cardiovascular system.

1.4 Perspectives of Biomechanics

1. Historical Perspective
2. Technological Perspective - Incorporation of engineering, physics, computer, and mathematical concepts applied to human movement patterns.
3. Philosophical Perspective-Multidisciplinary, Creativity and theorizing.
4. Future Perspectives- continuation of descriptive types of biomechanical analyses, continued modification and improvement of equipment, continued invasion of the discipline by other professions

1.5 Fundamentals of Biomechanics

Biomechanics has 9 fundamental principles.

1. Force Motion Principle

Unbalanced forces are acting on our bodies or objects when we either create or modify movement.

Free-body diagram is a simplified model of any system or object drawn with the significant forces acting on the object.

II. Force –Time Principle

It is not only the amount of force that can increase the motion of an object; the amount of time over which force can be applied also affects the resulting motion.

III. Range of Motion

Overall motion used in a movement and can be specified by linear or angular motion of the body segments.

Increasing the range of motion in a movement can be an effective way to increase speed or to gradually slow down from a high speed.

IV. Balance

Person's ability to control their body position relative to some base of support.

Stability and mobility ofbody postures are inversely related

V. Coordination Continuum

How the muscle actions and body segment motions are timed in a human movement.

Two strategies -simultaneous/ sequential can be viewed as a continuum,

VI. Segmental Interaction

Forces acting in a system of linked rigid bodies can be transferred through the links and joints.

VII. Optimal Projection

Optimal range of projection angles for a specific goal.

VIII. Spin

Rotations imparted to projectiles.

Lift force is used to create a curve or to counter gravity, which affects the trajectory and bounce of the ball.

IX. Inertia

Property of all objects to resist changes in their state of motion.

Linear and angular measures of inertia are mass (m) and moment of inertia (I).

1.6 Elements of Biomechanics

- **Dynamics**: Studying systems that are in motion with acceleration and deceleration
- **Kinematics**: Describing the effect of forces on a system, motion patterns including linear and angular changes in velocity over time as well as position, displacement, velocity, and acceleration are studied.
- **Kinetics**: Studying what causes motion, the forces, and moments at work
- **Statics**: Studying systems that are in equilibrium, either at rest or moving at a constant velocity

1.7 Newton's Laws of motions

Newton's three laws of motion are the 3 physical laws, these

Newton's First Law (Law of Inertia)

An object at rest remains at rest, or if in motion, remains in motion at a constant velocity unless acted on by a net external force. laws of motion laid the foundation for classical mechanics. These laws explain the relation between forces and the body on which these forces acted upon Newton's 1st law of motion deals with the inertial property of matter. Objects do not move by their own unless someone moves them.

Newton's Second Law (Law of Momentum or Law of Acceleration)

Newton's second law shows how the forces that create motion (kinetics) are linked to the motion (kinematics).

It is represented as $F = ma$. This is the law of acceleration, which describes motion (acceleration) for any instant in time. It states that the acceleration an object experiences is proportional to the resultant force, is in the same direction, and is inversely proportional to the mass. If the net force were doubled, the acceleration of the object would be twice as large. Similarly, if the mass of the object were doubled, its acceleration would be half as large.

Newton's Third Law

For every action, there is an equal and opposite reaction.

The statement means that in every interaction, there is a pair of forces acting on the two interacting objects. The direction of the force on the first object is opposite to the direction of the force on the second object. Forces always come in pairs - equal and opposite action-reaction force pairs.

1.8 Mechanical Properties of Materials

Mechanical properties are physical properties that a material exhibits upon the application of forces. It helps to classify and identify materials. Also affects the mechanical strength and ability of a material to be molded in suitable shape.

(i) Stress-

To compare specimens of different sizes, the load is calculated per unit area, also called normalization to the area. Force divided by area is called stress. In tension and compression tests, the relevant area is that perpendicular to the force. In shear or torsion tests, the area is perpendicular to the axis of rotation.

σ=F/A, where F is force (N) and A is area (mm2).

(ii) Strain

The amount of deformation that takes place in a stressed body. The extension for a given load varies with the geometry of the specimen and its composition. There is a change in dimensions, or deformation elongation, L as a result of a tensile or compressive stress. To enable comparison with specimens of different length, the elongation is also normalized, this time to the length L. This is called strain.

No unit as it is a ratio of lengths.

$\varepsilon=(l-l_0)/l_0$, where l_0 is starting or initial length (mm) and l is stretched length (mm).

(iii) Elasticity

The basic experiment to determine the mechanical property is tensile test. In 1678, Robert Hooke – showed when a material is subjected to tensile (distraction) force would extend in the direction of traction by an amount that was proportional to the load. This is Hooke's law.

Materials that rebound back to their original dimensions after deformation, or being removed from its load are elastic materials.

When stress is proportional to strain it is Hookes law.

$\sigma = E\,\varepsilon$

E is the slope of the stress-strain curve. E is Young's Young's modulus or modulus modulus of elasticity

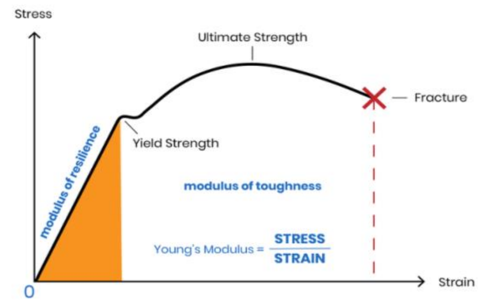

Fig 1.1 Stress Strain Curve

Yield Strength: Material stress value before plastic deformation. This place is called the yield point. Before it, a material regains its former shape when lifting the load. After exceeding the yield point, the material breaks.

Ultimate Tensile Strength: Indicates the maximum stress a material can withstand before fracturing. The deformation is permanent.

(iv) Shear

Shear is the Elastic property of a solid under the application of transverse internal forces or external.

Shear modulus is a measure of the ability of a material to resist transverse deformations forces.

It is the quotient of the shear stress divided by the shear strain.

Shear modulus = (shear stress)/(shear strain) = (F/A)/(x/y)

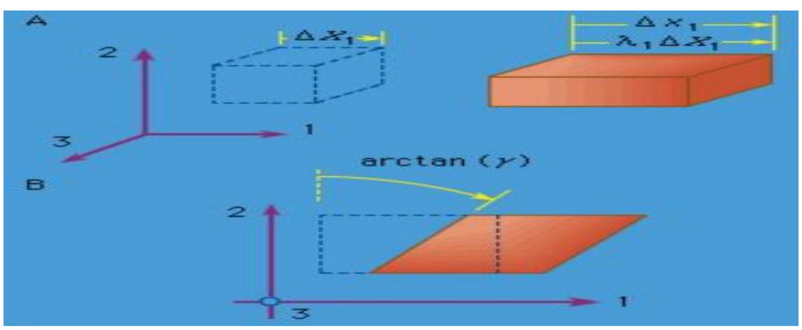

Fig 1.2 Shear

(v) Tension

A Pulling force transmitted axially by the means of a string, a cable, chain is tension.

When atoms or molecules are pulled apart from each other and gain potential energy with a restoring force still existing, the restoring force might create what is also called tension. Its unit is Newton.

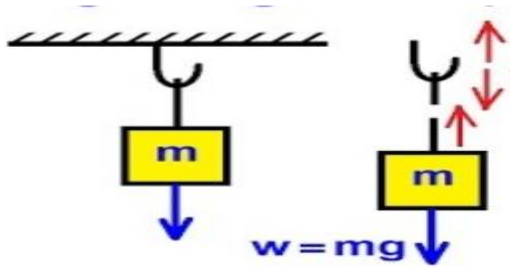

Fig 1.3 Tension

(vi) Compression

Physical force that presses inward on an object, causing it to become compacted. Relative positions of atoms and molecules of the object change. Change can be temporary or permanent depending on the type of material receiving the compressive force.

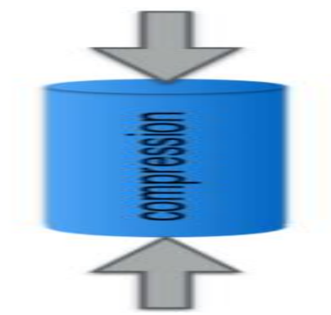

Fig 1.4 Compression

(vii) Plastic Deformation

It is a type of permanent deformation that occurs under stress before resulting in failure. Large scale displacement of atoms without complete rupture of a material is possible in the presence of metallic bond so only metals and alloys exhibit true plastic deformation.

For metals, alloys plastic deformation occurs before fracture occurs. Once plastic deformation starts, strain produced is very greater than those during elastic deformation and they are not recovered when stress is removed. This happens because whole array of atoms under the influence of an applied stress are forced to move to new locations in crystal. Since long distance re-arrangement of atoms under the influence of an applied stress cannot occur in ionic / convolutedly bonded materials, ceramic and many polymers exhibit only brittle behavior. This happens because whole array of atoms under the influence of an applied stress are forced to move to new locations in crystal.

Two related mechanical properties of materials are ductility and malleability.

Ductility - Property of a solid material which indicates that how easily a material gets deformed under tensile stress. It is expressed as a percent elongation or percent area reduction.

Malleability - Property of solid materials which indicates that how easily a material gets deformed under compressive stress.

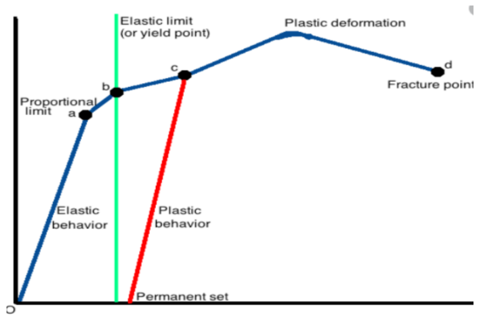

Fig 1.5 Plastic deformation curve

(viii) Creep

Creep is a slow, progressive deformation of a material under constant stress/load. A Time-dependent deformation under a certain applied load. Generally occurs at high temperature. Rate of deformation is called the creep rate.

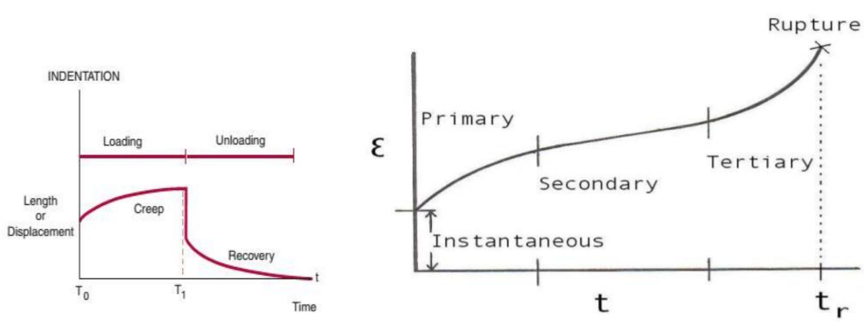

Fig 1.6 Creep curves

Stages of Creep

Primary Creep: starts at a rapid rate and slows with time.

Secondary Creep: has a relatively uniform rate.

Tertiary Creep: has an accelerated creep rate and terminates when the material breaks or ruptures. It is associated with both necking and formation of grain boundary voids.

(ix) **Fatigue**

It is the weakening of material caused by the repeated loading of the material.

When a material is subjected to cyclic loading, and loading greater than certain threshold value but much below the strength of material (ultimate tensile strength limit or yield stress limit), microscopic cracks begin to form at grain boundaries and interfaces.

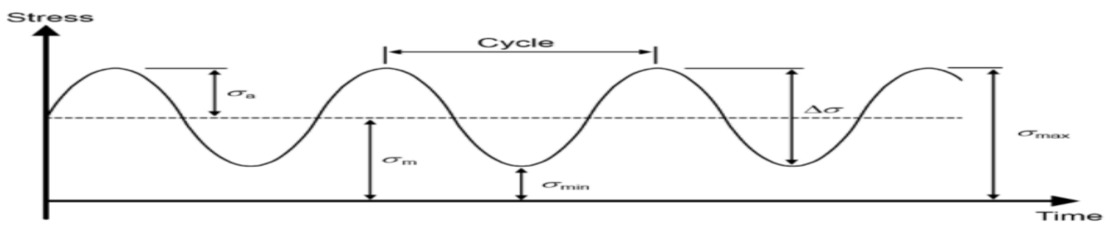

Fig 1.7 Fatigue Curve

1.9 Basic Engineering Mechanics

Statics

Dynamics

Kinetics

Kinematics

Rigid Body - A body is said to be rigid if the position of its various particles remain fixed relative to one another. A rigid body can be considered as a combination of a large number of particles in which all the particles remain at a fixed distance from one another, both before and after applying a load.

Mass- Matter contained in a body. Mass is scalar property of matter that does not change from one location to another.

Weight - Force by which the body is attracted towards the center of earth. It is defined as the force of gravity on the object and may be calculated as the mass times the acceleration of gravity, w = mg.

Time: Time is the measure of succession of events.

Space: Any geometric region in which the study of a body has been done is called space.

Displacement - Velocity of an object is the rate of change of its position with respect to a frame of reference, and is a function of time velocity.

Acceleration - Rate of change of velocity

Distance - Numerical description of how far apart objects are

Particle - Body with mass but with dimensions that can be neglected

Momentum: The product of mass and velocity is called momentum

1.10 Mechanical Testing of Materials

Mechanical testing is a standard and essential part of any design and manufacturing process. Whether it is characterizing the properties of materials or providing validation for final products, ensuring safety is the primary mission of all mechanical testing. Testing also plays a crucial role in ensuring a cost-effective design as well as technological evolution and superiority.

Two types of material testing

Destructive Testing/Mechanical Tests – Material may be physically tested to destruction or indentation. • To measure the strength, hardness, toughness, etc. • Example: Tensile testing, Impact testing, Hardness Testing etc.

Non-Destructive Tests (NDT) • Samples or finished articles are tested before being used and as routine maintenance checks. • Example: Radiography, Dye Penetration tests etc.

Testing Techniques

Tensile testing of materials

Impact testing of materials

Bend testing of materials

Hardness testing of materials

(i) Tensile Testing

Universal Testing Machine- It is used to test the tensile stress and compressive strength of materials. It can perform many standard tensile and compression tests on materials, components, and structures.

It can be used to perform following tests:

Tensile Test

Compression Test

Shear Test

UTM Components

- Load frame - Consists of two strong supports for the machine.
- Load cell - A force transducer or other means of measuring the load is required. Periodic calibration is usually called for.
- Cross head - A movable cross head is controlled to move up or down. Usually this is at a constant speed
- Output device - Means of providing the test result. Some machines have dial or digital displays and chart recorders. Many newer machines have a computer interface for analysis and printing.
- Conditioning - The machine can be in a controlled room or a special environmental chamber can be placed around the test specimen for the test.
- Test fixtures, specimen holding jaws, and related sample making equipment are called for in many test methods.

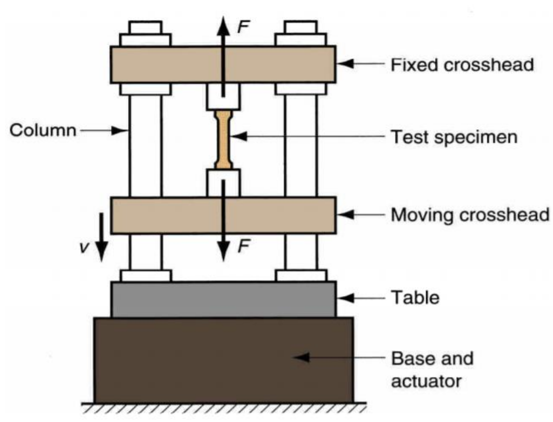

Fig 1.9 UTM

Working:

- Compressive strength:- Any shape specimen.

Steps 1. Mark the gauge length as per specification and record it accurately. The gauge length should be symmetrical with the length of the bar.

2. Grip the specimen firmly in the jaw of the Universal testing machine and adjust the machine to read zero.

3. Continue loading at increments each time and this loading should be continued till yield point is reached.

4. Record the load at the yield point. That is uniaxial compressive strength of the specimen.

- Tensile Strength

Specimen: Cross section of the specimen may be circular, squire, rectangular or in special cases of any other form.

Steps 1. Mark the gauge length as per specification and record it accurately. The gauge length should be symmetrical with the length of the bar.

2. Grip the specimen firmly in the jaw of the Universal testing machine and adjust the machine to read zero.

3. Continue loading at increments each time and this loading should be continued till yield point is reached.

(ii) Hardness Testing

Hardness is the ability to withstand indentation or scratches. Hardness measurement is also used to check response to heat treatment of a particular material.

Types of Hardness Measurement

Scratch Hardness: Uses Mohs Scale

Indentation Hardness - Brinell/Rockwell/ Vickers: For Metals

Brinell Hardness Test (BHN) • Uses spherical shaped indentor. Used on softer material • Surface area of indentation is measured. Spherical indenter is shot with desired load force at the target The diameter of the indentation caused is recorded The diameter of the indentation tells about the Brinell Hardness Number (BHN)

Rockwell Hardness Tests (HRC) • Gives direct reading. • Rockwell B (ball) used for soft materials. • Rockwell C (cone) uses diamond cone for hard materials. • Flexible, quick and easy to use.

Vickers Hardness Test (HV) • Measures Small Samples • Uses square shaped pyramid indenter. • Accurate results. • Measures length of diagonal on indentation. • Usually used on very hard materials and for surface hardness measurement.

(iii)Impact Testing

Impact test determines material toughness. It measure an objects ability to resist high-rate loading .The amount of energy absorbed by a material before fracture, is determined.

Impact test: • Charpy Impact Test • Izod Impact Test

(a)Izod Impact Test - Strikes from a height at =167 Joules. Test specimen is held vertically. Notch faces striker.

(b)Charpy Impact Test - Strikes form higher position with 300 Joules. Test specimen is held horizontally. Notch faces away from striker.

(iv)Bend Test

Bend tests deform the test material at the midpoint causing a concave surface or a bend to form without the occurrence of fracture and are typically performed to determine the ductility or resistance to fracture of that material. The test sample is loaded in a way that creates a concave surface at the midpoint with a specified radius of curvature according to the standard in relation to which the test is performed.

1.11 Forces and Resolution of Forces

A Push or Pull exerted by one body on another. When force is applied to an object , the velocity of that object changes. This change in velocity constitutes an acceleration.

Force is a vector quantity, therefore a force is completely described by; magnitude, direction and point of application

Types of Forces

- Concurrent Force System - The force system in which line of action of forces intersects through a common point.

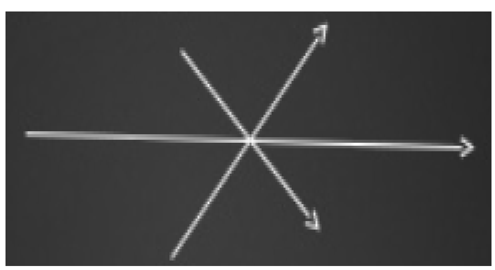

Fig 1.10 Concurrent force

- Parallel Force System - The force system in which line of action of forces are parallel to each other.

Fig 1.11 Parallel force

- Collinear Force System- The force system in which line of action of forces lies on the same path.

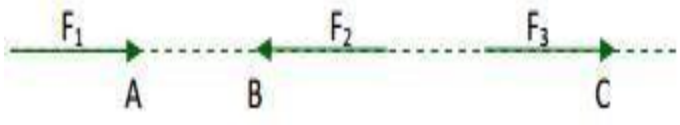

Fig 1.12 Colinear force

- Coplanar Force System -The force system in which line of action of forces lie on the same plane.

Resolution of Forces

A given force *F* can be resolved into (or replaced by) two forces, which together produces the same effects that of force *F*. These forces are called the components of the force *F*. The process of replacing a force into its components is known as resolution of a force into components.

A force can be resolved into two components, which are either perpendicular to each other or inclined to each other. If the two components are perpendicular to one another, then they are known as rectangular components and when the components are inclined to each other, they are called as inclined components.

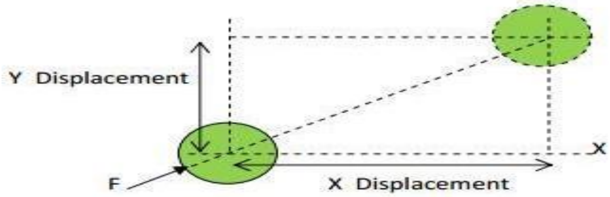

Fig 1.13 Resolution of force

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Question Bank

PART A

S.No.	Questions
1	List out the mechanical properties derivable from tensile test with units.
2	State Newton's laws of motion. State Hooke's law
3	Define creep, fatigue and stress relaxation
4	What is a microstructure?
5	Differentiate tension and compression.
6	What is brittle fracture? Plot the graph
7	Define isotropy. Give examples of isotropic materials.
8	How is bend test and torsion test conducted?
9	What is the reason for plastic deformation?
10	What is resolution of forces?

PART B

S.No.	Questions
1	Explain with examples three Newton's Laws of motion
2	Considering the stress-strain diagram of ductile material, explain the various properties derived from it.
3	Explain the mechanical testing of biomaterials.
4	Write notes on a) Plastic deformation b) Microstructure
6	Describe the various mechanical properties and discuss a method to test them
7	Explain the resolution of forces for two and three dimensions.
8	With diagram representation explain Tension and compression
9	Explain various mechanical testing methods.
10	Discuss on the fundamental concepts in biomechanics.

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FLUID MECHANICS

2.1 Viscosity

Viscosity is a measure of a fluid's resistance to flow. It is the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid. It describes the internal friction and thickness of a moving fluid.

A fluid with large viscosity resists motion because its molecular makeup gives it a lot of internal friction. A fluid with low viscosity flows easily because its molecular makeup results in very little friction when it is in motion.

Viscosity is measured in terms of a ratio of shearing stress to the velocity gradient in a fluid. Viscosity is measured in *Pascal seconds (Pa s)*. More viscous a fluid is, the more resistance it offers to any object moving inside it.

When 2 layers of fluid, a distance ‘dy’ apart, move over one another at different velocities, u and u+dv, viscosity together with relative viscosity causes shear stress acting between the fluid layers. The top layer causes shear stress on bottom layer and vice versa.

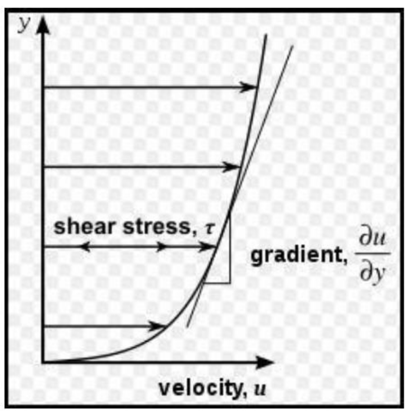


Fig 2.1 Viscosity curve

Shear stress is proportional to rate of change of velocity with respect to y.

$$\text{Viscosity, } \tau = \mu \frac{du}{dy}$$

Where,

μ = Dynamic viscosity

τ = Shear stress= F/A

$\frac{du}{dy}$ = Rate of shear deformation

Factors affecting Viscosity

Shear stress and shear rate

Shear stress is the force pushing one layer across another divided by the area of the layers.

Shear rate is essentially the rate at which the fluid layers are moving past each other.

Types

- Dynamic or absolute viscosity is the ratio of shear stress to shear rate
- Kinematic viscosity is the absolute viscosity divided by mass density

2.2 Properties of Fluids

Kinematic properties: These properties help in understanding the fluid motion. Velocity and acceleration are the kinematic properties of the fluids.

Thermodynamic properties: These properties help in understanding the thermodynamic state of the fluid. Temperature, density, pressure, and specific enthalpy are the thermodynamic properties of the fluids.

Physical properties: These properties help in understanding the physical state of the fluid such as colour and odour.

Density- It is the ratio of the mass of the fluid to its volume. The density of gases is dependent on pressure and temperature, while the density of liquid remains constant.

$$\rho = \frac{mass\ of\ fluid}{volume\ of\ fluid}$$

Specific weight - Weight possessed by unit volume of a fluid. Specific weight is dependent on acceleration due to gravity as it changes from place to place. The specific weight of water is 9.81×1000 $N.m^{-3}$

$$w = \frac{weight}{volume}$$

Specific Volume – It is the reciprocal of density. It can be expressed as the volume that a fluid occupies per unit mass.

$$\frac{Volume}{Mass}$$

Surface tension – The phenomenon in which the surface of liquid is in contact with another phase.

2.3 Types of Fluids

Ideal fluid - A fluid is said to be ideal when it cannot be compressed and the viscosity doesn't fall in the category of an ideal fluid. It is an imaginary fluid which doesn't exist in reality.

Real fluid - All the fluids are real as all the fluid possesses viscosity.

Newtonian fluid - When the fluid obeys Newton's law of viscosity, it is known as a Newtonian fluid.

Non-Newtonian fluid - When the fluid doesn't obey Newton's law of viscosity, it is known as Non-Newtonian fluid.

Ideal plastic fluid - When the shear stress is proportional to the velocity gradient and shear stress is more than the yield value, it is known as ideal plastic fluid.

Incompressible fluid - When the density of the fluid doesn't change with the application of external force, it is known as an incompressible fluid.

Compressible fluid - When the density of the fluid changes with the application of external force, it is known as compressible fluid.

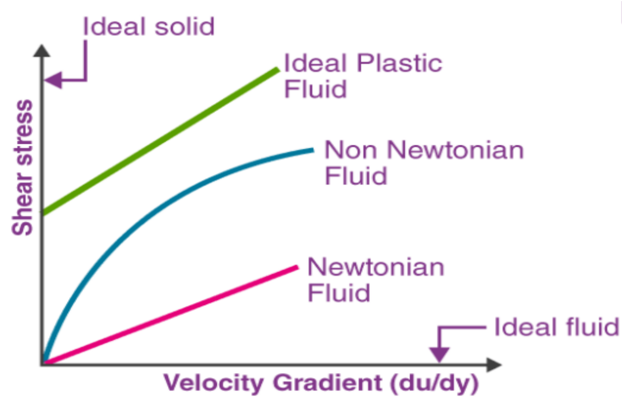


Fig 2.2 Fluid curves

Newton's Law of viscosity

Newton's viscosity law's states that the shear stress between adjacent fluid layers is proportional to the velocity gradients between the two layers.

The ratio of shear stress to shear rate is a constant, for a given temperature and pressure, and is defined as the viscosity or coefficient of viscosity.

2.4 Fluid Flow and Types

Fluid is any substance that flows or deforms under applied shear stress. Fluid has tendency to flow.

(a) Steady and Unsteady Flow

The steady flow is defined as that type of flow in which the fluid characteristics like velocity, density, pressure, etc at a point do not change with the time. E.g. flow of water with constant discharge through a pipeline is as steady flow

$$\frac{\partial V}{\partial t} = 0, \frac{\partial p}{\partial t} = 0, \frac{\partial J}{\partial t} = 0$$

The Unsteady flow is defined as that type of flow in which the fluid characteristics like velocity, density, pressure, etc at a point change respected to time. E.g. flow of water with varying discharge though a pipe is as unsteady flow.

$$\frac{\partial V}{\partial t} \neq 0, \frac{\partial p}{\partial t} \neq 0, \frac{\partial J}{\partial t} \neq 0$$

(b)Uniform and Non uniform flow

Uniform fluid flow is defined as the type of flow in which the velocity at any given time does not change with respect to space (i.e length of direction of the flow).

$$(\frac{\partial V}{\partial t})_{t\ is\ a\ constant} = 0$$

Non-uniform fluid flow is defined as the type of flow in which the velocity at any given time changes with respect to space (i.e length of the direction of the flow).

$$(\frac{\partial V}{\partial t})_{t\ is\ a\ constant} \neq 0$$

(c) Compressible and In-compressible flow

Compressible fluid flow is defined as the flow in which the density is not constant which means the density of the fluid changes from point to point.

$$\rho \neq \text{constant}$$

Incompressible fluid flow is defined as the flow in which the density is constant which means the density of the fluid does not change from point to point.

$$\rho = \text{constant}$$

(d) Rotational and Irrotational flow

Rotational fluid flow is defined as the type of fluid flow in which the fluid particles while flowing along streamline and also rotate about their own axis.

Irrotational fluid flow is defined as the type of fluid flow in which the fluid particles while flowing along streamline and do not rotate about their own axis.

(e) Laminar and Turbulent Flow

Laminar fluid flow is defined as the type of flow in which the fluid particles move along well-defined paths or streamline and all the streamlines are straight and parallel. Thus the particles move in laminas or layers gliding smoothly over the adjacent layer. This type of fluid is also called as streamline flow or viscous flow.

Turbulent fluid flow is defined as the type of flow in which the fluid particles move in a zig-zag way.

For vessel flow, the type of flow is determined by a non-dimensional number $[(VD) / (\nu)]$ called the Reynolds number.

Where,

D = Diameter of pipe

V = Mean velocity flow in a pipe

ν = Kinematic viscosity of the fluid.

If Reynold Number is less than 2000, the flow is called Laminar flow.

Reynold Number is more than 4000, the flow is called Turbulent flow.

If the Reynold Number is lies between 2000-4000, the flow may be laminar or turbulent.

6. One, Two, and Three -dimensional Fluid Flow

One dimensional flow is that type of flow in which the flow parameter such as velocity is a function of time and one space co-ordinate only, say x.

$$u=f(x),\ v=0 \text{ and } w=0$$

Where u,v and w are velocity component in x,y and z directions respectively.

Two-dimensional fluid flow is the type of flow in which velocity is a function of time and two rectangular space co-ordinate say x,y.

u= f1(x,y,), v= f2(x,y,) and w= 0.

Three-dimensional fluid flow is the type of flow in which velocity is a function of time and three mutually perpendicular directions. The function of 3 space coordinates (x,y,z).

u= f1(x,y,z), v= f2(x,y,z) and w= f3(x,y,z).

2.5 Viscoelasticity

Elasticity refers to the material's ability to return to its original state after deformation. Viscosity refers to a material's resistance to flow. It is a fluid property and depends on the PG and water composition of the tissue. A tissue with high viscosity will exhibit high resistance to deformation. When forces are applied to viscous materials, the tissues exhibit time dependent and rate-dependent properties. Viscosity diminishes as temperature rises and increases as pressure increases. All connective tissues are viscoelastic materials

Three characteristics of VE materials-

Creep

Creep is a slow, progressive deformation of a material under constant stress/load. A Time-dependent deformation under a certain applied load. Generally occurs at high temperature. Rate of deformation is called the creep rate.

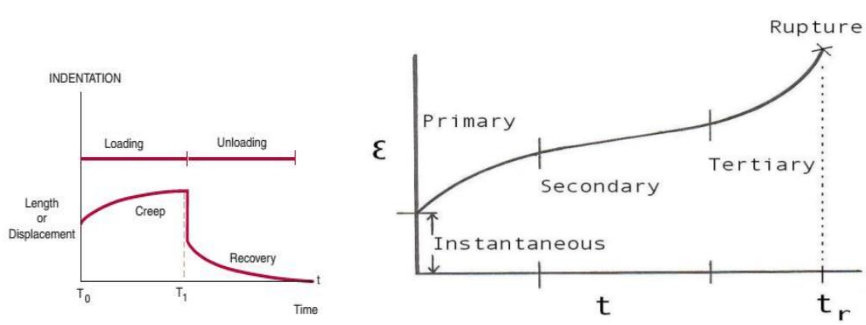


Fig 2.3 Creep curve

Stages of Creep

Primary Creep: starts at a rapid rate and slows with time.

Secondary Creep: has a relatively uniform rate.

Tertiary Creep: has an accelerated creep rate and terminates when the material breaks or ruptures. It is associated with both necking and formation of grain boundary voids.

Stress Relaxation

Indicates stress acting upon a tendon will eventually reduce under a constant deformation. It is studied by applying a constant deformation to the specimen and measuring the stress required to maintain that strain as a function of time. It is due to a re-arrangement of the material on the molecular or micro-scale.

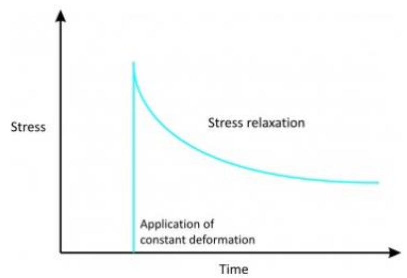


Fig 2.4 Stress relaxation curve

Hysteresis

When the force and length of the tissues are measured as force is applied (loaded) and removed (unloaded), the resulting load-deformation curves do not follow the same path. The energy gained as a result of the lengthening work (force * distance) is not recovered 100% during the exchange from energy to shortening work. Some energy is lost, usually as heat.

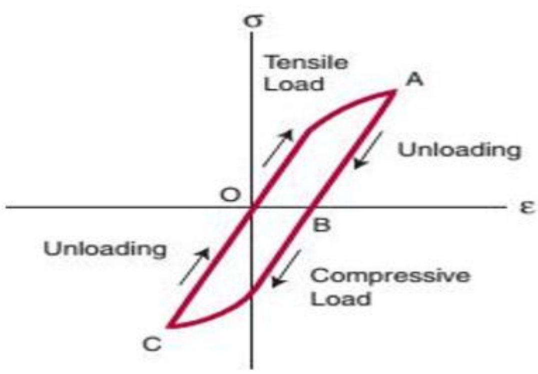


Fig 2.5 Hystresis Curve

2.6 Viscoelastic Models

Springs and dashpots constitute the building blocks of model analysis in viscoelasticity. They are connected to one another in various forms are used to construct empirical viscoelastic models. Springs are used to account for the elastic solid behavior and dashpots are used to describe the viscous fluid behavior.

It is assumed that a constantly applied force (stress) produces a constant deformation (strain) in a spring and a constant rate of deformation (strain rate) in a dashpot. The deformation in a spring is completely recoverable upon release of applied forces, whereas the deformation that the dashpot undergoes is permanent.

Three viscoelastic models are based on the arrangement of spring and dashpot.

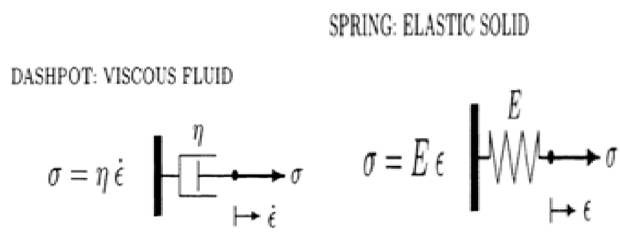


Fig 2.6 Spring and Dashpot Model

a)Kelvin Voight Model

A system consisting of a spring and a dashpot connected in a parallel arrangement. It predicts the creep.

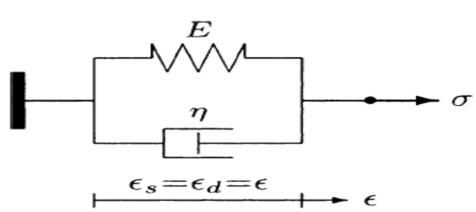


Fig 2.7 Kelvin Voight Model

If s and d denote the spring and dashpot, respectively, then a stress 's' applied to the entire system will produce stresses σ s and σ d in the spring and the dashpot.

Total stress applied to the system will be shared by the spring and the dashpot.

$$\sigma = \sigma_s + \sigma_d.$$

As the stress σ is applied, the spring and dashpot will deform by an equal amount because of their parallel arrangement. Therefore, the strain ε of the system will be equal to the strains ε_s and ε_d occurring in the spring and the dashpot:

$$\varepsilon = \varepsilon_s = \varepsilon_d. \quad 1$$

The stress–strain relationship for the spring and the stress–strain rate relationship for the dashpot are:

$$\sigma_s = E\varepsilon_s, \quad 2$$

$$\sigma_d = \eta\dot{\varepsilon}_d. \quad 3$$

Substituting Eqs. 2 and 3 into Eq. 0 will yield:

$$\sigma = E\varepsilon_s + \eta\dot{\varepsilon}_d. \quad 4$$

From 1, $\varepsilon_s = \varepsilon_d = \varepsilon$. Therefore,

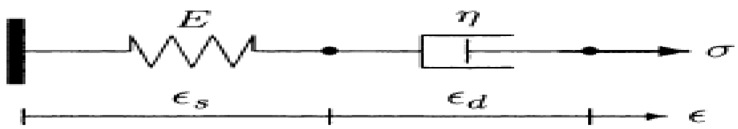
$$\sigma = E\varepsilon + \eta\dot{\varepsilon}. \quad 5$$

b) Maxwell Model

It is constructed by connecting a spring and a dashpot in a series. It predicts stress decays exponentially with time.

stress σ applied to the entire system is applied equally on the spring and the dashpot ($\sigma = \sigma_s = \sigma_d$), and the resulting strain ε is the sum of the strains in the spring and the dashpot ($\varepsilon = \varepsilon_s + \varepsilon_d$). Through stress–strain analyses similar to those carried out for the Kelvin–Voight model, a differential equation relating stresses and strains for the Maxwell model can be derived in the following form:

$$\eta\dot{\sigma} + E\sigma = E\eta\dot{\varepsilon}.$$



c) Standard Linear Model

It is composed of a spring and a Kelvin–Voight solid connected in a series. Three-parameter model used to describe the viscoelastic behavior of a number of biological materials such as the cartilage and the white blood cell membrane. It gives information of both creep and stress relaxation.

$$(E_1 + E_2)\sigma + \eta\dot{\sigma} = (E_1 E_2 \varepsilon + E_1 \eta\dot{\varepsilon}).$$

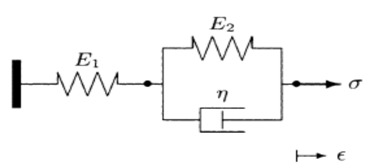


Fig 2.8 Standard linear model

2.7 Blood- Physical and Chemical Properties

Blood is a liquid connective tissue that contains cellular elements (blood cells) and fluid matrix (plasma). Blood helps in the transportation of different substances throughout the body. The study of blood and its disease is known as Hematology

Cellular substances (Blood cells) : 45% (44% RBC & 1% buffy coat containing platelets & WBC)

Plasma: 55% (Of total: 91% liquid & Solid 9%).

Amount: : 7-9% of total body weight; 79ml/kg

Blood volume: 5-6 liters

PH:3-7.4 (slightly alkaline)

Venous blood has low pH than the arterial blood as venous blood has more CO

Temperature- 380C (100.4F)

Osmotic pressure– 25 mm Hg

Color: red, due to haemoglobin

Specific gravity: – total blood (1.050-1.060)– plasma (1.025-1.030)– RBC (1.090-1.092).

Viscosity: – Blood relative viscosity (4~5) mainly depends on the numbers of red blood cells. – Plasma relative viscosity (1.6~2.4) is mainly involved in plasma protein

Plasma pH value is about 7.35~7.45

Shape: Biconcave

Size: 7.2um in diameter

Thickness: 2um at the periphery and 1um at the center

Volume: 87um3

2.8 Flow/Rheological Properties of blood

(i)Viscosity of Plasma

It is obtained by centrifuging blood and removing blood sample. Viscosity of plasma is dependent on the concentration of plasma proteins, such as fibrinogen, α1-globulins, α2-globulins, β-globulins, and γ-globulins. Heparin is added to prevent coagulation.

Plasma Density- 1.035gm/cc, Coefficient of Viscosity- 0.011-0.016 Poise

Factors affecting viscosity are Temperature and Protein concentration.

Plasma is considered Newtonian with constant viscosity.

(ii) Viscosity of Whole Blood

Viscosity of blood is 3 times of water.

Hematocrit is the measure of volume percent of formed elements in blood. When hematocrit rises to 60-70%, viscosity becomes 10 times that of water. Bulk viscosity decreases with rising shear rate. Aggregates of RBC's are called Rouleaux. Large aggregates are formed during lower shear rate. When shear rate is zero blood becomes one big aggregate and is considered as a viscoplastic solid. The rouleaux breaks up with an increase in shear rate.

Coefficient of Viscosity- 0.0027Ns/m^2

(iii) Effect of Hematocrit

Blood viscosity is dependent on the number (and volume) of erythrocytes in the blood, and is thus linearly related to hematocrit. It is usually 40-45%. RBC's are centrifuged and reconstructed in appropriate proportions with serum, saline. Viscosity increases with increased hematocrit and it decreases with increased rate of shear. A rise of hematocrit of one unit would cause an increase of blood viscosity of 4%

(iv) Effect of temperature

Research still going on but it should be maintained constant during measurements.

(v)Effect of protein content in plasma

Globulin has a dominant effect on increasing viscosity. Albumin shows a moderate rise whereas presence of fibrinogen is less considered.

2.9 Hagen-Poiseuille's Equation

Consider steady flow of Newtonian fluid through a solid cylinder of fluid, of radius *r* inside a hollow cylindrical pipe of radius *R*. Let the difference in pressures at ends be ΔP.

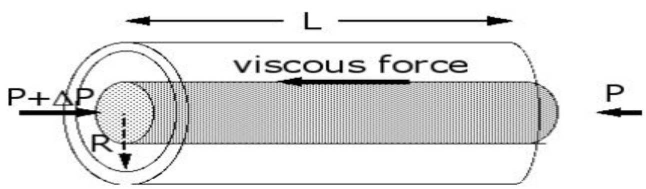


Fig 2.9 Cylinder with fluid flow

Net force pushing the fluid is given by

$$F_{pressure} = \Delta P\left(\pi r^2\right)$$

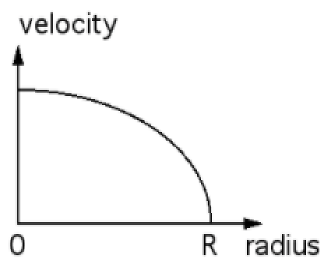
Force inducing motion is gradient in pressure. Flow is from positive to negative pressure. In viscous fluids, resistance to motion is produced as shear stress is induced between layers. The viscous drag force opposing motion depends on the surface area of the cylinder (length L and radius r).

$$F_{viscosity} = -\eta\left(2\pi rL\right)\frac{dv}{dr}$$

In steady flow, these 2 forces balance each other

$$F_{pressure} + F_{viscosity} = 0$$
$$\Delta P(\pi r^2) = \eta(2\pi r L)\frac{dv}{dr}$$
so
$$\frac{dv}{dr} = \frac{\Delta P(\pi r^2)}{\eta(2\pi r L)} = \left(\frac{\Delta P}{2\eta L}\right)\cdot r$$

Taking boundary conditions

We know empirically that the velocity gradient should look like this:  	At the centre • $r=0$ • $\frac{dv}{dr} = 0$ • v is at its maximum. At the edge • $r=R$ • $v=0$

From the velocity gradient equation, and using the empirical velocity gradient limits, an integration can be made to get an expression for the velocity.

$$\frac{dv}{dr} = \left(\frac{\Delta P}{2\eta L}\right)\cdot r$$
rewriting
$$\int_v^0 dv = \left(\frac{\Delta P}{2\eta L}\right)\cdot\int_r^R r\,dr$$
$$v(r) = \left(\frac{\Delta P}{4\eta L}\right)\left[R^2 - r^2\right]$$

Equation of continuity giving the volume flux for a variable speed

$$\frac{dV}{dt} = \int v \bullet dA$$

Substituting the velocity profile equation and the surface area of the moving cylinder

$$\frac{dV}{dt} = \int v \cdot dA = \int_0^R \left(\frac{\Delta P}{4\eta L}\right)\left[R^2 - r^2\right] \cdot (2\pi r dr)$$
$$= \left(\frac{\pi \cdot \Delta P}{2\eta L}\right)\int_0^R \left(R^2 r - r^3\right)dr$$
$$= \left(\frac{\pi \cdot \Delta P}{2\eta L}\right)\left[\frac{R^4}{2} - \frac{R^4}{4}\right]$$
$$= \frac{\pi \cdot \Delta P \cdot R^4}{8\eta L}$$

Poiseuille's equation

$$Q = \frac{\pi \cdot \Delta P \cdot R^4}{8\eta L}$$

Where,

Q= Flow rate (cm3/s or m3/s)

R= the radius of the tube (cm or m)

ΔP= Pressure gradient

η = the dynamic viscosity of the fluid (poise or Pa.s)

L= the length of the tube (cm or m)

Poiseuille's law states that the flow of liquid depends on following factors like the pressure gradient (**ΔP)**, the length of the narrow tube (L) of radius (r) and the viscosity of the fluid **(η)** along with relationship among them.

2.10 Apparent and Relative Viscosity

Apparent (shear) viscosity: Refers to the relationship between viscosity and shear rate. In Newtonian fluids, this value doesn't change, but with non-Newtonian fluids, apparent viscosity is directly affected by the shear rate. It can be calculated by dividing shear stress by shear rate.

Relative viscosity: Relative viscosity is important for non-Newtonian fluids, specifically polymers. It refers to the relationship between molar mass (the mass of a chemical compound divided by total amount) and viscosity — higher molar mass means higher viscosity in the polymer. It's calculated by dividing the polymer viscosity by the viscosity of the pure solvent.

2.11 Fahraeus-lindqvist effect

The apparent viscosity of blood is very low when it flows through small diameter tubes. The viscosity increases with increase in tube diameter.

The decrease in apparent viscosity that occurs when a suspension, such as blood, is made to flow through a tube of small diameter is called Fahraeus-lindqvist effect.

It occurs in tubes less than about 0.3 mm in diameter. The fahraeus-lindqvist effect becomes stronger as the tube diameter decreases relative to the size of the particles.

As blood flows, blood cells tend to rotate. Due to spinning of cells, they move towards centre of the tube and a cell free layer[plasma skimming] layer forms near the wall. In tubes with small diameter, area of CS of cell free zone is comparable to central core. Net effect of cell free zone is to reduce the apparent viscosity of flow through tube. With increase in diameter, effect of cell free zone reduces, viscosity increases.

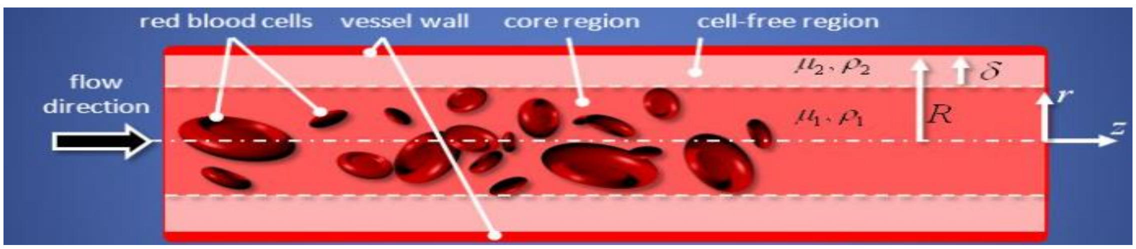


Fig 2.10 Fahraeus-lindqvist effect

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Question Bank

PART A

S.No.	Questions
1	What is viscoelasticity? What are the three viscoelastic models?
2	Draw the structure of RBC.
3	Define Reynold's number and state the conditions.
4	What is a real fluid and ideal plastic fluid?
5	Define apparent and relative viscosity.
6	List the properties of fluids
7	Give the Fahraeus-Lindqvist effect.
8	State Newton's law of viscosity
9	Draw the vascular tree
10	Give the various properties of fluids

PART B

S.No.	Questions
1	Explain the physical and chemical properties of blood.
2	Explain the rheological properties of blood.
3	Considering a laminar flow of Newtonian fluid through a horizontal pipe, derive the Poiseulle's equation.
4	Explain the different types of fluid flows
5	What is viscoelasticity? Explain the various models.
6	Explain in detail about the vascular network and various determinants of resistance to fluid flow.
7	Explain the types of fluids in detail.
8	Write notes on a) Viscoelastic models b) Apparent and Relative Viscosity

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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – III – BIOMECHANICS – SBMA1403

HUMAN LOCOMOTION

3.1 Anthropometric Considerations of Human Body

Anthropometric measurements are those which characterize human body dimensions — size and shape. These measurements are primarily of bone, muscle and adipose tissue (fat). The word combines the Greek root words anthropos (human) and metron (measure).

Typical Anthropometric Measurements

Height, (standing), Height,(sitting), Weight, Waist circumference, Waist to hip ratio, Waist to height ratio, BMI, Pondreal Index, Somatotype, Body Proportions.

Purpose

Anthropometric measurements are useful in many fields. For example, athletes understand that body size and composition are important factors in sports performance. Sports coaches can also use these measurements to monitor an athlete's body to ensure they stay in peak physical shape. Health care professionals rely on body measurements to evaluate a patient's overall health. Anthropometric measurements can also be used when studying groups of people. This broader approach allows researchers to evaluate health trends and concerns in various populations.

Factors

1.Height and Weight

Measure the height using a scale or stadiometer and weight using a weighing scale.

2.Pondreal Index

The Ponderal Index is a measure of body composition using height and weight. It is also known as the Corpulence Index (CI).

PI is calculated from measurements of body mass (M) and height (H). PI = the cube root of body weight divided by height, where body mass is in kilograms and height in meters.

$$PI = 10^3 \, 3\sqrt{} \, W/H$$

3.Somatotype

Somatotype, human body shape and physique type. The term somatotype is used in the system of classification of human physical types.

The system, uses the terms ectomorph, endomorph, or mesomorph to describe the body build of an individual.

Endomorph

Short and Fat - A pear-shaped body, Wide hips and shoulders, A lot of fat on the body, upper arms and thighs

An endomorphic individual typically has short arms and legs and a large amount of mass on their frame. Sports of pure strength, like powerlifting, are perfect for an endomorph. They can gain weight easily and lose condition quickly if training stops.

Sports Benefits

Size benefits sports such as rugby where bulk is useful, provided it can be moved powerfully, Tend to have large lung capacity which can make them suited to sports such as rowing.

Ectomorph

Tall and Thin - Narrow shoulders and hips, A narrow chest and abdomen ,Thin arms and legs, Little muscle and fat

Ectomorphic individuasl are long, slender and thin. Ectomorphs dominate endurance sports and gymnastics. They can archive low levels of body fat which can be detrimental to health.

Sports Benefits

The light frame makes them suited for aerobic activity like gymnastics, Smaller body surface area also enhances their suitability for endurance activity.

Mesomorph

Athletic Build - A wedge-shaped body, Wide broad shoulders, Muscled arms and legs, Narrow Hips, A minimum amount of fat

A mesomorphic individual excels in strength, agility, and speed. Their medium structure and height, along with their tendency to gain muscle and strength easily make them a strong candidate for a top athlete in any sport. They can sustain low body fat levels and find it easy to lose and gain weight.

Sports Benefits

Respond well to cardiovascular and resistance training, All muscle groups can be used to derive positive training adoption

4.Crural index

The ratio of thigh length to leg length. It describes the proportion of the legs. A high crural index is advantageous to long-jumpers since it enables the jumper to apply a force against the ground for a longer time than someone with a low crural index.

Ratio > 1, Lower leg longer than thigh

Ratio < 1, Lower leg shorter than thigh.

5.Body Proportions

Absolute Measures – Height of the body and length of its segments are important.

For equal height persons, different proportions are noticed.

Example:

Person 1 : Long legs & Short trunk

Person 2: Short Legs & Long trunk

Person 3 : Equal Lengths

3.2 Types of motion in Humans

Anatomical Concepts in Biomechanics

1. Anatomical Reference Position- Standing up straight with the body at rest. The feet are slightly separated and arms relaxed and palms facing forward. It is the starting point for describing the body. It helps to talk about different parts of human body.

2. Reference Plane

Three basic reference planes used in anatomy:

Sagittal plane- Divides the body into left and right halves.

Coronal/Frontal plane- Divides the body into back and front halves.

Transverse plane - Divides the body into top and bottom halves.

3. Forms of Motion

Linear Motion- A uniform 1 D motion with all parts in same direction and same speed. Velocity does not continuously change direction.

Rectilinear- Straight Line

Curvilinear- Curved line

Angular Motion - The motion of a body about a fixed point or fixed axis.

Axis of Rotation - Equal to the angle passed over at the point or axis by a line drawn to the body.

4. Plane Movements

Sagittal Plane Movements

Flexion- Movement that decreases the angle between two body parts.

Extension- Movement that increases the angle between two body parts.

Hyperextension- Rotation beyond anatomical position. Excessive movement of a joint in one direction

Frontal Plane Movements

Abduction- Taking the body part away from the central line.

Adduction- Moving the body part towards the central line.

Lateral Flexion-Bending movement of a body part in the lateral direction – side wards. Shoulder,Fingers and hip joints undergo these movements.

Transverse Plane Movements

Rotation- It is twisting motion. Joints which permit rotation include the shoulder and hip. Ex- Ball and socket joints.

Medial rotation - rotational movement towards the midline.(Internal rotation)

Lateral rotation - rotational movement away from the midline.

Supination- Outward rotation of forearm

Pronation- Inward rotation of forearm

Dorsiflexion - Flexion at the ankle, so that the foot points more superiorly.

Plantarflexion -Extension at the ankle, so that the foot points inferiorly.

Circumduction- Conical movement of a limb extending from the joint at which the movement is controlled. A general motion with circular movement

Inversion -Movement of the sole towards the median plane

Eversion- Movement of the sole of the foot away from the median plane.

Elevation - Movement in a superior direction (e.g. shoulder shrug),

Depression -Movement in an inferior direction.

Protraction- Occurs when shoulder is moved forward or when jaw is pushed forward.

Retraction - the scapula being pulled posteriorly and medially, toward the vertebral column or pulls the lower jaw backward.

Opposition is the thumb movement that brings the tip of the thumb in contact with the tip of a finger.

Reposition - Returning the thumb to its anatomical position next to the index finger.

Excursion - Side to side movement of the mandible. Lateral excursion moves the mandible away from the midline, toward either the right or left side. Medial excursion returns the mandible to its resting position at the midline.

3.3 Gait Analysis

A series of rhythmical, alternating movements of the trunk & limbs which results in the forward progression of the center of gravity. Activities that occur from the point of initial contact of one lower extremity to the point at which the same extremity contacts the ground again. Measurement of body in space(kinematics) and the forces which produce the movement(kinetics).

Equipments and Techniques

1. Photography – Basic method
2. Video recording – Single and multiple cameras
3. Active markers- Markers triggered by IR cameras and produce signals of their own
4. Passive markers – Reflective markers. IR signals produced and cameras pick the reflected light.

Gait Cycle

A single sequence of function by one limb. It begins when reference foot contacts the ground and ends with subsequent floor contact of the same foot

Step Length

Distance between corresponding successive points of heel contact of the opposite feet

Rt step length = Lt step length (in normal gait)

Stride Length

Distance between successive points of heel contact of the same foot

Double the step length (in normal gait)

Walking Base

Side-to-side distance between the line of the two feet

Also known as ‘stride width’

Cadence

Number of steps per unit time

Normal: 100 – 115 steps/min

Support:

Single Support: only one foot in contact with the floor

Double Support: both feet in contact with floor

Gait Phases

Each extremity passes through two phases, a single stance phase and a single swing phase

Stance Phase: Reference limb in contact with floor.

Swing Phase: Reference limb not in contact with the floor.

Stance Phase

Stance phase comprises 60% of the gait cycle

Heel strike – moment when the heel first strikes the ground

Foot flat – from heel strike to when the full foot is in contact with the ground

Midstance – body weight is directly over the stance leg

Heel off – moment the heel of the stance leg leaves the ground

Toe off – when only the toe of the stance leg is in contact with the ground

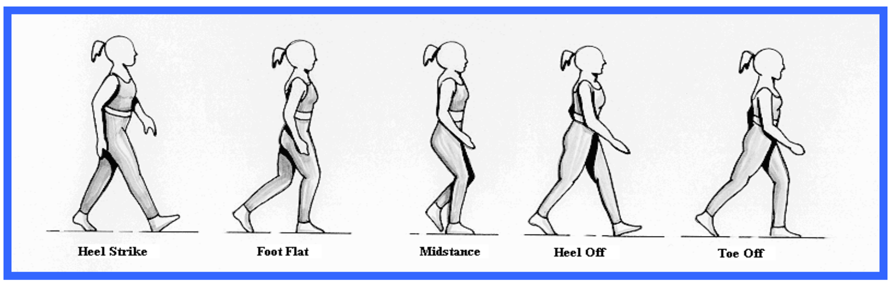

Fig 3.1 Stance Phase

Swing Phase

Swing phase comprises 40% of the gait cycle

Acceleration – the toe of the stance leg leaves the ground and begins to swing forward

Midswing – the swinging leg is directly beneath the body

Deceleration – the swinging leg continues forward towards knee extension but is slowing down as it travels, stopping just prior to full knee extension and heel contact with the ground.

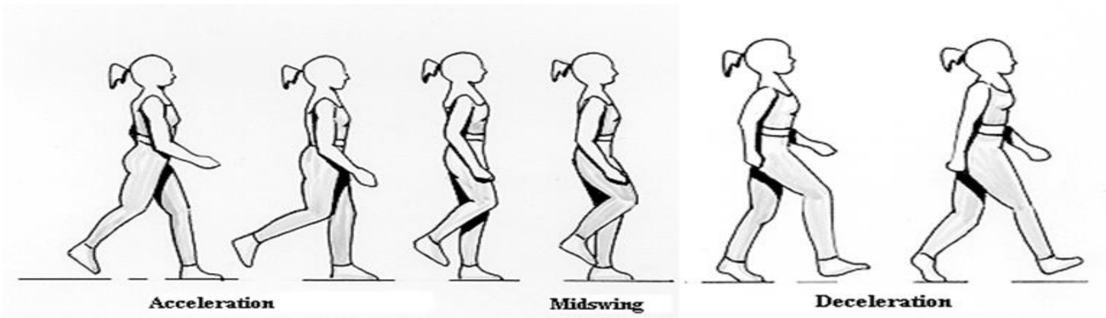

Fig 3.2 Swing Phase

3.4 Goniometry

A goniometer is an instrument used to measure angles. The term goniometry is derived from two Greek words, gonia meaning angle and metron, meaning measure.

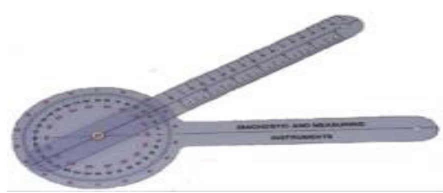

Fig 3.3 Goniometer

Goniometry is used to measure the total amount of available motion at a specific joint. Goniometry can be used to measure both active and passive range of motion.

A goniometer is often used in patients who have limitations of movement due to muscle tightness, joint stiffness or other conditions affecting their joint range of motion. Goniometers are produced in a variety of sizes and shapes and are usually constructed of either plastic or metal. Small goniometers are available to measure range of motion around the joints of the fingers, thumbs and hands. Large goniometers are used to measure the range of motion around the hips or knees.

Types of goniometer

The two most common types of instruments used to measure joint angles are the bubble goniometer and the traditional goniometer.

Bubble goniometer- The bubble goniometer, which has a 360° rotating dial and scale with fluid indicator can be used for flexion and extension; abduction and adduction; and rotation in the neck, shoulder, elbow, wrist, hip, knee, ankle, and the spine.

Traditional goniometer - The traditional goniometer, can be used for flexion and extension; abduction and adduction; and rotation in the shoulder, elbow, wrist, hip, knee, and ankle.

Digital goniometers are also available, but they are quite expensive.

Parts of goniometer

It consists of three parts:

A body - The body of the goniometer is designed like a protractor and may form a full or half circle. A measuring scale is located around the body. The scale can extend either from 0 to 180 degrees and 180 to 0 degrees for the half circle models, or from 0 to 360 degrees and from 360 to 0 degrees on the full circle models.The intervals on the scales can vary from 1 to 10 degrees

A stationary arm - The stationary arm is structurally a part of the body and therefore cannot move independently of the body

A moving arm - The moving arm is attached to the fulcrum in the center of the body by a rivet or screw-like device that allows the moving arm to move freely on the body of the device.

The correct selection of which goniometer device to use depends on the joint angle to be measured. The length of arms varies among instruments and can range from 3-18 inches.

Range of Motion

ROM is a motion that occurs at a joint or series of joints.

Starting position for ROM is anatomical position except rotations in transverse plane.

3 notation systems have been used to design ROM:0-180˚, 180-0˚, 360˚

0-180 system of notation is called neutral zero method.

Active Range of Motion

AROM is the arc of motion attained by a subject during unassisted voluntary joint motion.

It provides the examiner with information about the subject's willingness to move, coordination, muscle strength and joint range of motion.

Passive Rom

PROM is the arc of motion attained by an examiner without assistance from the subject.

Normally PROM is slightly greater than AROM. It provides the examiner with information about the integrity of the articular surfaces and the extensibility of soft tissues around the joint.

Procedure

Each arm is positioned at specific points on the body and the center of the goniometer is aligned at the joint to be measured.

The patient is positioned in the recommended testing position. While stabilizing the proximal joint component, the clinician gently moves the distal joint component through the available range of motion until the end feel is determined. An estimate is made of the available range of motion and the distal joint component is returned to the starting position. A record is made of the starting measurement. The goniometer is then removed and the patient moves the joint through the available range of motion. Once the joint has been moved through the available range of motion, the goniometer is replaced and realigned, and a measurement is read and recorded.

Applications

1. To check the effectiveness of the treatment

2. To establish diagnosis

3. To evaluate the progress of treatment

4. To fabricate orthotic devices.

3.5 Accelerometer

An accelerometer is an electromechanical device used to measure acceleration forces. Such forces may be static, like the continuous force of gravity or, as is the case with many mobile devices, dynamic to sense movement or vibrations. Acceleration is the measurement of the change in velocity, or speed divided by time.

An accelerometer behaves as a damped mass on a spring. When the accelerometer experiences an acceleration, the mass is displaced to the point that the spring is able to accelerate the mass at the same rate as the casing. The displacement is then measured to give the acceleration.

Types of accelerometers

Strain gauges – Voltage changes are proportional to acceleration.

Piezoelectric rely on piezoceramics (e.g. lead zirconate titanate) or single crystals (e.g. quartz, tourmaline). The piezoelectric effect is the most common form of accelerometer and uses microscopic crystal structures that become stressed due to accelerative forces. These crystals create a voltage from the stress, and the accelerometer interprets the voltage to determine velocity and orientation.

Piezoresistive accelerometers are preferred in high shock applications.

Capacitive accelerometers use a silicon micro-machined sensing element. The capacitance accelerometer senses changes in capacitance between microstructures located next to the device. If an accelerative force moves one of these structures, the capacitance will change and the accelerometer will translate that capacitance to voltage for interpretation.

Modern accelerometers are often small micro electro-mechanical systems (MEMS)

Medical applications

CPR-D•padz which contain an accelerometer to measure the depth of CPR chest compressions.

Footpods, containing accelerometers help determine the speed and distance for the runner wearing the unit.

In Belgium, accelerometer-based step counters are promoted by the government to encourage people to walk a few thousand steps each day.

Herman Digital Trainer uses accelerometers to measure strike force in physical training.

Football helmets with accelerometers in order to measure the impact of head collisions.

Accelerometers have been used to calculate gait parameters, such as stance and swing phase. This kind of sensor can be used to measure or monitor people.

Accelerometers may help save the lives of those who are elderly or who have difficulty standing. These accelerometers are used in different fall detection devices. They sense when someone has suddenly fallen by determining the change in their velocity and in the direction they are moving. If the device determines that the values for these two variables fall into the danger category, it will automatically send out a call for help.

3.6 Pedobarograph

The instrument is used as a gait analysis tool that measures the pressure distribution on the bottom of the foot through all stages of the gait cycle.

Types

Optical Pedobarograph

It uses digital video capture technology to record the pressure variations on the sole of the foot. The subject walks across the force plate fitted with an illuminated glass plate. As the foot hits the device, the glass surface deflects due to the force, causing the horizontal light beams to reflect downwards and be read by the video camera. The amount of light reflected is proportional to the pressure caused by the foot striking the plate.

Musgrave Foot pedobarograph - Computerized form of gait analysis that is used in the measurement and evaluation On the bottom of the foot through all stages of the gait cycle.

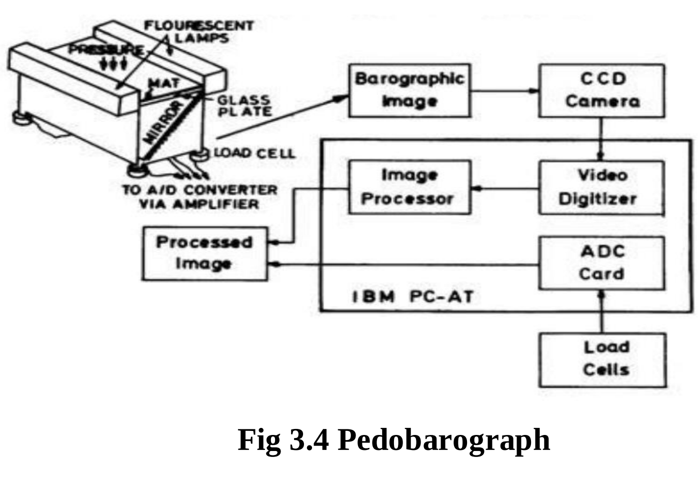

Fig 3.4 Pedobarograph

Procedure

It has a thick tempered glass plate. The glass plate is illuminated at two edges by fluorescent lights. The top surface of glass is covered with a sheet of photographic paper and thin sheet of plastic. The video camera captures the image of the foot when subject steps on it. As light enters the glass plate through the sides, the light rays which have an angle of incidence> critical angle will experience total internal reflection between top and bottom surface of the glass. When subject is made to step on the apparatus, the plastic sheet deforms and comes in contact with the top surface of the glass. The amount of pressure applied to the plastic is proportional to how intimate the contact with the glass plate will be and how much internal reflection will be broken. The areas which are in contact with the glass plate are observed as low intensity regions in the image. The mirror collects the reflected light beam and it focuses on the camera and the image is captured.

Applications

To study clinical conditions like diabetes mellitus, rheumatoid arthritis,etc

To study the severity of deformity of patients with foot dysfunction

Used in forensics to examine the shoe marks found at scene of crime.

Disadvantages

Proper calibration is not possible

Transducer material is used instead of plastic sheet materials

3.7 Podiascan

A Simple and noninvasive procedure that assesses abnormalities of the nerves based on the plantar distribution of pressure. It assesses deformity, infection, breakdown of skin, temperature, edema, ischemia, and callosities. It produces instantaneous and high resolution images of the pressure distribution across the plantar surface.

Diabetic Neuropathy

Diabetic neuropathy is a common complication that affects numerous patients with diabetes. Disorder of the nerves caused due to diabetes is called diabetic neuropathy. Neuropathy is caused when patients have high blood sugar levels for a prolonged period of time. It also caused due to smoking and alcohol abuse.

High blood sugar levels lead to a damage of the blood vessels and the nerves of the feet. Over a period of time, this damage leads to a decreased sensation in the feet. When these add up, the patient is at a higher risk of damage to the feet. Patients have ulcers on the feet. These ulcers take a long time to heal as the immunity system of a diabetic is compromised. Wounds and ulcers take a lot of time to heal and in some cases, lead to amputation of the feet. With such high risk factor involved, it is important for every diabetic to get a periodical foot exam. This foot exam is done with a procedure called PodioScan.

Components

It consists of Harris mat, special scanner copier and printer, image analysis software and patient reporting software. When the patient steps over the Harris mat, greater local foot forces deposit more ink and detects the area of greatest concern for ulceration. Harris mat produces a weight bearing imprint of the foot and the podia scan produces qualitative multi color output and makes the pressure reading easier. Easily interpreted visuals obtained in seconds.

Applications

- Identify potential ulcerations
- Pre and post surgical evaluations
- Prescription of foot orthoses
- Determine degree of pronation and supination.
- Monitoring degenerative foot disorders
- Detection of scoliosis.
- Screening diabetes.

3.8 Force Platform

They are measuring instruments that measure the ground reaction forces generated by a body standing on or moving across them, to quantify balance, gait and other parameters of biomechanics. Force Plates can be used for: Gait, Sport and Balance. A force plate measures the force that is exerted by the ground in opposition to the weight on it.

Force plate is also able to provide information about the forces exerted parallel to the ground and the location of the force vector. Portable in which case it looks like a giant set of scales or fixed. Force plate has sensors, built into feet of its platform, which constantly measures the take-off force and relays it hundreds of times per second to a computer. The height of jump, jump power and other parameters are automatically calculated from the take off force.

Load cells are employed to read forces. They are strain gauges, which essentially are variable resistors that change their resistance relative to their strain (basically how much they stretch). By measuring the resistance, and calibrating each load cell so that the resistance is meaningful in proportion to force.

Ideal Force Plate

- Be able to resolve the vertical, forward and lateral components of the force
- Have low 'cross talk' between the measured components of the force
- Have sufficient sensitivity and resolution for the subject of interest
- Have a linear response
- Have a response independent of where on the plate surface the force is exerted
- Have a high natural frequency of oscillation
- Have sufficient safety margin to protect both the plate and the subject from damage due to failure
- Be Simple and inexpensive

Components

1. AMTI force plates
2. Amplifiers
3. A/D Interface Unit (ADIU)
4. Event and video control unit (E&VCU) (for use with peak video/optical motion capture system)
5. Data acquisition computer with A/D converter card

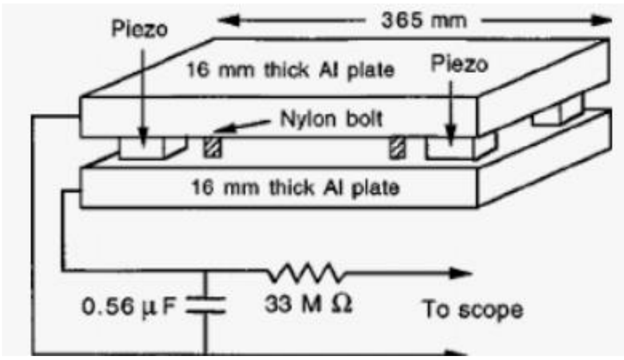

Fig 3.5 Force Platform

Force plates

Each plate will produce forces and moments along all three axes, giving a total of 6 channels per plate. The output voltages are fed into fed into two strain gauge amplifiers, one for each plate with their gain set to 2000x.

Amplifiers

Each force plate connects to a six channel strain gauge amplifier. These have switch selectable gains of 1000x, 2000x, 4000x for each channel. All channels also have a selectable low-pass filter of 10Hz or 1050 HZ cutoff. Bridge excitation levels of 2.5, 5 or 10 volts can be chosen. The output signal is rate up to +10V and is suitable for input into an A/D converter.

A/D converter

32 channel A/D interface unit receives up to thirty two analog channels and outputs the signals to a DT-3010 board in the data acquisition (DAQ) computer.

Force Plates Data Acquisition Equipment

A force transducer allows forces exerted on a body to be measured. Force applied to the transducer causes an electrical signal proportional to the applied force. AMTI force plates simultaneously measure three force components along the x, y and z axes and three moment components about the x, y and z axes. The forces and moments are measured by foil strain gauges attached to the load cells at the four corners of the platform. The gauges form six wheatstone bridges having active arms each with eight or more gauges per bridges.

3.9 Mechanics of Foot

The foot consists of 26 bones: 14 phalangeal, 5 metatarsal, and 7 tarsal. Toes are used to balance and propel the body. Metatarsal Bones gives elasticity to the foot in weight bearing. Tarsal bones located between the bones of the lower leg and the metatarsals are extremely important for support and locomotion.

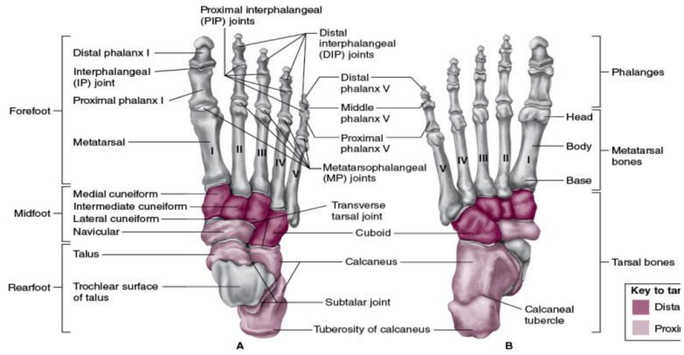

Fig 3.6 Foot

Foot Arches

Foot arches assist the foot in supporting the body weight; in absorbing shock of weight bearing; and in providing a space on the plantar aspect of the foot for the blood vessels, nerves, and muscles. There are 4 arches: The metatarsal, transverse arch, medial longitudinal arch, lateral longitudinal arch.

Plantar Fascia

These are thick bands of fascia that cover the plantar aspects of the foot. During weight bearing= mechanical energy is stored in the stretched ligaments, tendons, and plantar fascia of the foot. This energy is released to assist with push-off of the foot from the surface.

Foot Joints

Interphalangeal Joint: located at the distal extremities of the proximal and middle phalanges. Designed for flexion and extension.(hinge joint)

Metatarsophalangeal Joint: Permits flexion, extension, adduction, and abduction.(condyloid joint)

Intermetatarsal Joint: Permits slight gliding movements.

Tarsometatarsal Joint: allows some gliding and restriction of flexion, extension adduction and abduction.

Midtarsal Joint: Provides shock absorption.

Muscles of the foot

They are divided into two distinct groups; **extrinsic** and **intrinsic** muscles. **Extrinsic** muscles arise from the anterior, posterior and lateral compartments of the leg. They are mainly responsible for actions such as eversion, inversion, plantarflexion and dorsiflexion of the foot. **Intrinsic** muscles are located within the foot and are responsible for the fine motor actions of the foot, for example movement of individual digits.

Movements of the foot

Toe flexion and extension – Curling of toes

Inversion and Eversion – Sole moving inwards and outwards

Pronation and supination

Inversion, Abduction and Supination- Produce medial movements of the foot.

Eversion, Abduction, and Pronation- Produce lateral movements of the foot.

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Question Bank

PART A

S.No.	Questions
1	What is gait analysis?
2	What is Pondreal Index? Give its equation.
3	What are the advantages, disadvantages and applications of a pedobarograph?
4	What are the requisites of an ideal force plate?
5	Name few instruments to measure foot pressure.
6	State the difference between goniometer and accelerometer.
7	Write about the stages in a gait cycle.
8	What are the movements possible at ankle?
9	Give the classification of somatotype.
10	What is a pedobarograph?

PART B

S.No.	Questions
1	Explain the various stages of human locomotion.
2	Explain the mechanics of foot.
3	What is gait analysis? Give an account of gait analysis with various stages
4	Explain the working of a pedobarograph.
5	How is a force platform/plate used to measure the foot pressures? Describe the components
6	Describe the various anthropometric considerations of human body.
7	Discuss on the instruement used to measure body angles.
8	Write short notes on a)Accelerometer b)Podiascan

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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – IV – BIOMECHANICS – SBMA1403

HARD AND SOFT TISSUE MECHANICS

4.1 Biomechanics of Elbow

The elbow increases the flexibility of the upper limb. It also transmits forces between the arm and the forearm and acts as the axis for the forearm lever system. The elbow is a complex of three joints of humerus, ulna and radius: humeroulnar, humeroradial and proximal radioulnar joints. All three joints are enclosed within the same capsule.

The distal humerus is divided into medial and lateral columns, which are tilted anteriorly approximately 40° from the humeral shaft. The columns form two articulating surfaces at the elbow joint: capitellum and trochlea.

The humeroulnar joint is a hinge joint formed by the hourglass-shaped trochlea articulating with the saddle-shaped trochlea notch of the ulna. This is an inherently stable configuration, and restricts undue relative motion between the articulating surfaces. The humeroradial joint is a ball and socket joint. It is an unconstrained joint formed between capitellum, which is an almost perfect hemisphere, and radial head, which has little contact with the capitellum. The proximal radioulnar joint is a pivot joint formed by articulation between the adjacent surfaces of the radius and ulna. It is a relatively constrained joint.

Articulating Surface

It consists of two separate articulations:

Trochlear notch of the ulna and the trochlea of the humerus

Head of the radius and the capitulum of the humerus

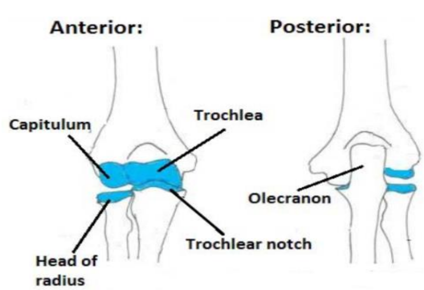


Fig 4.1 Elbow joints

Articulations

Ligaments

The joint capsule of the elbow is strengthened by ligaments medially and laterally.

The radial collateral ligament is found on the lateral side of the joint, extending from the lateral epicondyle, and blending with the annular ligament of the radius (a ligament from the proximal radioulnar joint).

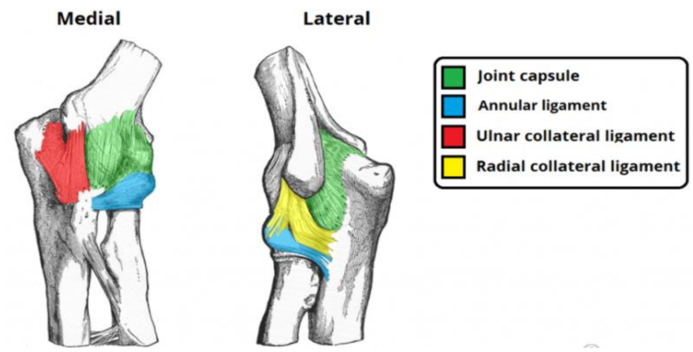


Fig 4.2 Ligaments

The ulnar collateral ligament originates from the medial epicondyle, and attaches to the coronoid process and olecranon of the ulna.

Movements

The elbow joint complex allows two types of motion: flexion and extension occur at the humeroulnar and humeroradial joints; and pronation and supination occur at the humeroradial and proximal radioulnar joints, and also require simultaneous motion at the distal radioulnar joint. The two types of motion are independent of each other. The normal range of flexion–extension is 0°–140°, and pronation–supination is 75° pronation – 85° supination. The functional range of flexion–extension is 30°–120°, and pronation–supination is 50° pronation – 50° supination.

4.2 Biomechanics of Shoulder

The shoulder joint (glenohumeral joint) is a ball and socket joint between the scapula and the humerus. It is the major joint connecting the upper limb to the trunk. It is one of the most mobile joints in the human body.

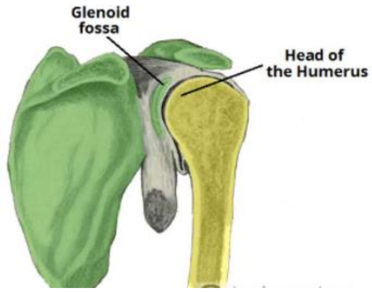


Fig 4.3 Shoulder Joint

Articulating Surfaces

The shoulder joint is formed by the articulation of the head of the humerus with the glenoid cavity (or fossa) of the scapula. This gives rise to the alternate name for the shoulder joint – the glenohumeral joint. Like most synovial joints, the articulating surfaces are covered with hyaline cartilage. The head of the humerus is much larger than the glenoid fossa, giving the joint a wide range of movement at the cost of inherent instability.

The shoulder complex involves 3 physiological joints and one floating joint:

Glenohumeral (GH) joint - Ball and socket synovial joint, where the head of the humerus (convex surface) articulates with the glenoid fossa (concave surface) of the scapula. Because of the relatively large surface area of the humeral head in relation to the fossa, the joint itself has limited bony congruency, and consequentially heavily depends on surrounds soft tissues for structural support.

Acromioclavicular (AC) joint- diarthrodial and synovial joint. It allows for axial rotations and antero-posterior glides. Because there are not direct attachements of muscles to the joint, all movements are passive and initiated by movements at other joints

Sternoclavicular (SC) joint

Scapulothoracic (ST) joint - known as a "functional joint". is not a true joint

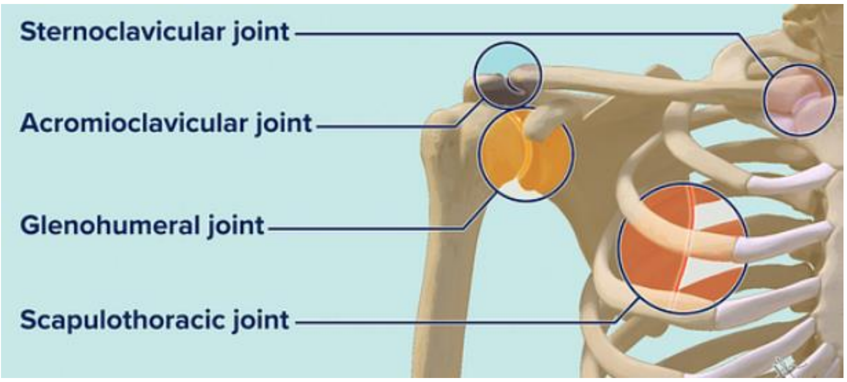


Fig 4.4 Joints of shoulder

Joint Capsule and Bursae

The joint capsule is a fibrous sheath which encloses the structures of the joint. It extends from the anatomical neck of the humerus to the border or 'rim' of the glenoid fossa. The joint capsule is lax, permitting greater mobility (particularly abduction).

The synovial membrane lines the inner surface of the joint capsule, and produces synovial fluid to reduce friction between the articular surfaces. To reduce friction in the shoulder joint, several synovial bursae are present. A bursa is a synovial fluid filled sac, which acts as a cushion between tendons and other joint structures.

Ligaments

In the shoulder joint, the ligaments play a key role in stabilising the bony structures.

Glenohumeral ligaments (superior, middle and inferior) – the joint capsule is formed by this group of ligaments connecting the humerus to the glenoid fossa. They are the main source of stability for the shoulder, holding it in place and preventing it from dislocating anteriorly. They act to stabilise the anterior aspect of the joint.

Coracohumeral ligament – attaches the base of the coracoid process to the greater tubercle of the humerus. It supports the superior part of the joint capsule.

Transverse humeral ligament – spans the distance between the two tubercles of the humerus. It holds the tendon of the long head of the biceps in the intertubercular groove.]

Coraco–clavicular ligament – composed of the trapezoid and conoid ligaments and runs from the clavicle to the coracoid process of the scapula. They work alongside the acromioclavicular ligament to maintain the alignment of the clavicle in relation to the scapula.

The other major ligament is the coracoacromial ligament. Running between the acromion and coracoid process of the scapula it forms the coraco-acromial arch. This structure overlies the shoulder joint, preventing superior displacement of the humeral head.

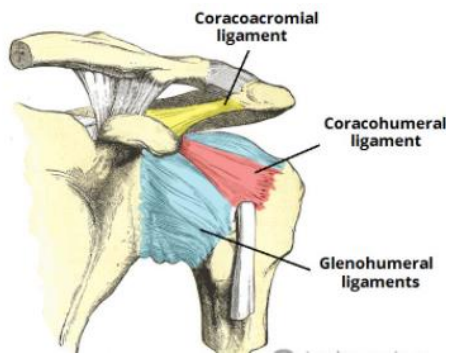


Fig 4.5 Ligaments of shoulder

Movements

As a ball and socket synovial joint, there is a wide range of movement permitted:

Extension , Flexion, Abduction , Adduction , External rotation

4.3 Biomechanics of Hip

The hip joint is a ball and socket synovial joint, formed by an articulation between the pelvic acetabulum and the head of the femur. It forms a connection from the lower limb to the pelvic girdle, and thus is designed for stability and weight-bearing – rather than a large range of movement.

Articulating Surfaces

The hip joint consists of an articulation between the head of femur and acetabulum of the pelvis.

The acetabulum is a cup-like depression located on the inferolateral aspect of the pelvis. Its cavity is deepened by the presence of a fibrocartilaginous collar – the acetabular labrum. The head of femur is hemispherical, and fits completely into the concavity of the acetabulum. Both the acetabulum and head of femur are covered in articular cartilage, which is thicker at the places of weight bearing.

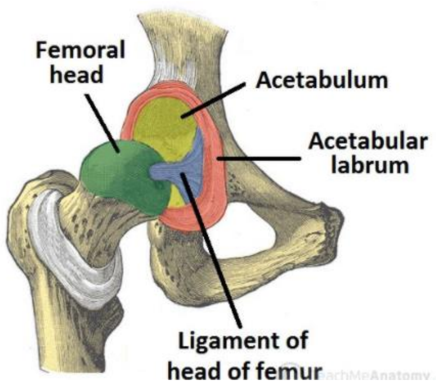


Fig 4.6 Hip Joint

Ligaments

The ligaments of the hip joint act to increase stability. They can be divided into two groups – intracapsular and extracapsular:

Intracapsular

The only intracapsular ligament is the ligament of head of femur

Extracapsular

There are three main extracapsular ligaments, continuous with the outer surface of the hip joint capsule:

Iliofemoral ligament – arises from the anterior inferior iliac spine and then bifurcates before inserting into the intertrochanteric line of the femur. It has a 'Y' shaped appearance, and prevents hyperextension of the hip joint. It is the strongest of the three ligaments.

Pubofemoral – spans between the superior pubic rami and the intertrochanteric line of the femur, reinforcing the capsule anteriorly and inferiorly. It has a triangular shape, and prevents excessive abduction and extension.

Ischiofemoral– spans between the body of the ischium and the greater trochanter of the femur, reinforcing the capsule posteriorly. It has a spiral orientation, and prevents hyperextension and holds the femoral head in the acetabulum.

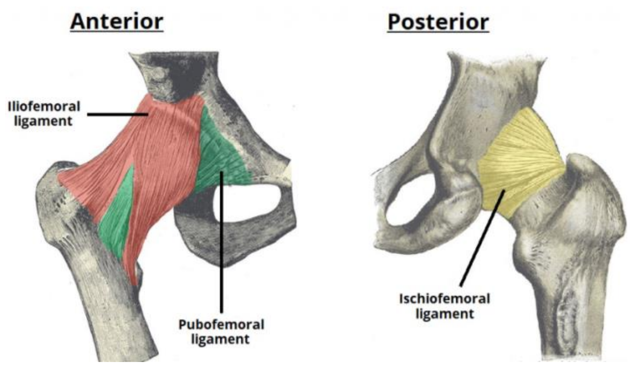


Fig 4.7 Ligaments of hip joint

Movements

Flexion, Extension, Abduction, Adduction, Lateral and Medial Rotation

4.4 Biomechanics of Knee

Knee joint is a hinge type synovial joint, which mainly allows for flexion and extension (and a small degree of medial and lateral rotation). It is formed by articulations between the patella, femur and tibia.

Articulating Surfaces

The knee joint consists of two articulations – tibiofemoral and patellofemoral. The joint surfaces are lined with hyaline cartilage and are enclosed within a single joint cavity.

Tibiofemoral – medial and lateral condyles of the femur articulate with the tibial condyles. It is the weight-bearing component of the knee joint.

Patellofemoral – anterior aspect of the distal femur articulates with the patella. It allows the tendon of the quadriceps femoris (knee extensor) to be inserted directly over the knee – increasing the efficiency of the muscle.

Menisci

The medial and lateral menisci are fibrocartilage structures in the knee that serve two functions:

To deepen the articular surface of the tibia, thus increasing stability of the joint.

To act as shock absorbers by increasing surface area to further dissipate forces.

They are C shaped and attached at both ends to the intercondylar area of the tibia.

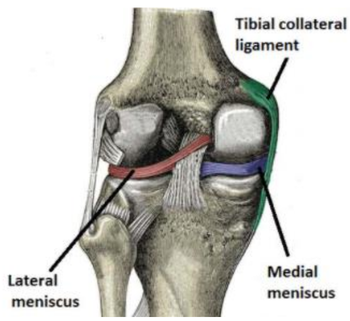


Fig 4.8 Mensci of knee

Ligaments

The major ligaments in the knee joint are:

Patellar ligament – a continuation of the quadriceps femoris tendon distal to the patella

Collateral ligaments – two strap-like ligaments. They act to stabilise the hinge motion of the knee, preventing excessive medial or lateral movement

Tibial (medial) collateral ligament – wide and flat ligament, found on the medial side of the joint. Proximally, it attaches to the medial epicondyle of the femur, distally it attaches to the medial condyle of the tibia.

Fibular (lateral) collateral ligament – thinner and rounder than the tibial collateral, this attaches proximally to the lateral epicondyle of the femur, distally it attaches to a depression on the lateral surface of the fibular head.

Cruciate Ligaments – these two ligaments connect the femur and the tibia. In doing so, they cross each other, hence the term 'cruciate'.

Anterior cruciate ligament – attaches at the anterior intercondylar region of the tibia where it blends with the medial meniscus. It prevents anterior dislocation of the tibia onto the femur.

Posterior cruciate ligament – attaches at the posterior intercondylar region of the tibia and ascends anteriorly to attach to the anteromedial femoral condyle. It prevents posterior dislocation of the tibia onto the femur.

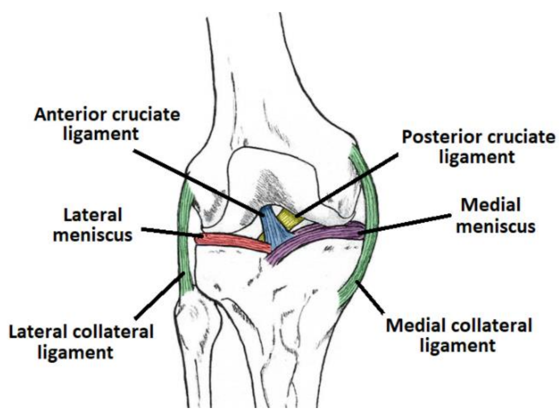


Fig 4.9 Ligaments of knee

Movements

Extension, Flexion, Lateral and Medial Rotation

4.6 Mechanical Properties of Tissues

Ligament - Tough fibrous band of connective tissue that serves to support the internal organs and hold bones together in proper articulation at the joints. A ligament is composed of dense fibrous bundles of collagenous fibres and spindleshaped cells known as fibrocytes, with little ground substance (a gel-like component of the various connective tissues). Ligaments may be of two major types: white ligament is rich in collagenous fibres, which are sturdy and inelastic; and yellow ligament is rich in elastic fibres, which are quite tough even though they allow elastic movement.

Tendons are the connective tissues that transmit the mechanical force of muscle contraction to the bones; the tendon is firmly connected to muscle fibres at one end and to components of the bone at its other end. Tendons are remarkably strong, having one of the highest tensile strengths found among soft tissues. Their great strength, which is necessary for withstanding the stresses generated by muscular contraction, is attributed to the hierarchical structure, parallel orientation, and tissue composition of tendon fibres.

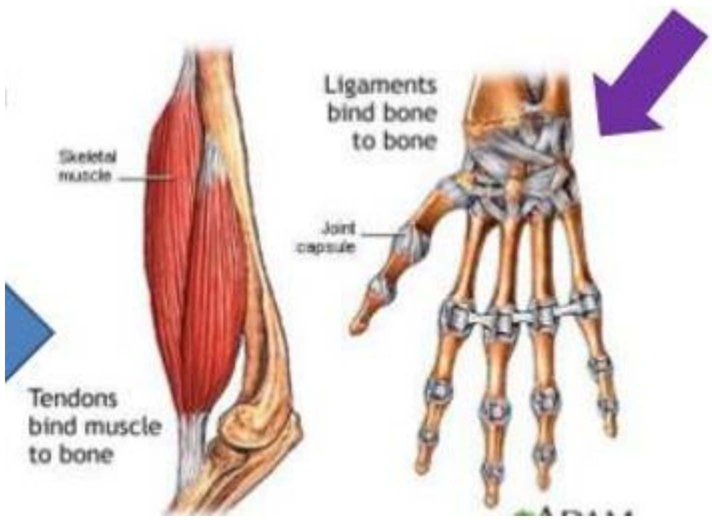


Fig 4.10 and ligaments

Cartilage is a connective tissue consisting of a dense matrix of collagen fibres and elastic fibres embedded in a rubbery ground substance. The matrix is produced by cells called chondroblasts, which become embedded in the matrix as chondrocytes. The surface of most of the cartilage in the body is surrounded by a membrane of dense irregular connective tissue called perichondrium. Cartilage contains no blood vessels or nerves - except in the perichondrium.

Three types of cartilage:

Elastic cartilage- Yellow in appearance, contains elastic fibres in addition to collagen. Found in external ear, the auditory tube of the middle ear, and the epiglottis.

Fibrocartilage- Tough, very strong tissue found in the intervertebral disks and at the insertions of ligaments and tendons; contains cartilage ground substance and chondrocytes

Hyaline cartilage - smooth and shiny, found in nose, windpipe, and most of the body's joints. Also called articular cartilage

Skin

Skin is the heaviest single organ. Its thickness varies throughout the body. For eg: Scalp is 1.5mm thick while the back is 4mm thick. Skin is composed of three layers: Epidermis (outer layer), Dermis, and Hypodermis. The outermost layer epidermis acts as a skin barrier. The dermis is the layer of skin beneath the epidermis that consists of connective tissue and cushions the body from stress and strain. The third layer is the mainly made of adipose cell. Skin is considered to be viscoelastic.

Skin has mesodermal cells, pigmentation, such as melanin provided by melanocytes, which absorb some of the potentially dangerous ultraviolet radiation (UV) in sunlight.

The mechanical properties of the skin depends on the nature of collagen and elastin fibres.

Functions - Protection of internal structures – physical barrier to microorganisms and foreign matter, acid PH helps to prevent infection, Sensory perception, Thermoregulation, Excretion, Metabolism, Absorption

Mechanical Properties

Connective tissues are described as heterogeneous because they are composed of a variety of solid and semisolid components.

Force and Elongation

The force values in the load-deformation curve depend on both the size of the structure and its composition. A larger structure (cross-sectional area) will be able to withstand more force, and a longer structure will elongate further when a force is applied. Thus, if two tissues are composed of the same material, a larger tissue will have greater tensile strength, and a longer tissue will have less stiffness.

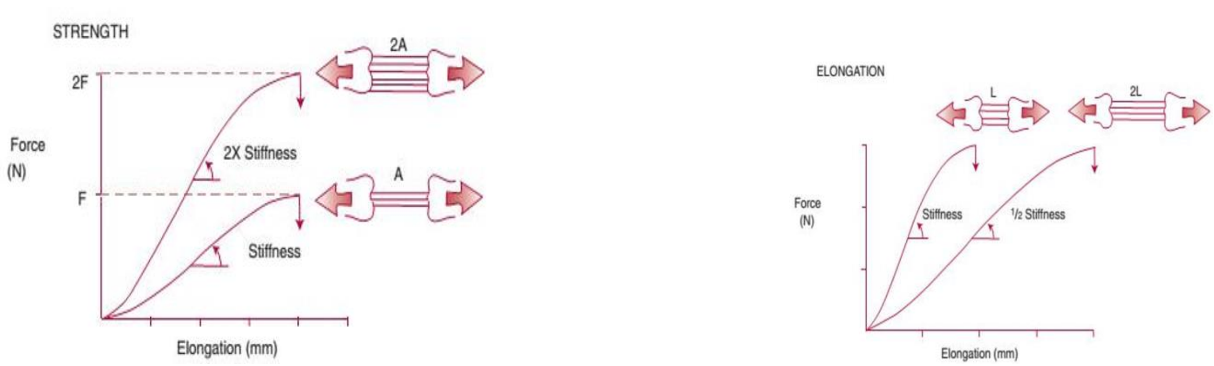


Fig 4.11 Force and Elongation

Stress and Strain

When loads (forces) are applied to a structure or material, an internal resistance to that deformation is produced in the structure or material. The internal reaction to the applied force is called stress. Stress is defined as the force per unit of crosssectional material and can be expressed mathematically in the following formula, where S stress, F applied force, and A area:

S F/A

The relative deformation (change in shape, length, or width) of the structure or material that accompanies the stress is referred to as strain. Strain is the amount of deformation that takes place relative to the original length of the material.

Young's modulus

It is also known as the elastic modulus, is a mechanical property of linear elastic solid materials. It defines the relationship between stress (force per unit area) and strain (proportional deformation) in a material. The modulus of elasticity defines the mechanical behavior of the material and is a measure of the material's stiffness (resistance offered by the material to external loads).

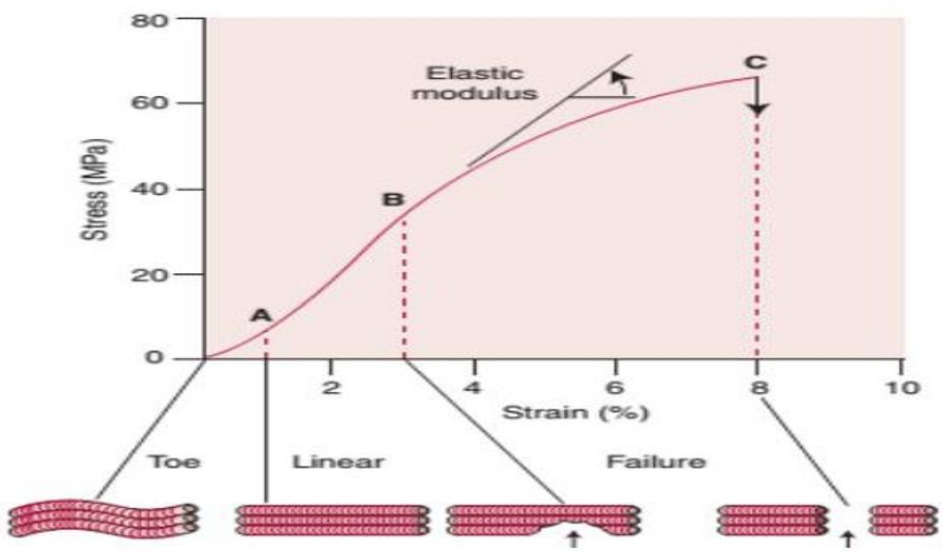


Fig 4.12 Stress strain curve

Toe Region : Uncrimping of crimped tendons

Non linear

2% strain

Linear Region: Fibrils stretch

Linear

Strain less than 4%,returns to original state

Slope gives the Youngs Modulus

Yield & Failure Region: 8-10%- Fibril fractures

Stiffness reduced

Mechanical Properties of skin

The stress-strain behaviour of the skin is typically explained in three phases: When a strain of up to 0.3% is applied, the elastin fibres offer low resistance to the applied strain. The skin exhibits isotropic behaviour and collagen fibres remain tangled and intertwined and do not contribute to the stiffness. Phase 1 offers a linear stress-strain relationship and a low Young's Modulus (0.1-2MPa).

In Phase 2, the collagen fibres offer some resistance to the deformation and the crimped collagen fibres begin to stretch, thus introducing non-linearity into the stress strain relationship.

In the final Phase 3, for applied strain above 0.6%, the crimps begin to disappear and a linear stress-strain relationship can be observed. The collagen fibres break after the application of an ultimate tensile strain of 0.7% .

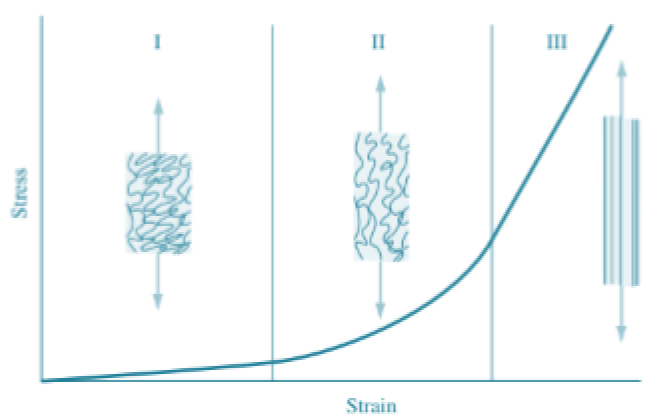


Fig 4.13 Skin stress strain curve

Young's Modulus of the skin is a vital parameter to estimate the characteristics of skin. One of the striking features of a healthy skin is its ability to get back to normal after being pulled. Knowing the Young's Modulus of skin can help in calibrating the elasticity of bio-sensors to measure skin-stretch induced motion artifacts.

Nonlinear stress–strain relationship - The mechanical response of skin tissue is highly non-linear due to the makeup of its microstructural constituents.

Skin also exhibits the relaxation behavior characteristic of viscoelastic materials. When stretched and held to a constant strain level, the stress within the skin material will decay over time.

4.7 Biological Materials

A primary group of tissue which binds, supports and protects our human body and structures such as organs is soft connective tissue. In contrary to other tissues, it is a wide-ranging biological material in which the cells are separated by extracellular material.

Examples for soft tissues are tendons, ligaments, blood vessels, skins or articular cartilages among many others. Tendons are muscle-to-bone linkages to stabilize the bony skeleton (or to produce motion), while ligaments are bone-to-bone linkages to restrict relative motion. Blood vessels are prominent organs composed of soft tissues which have to distend in response to pulse waves. The skin is the largest single organ (16% of the human adult weight). It supports internal organs and protects our body. Articular cartilages form the surface of body joints (which is a layer of connective tissue with a thickness of 1-5 mm) and distribute loads across joints and minimize contact stresses and friction.

Collagen. Collagen is a protein which is a major constituent of the extracellular matrix of connective tissue. It is the main load carrying element in a wide variety of soft tissues and is very important to human physiology (for example, the collagen content of (human) achilles tendon is about 20 times that of elastin).

Collagen is a macromolecule with length of about 280 nm. Collagen molecules are linked to each other by covalent bonds building collagen fibrils. Depending on the primary function and the requirement of strength of the tissue the diameter of collagen fibrils varies. In the structure of tendons and ligaments, for example, collagen appears as parallel oriented fibers , while many other tissues have an intricate disordered network of collagen fibers embedded in a gelatinous matrix of proteoglycans.

More than 12 types of collagen have been identified . The most common collagen is type I, which can be isolated from any tissue. It is the major constituent in blood vessels.

4.8 Properties of cortical and Cancellous Bone

Bones are composed of two types of tissue:

1. Compact (cortical) bone: A hard outer layer that is dense, strong, and durable. It makes up around 80 percent of adult bone mass.

2. Cancellous (trabecular or spongy) bone: This consists of a network of trabeculae or rod-like structures. It is lighter, less dense, and more flexible than compact bone.

The compact bone constitutes up to 80% of the bones weight, with spongy bone making up the additional 20%, despite its much larger surface area.

Bones also consists of osteoblasts and osteocytes, responsible for creating bone, osteoclasts or bone resorbing cells ,osteoid, a mix of collagen and other proteins, inorganic mineral salts within the matrix, nerves and blood vessels, bone marrow, cartilage, membranes.

Structural Properties- Mechanical properties that a structure possesses due to its size & geometry. Structural properties are usually determined by plotting load-deformation relationships of structures made up of like tissues.

Material properties - Mechanical properties that a material or tissue possesses due to the make-up the tissue (the content as well as the arrangement of fibers & cells). Material properties are usually determined by plotting stress-strain relationships of different tissues.

Mechanical parameters depend on the content of organic and inorganic materials. Inorganic materials are responsible for giving the bones elastic properties, are related to the activity of cells which in turn depends on the correct blood supply of the bone tissue.

The forces to which the bone is usually exposed include compression, tension, torsion, bending and shear stress.

1.Elastic behavior (Hookes law)

Law of elasticity states that a material subjected to tensile force would extend in the direction of traction by an amount that is proportional to the load, in other words Stress is directly proportional to the strain.

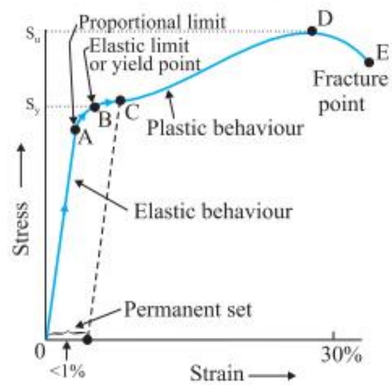


Fig 4.14 Elastic Behaviour

2.Stress and Strain

Stress: The force per unit of cross sectional area. The SI Unit of stress is newton per square meter.

$$\sigma = \frac{F}{A}$$

Strain : It is the ratio of the change in size or shape to the original size or shape. It has no dimensions, it is just a number.

$$\varepsilon = \frac{e}{lo}$$

3.Tension and Compression

A tension is a force that pulls a material apart and compression is a force that squeezes a material together.

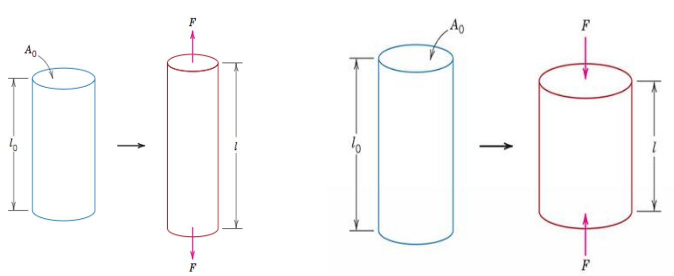


Fig 4.15 Tension and Compression Stress

4.Shear

If instead of applying a force perpendicular to the surface, we apply parallel but opposite forces on the two surfaces we are applying a shear stress.

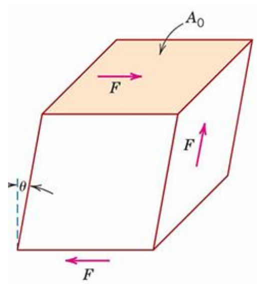


Fig 4.16 Shear stress

5.Torsion

If we hold one end of a cylinder fixed and twist the other end as shown in the figure below, we are applying a torsional (or twisting) stress.

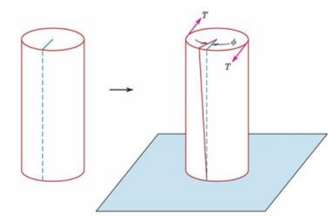


Fig 4.17 Torsion stress

Bulk Properties

Ductility - Characteristic of a material that undergoes considerable plastic deformation under tensile load before rupture

Brittleness- Absence of any plastic deformation prior to failure

Malleability- Characteristic of a material that undergoes considerable plastic deformation under compressive load before rupture

Resilience- Ability of a material to absorb energy when it is deformed elastically, and release that energy upon unloading.

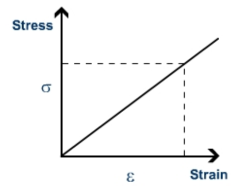
Toughness – property of a material enabling it to endure high-impact or shock loads; ability to absorb energy during plastic deformation

Hardness - Resistance of a material to scratching, wear, or penetration

Elastic properties of bones

1.Young’s Modulus

The gradient of the straight-line graph is the Young's modulus, E



$$E = \frac{stress}{strain} = \frac{\sigma}{\varepsilon}$$

E is constant and does not change for a given material. It in fact represents 'stiffness' property of the material.

2.Fracture:

Separation of a body into pieces due to stress.

Depending on the ability of material to undergo plastic deformation before the fracture two fracture modes can be defined - ductile or brittle.

Ductile fracture -most metals:

Ductile fracture is a type of fracture characterized by extensive deformation of plastic or "necking." This usually occurs prior to the actual fracture. Crack is stable: resists further extension unless applied stress is increased

Brittle fracture –

Brittle Fracture is the sudden, very rapid cracking of equipment under stress where the material exhibited little or no evidence of ductility or plastic degradation before the fracture occurs.

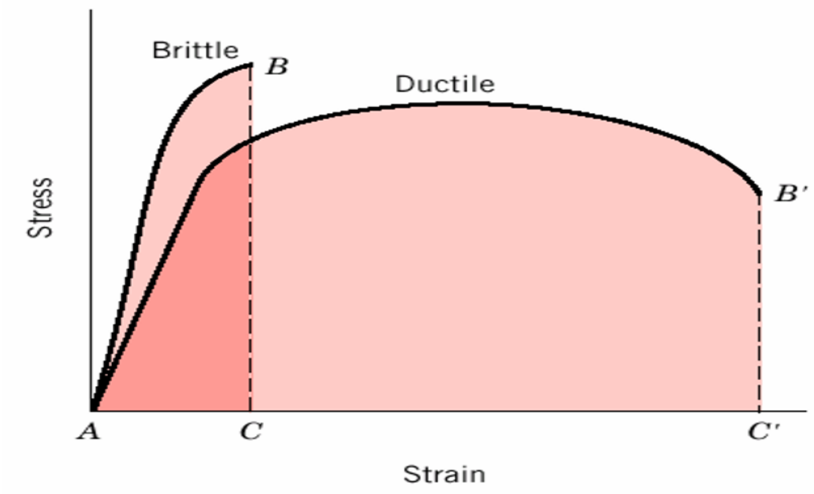


Fig 4.18 Ductile and Brittle Fracture

3.Plastic Deformation:

At some point, the strain is no longer proportional to the applied stress. At this point, bonds with original atom neighbors start to break and reform with a new group of atoms. When this occurs and the stress is relieved, the material will no longer return to its original form, i.e., the deformation is permanent and non recoverable. The material has now moved into the region referred to as plastic deformation. It produces a permanent change in the shape or size of a solid body without fracture, resulting from the application of sustained stress beyond the elastic limit.

4.10 Mechanical Testing of soft tissues

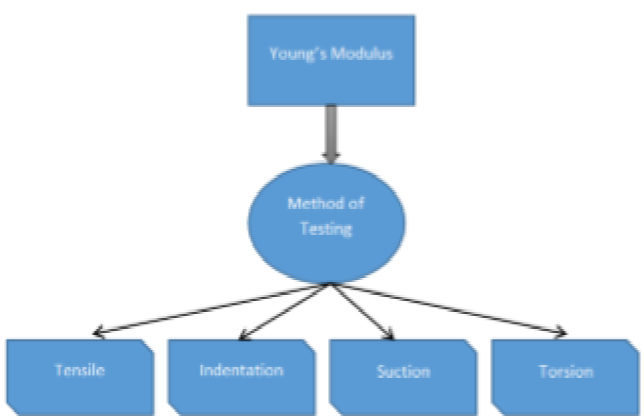


Fig 4.19 Testing methods

The mechanical behaviour of the skin is measured by changing the shape of skin by employing different techniques such as stretching (tensile test), applying normal load on the skin (indentation test), elevating the skin in an aperture (suction test) and rotating the epidermis to different degrees (torsion test).

The mechanical testing of skin can be further classified into in vivo and in vitro tests. In vitro tests provide a simple and easy to model Stress-Strain relationship under controlled conditions. In vitro tests can also be used to calculate the ultimate tensile stress and strain when the skin ruptures. In comparison, in vivo tensile measures are able to include anatomical and physiological effects on skin properties. For example, skin ageing provides a negative impact on skin's ability to perform functions like body temperature regulation and water loss prevention. Longitudinal studies of Young's Modulus values of skin must therefore be done in vivo.

Tensile test

Tensile testing is the most common type of test performed ex vivo under controlled conditions . In tensile tests, the skin is stretched parallel to the plane of the skin. The load can either be uniaxial or biaxial. The maximum and minimum values of the Young's Modulus across the tibial axis were found to be 0.32 and 4 MPa respectively and 0.3 and 20 MPa, respectively. A customised tensile device was used to measure the ultimate stress along with the longitudinal, transverse and shear strain field in an I-shaped tissue sample (taken from an 85-year old male) using Image Correlation Method. The machine had been divided into an upper chamber and a lower chamber to clamp the tissue from both ends. Young's Modulus was calculated for longitudinal, transverse and shear strains.

Indentation test

Indentation is one of the most widely used and accepted means of measurement of skin's bio-mechanical properties in vivo. It employs the use of an indenter which comes in to contact with and applies a perpendicular force on a small area of skin. The indentation method delivers Young's Modulus in the perpendicular direction without any skin pre-stressing Laser or ultrasound sensors are employed to measure the distance of depths on indentation. Spherical and cylindrical indentors are employed for the test. The cylindrical indenter measured a higher average value of Young's Modulus than the spherical indenter at higher indentation depths.

Suction test

The mechanical properties of thin elastic membranes of materials like rubber can be determined using Diaphragm tests, where the membrane is clamped at two ends and inflated in the form of a dome while the pressure of suction is controlled by a pressure controller.

The suction method to investigate anisotropy of skin has evolved to become a common procedure for skin mechanical testing. Generally, it employs the measurement of skin elevation in a circular aperture caused due to vacuum conditions using optical systems like Dermaflex and Cutometer.

Dermaflex is a device with an aperture size of 10 mm, the cup being adhered to the skin to prevent creep. It has been used to measure skin distensibility and to account for mechanical properties of dermis in by measuring elasticities as a percentage of skin retraction after the stretch. The Cutometer is a suction device employing probe apertures between 2-8 mm with the application of negative pressure through a vacuum pump.

Torsion test

Torsion measurements are carried out by applying a constant torque through a guard ring and an intermediary disc and measuring the resultant rotation of skin. As the torque is applied, an immediate elastic deformation occurs followed by the occurrence of creeping viscoelastic deformation which is time dependent. The release of torque leads to immediate recovery followed by a slow recovery process which is usually not completed. In torsion, the elongation is replaced by rotation and hence the measurement of elasticity becomes more complex.

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Question Bank

PART A

S.No.	Questions
1	What are the types of bone tissue?
2	Specify few mechanical properties of soft tissues.
3	What are the types of cortical bone?
4	Mention on the shoulder ligaments.
5	Give the movements available in the elbow.
6	State few problems associated with mechanical testing of soft tissues.
7	Draw the stress strain curve for tissue, elastin and collagen
8	What are the features of soft tissues?
9	What is the role of mesnisci in a knee joint?
10	List the properties of cancellous bone.

PART B

S.No.	Questions
1	Explain the biomechanics of knee joints.
2	Give an account of biomechanics of elbow.
3	Explain in detail the mechanical properties of the various soft tissues.
4	Describe the steps involved and problems encountered in mechanical testing of soft tissue.
5	Give an account of the mechanical properties of collagen
6	Explain briefly the mechanical properties of cartilage.
7	Describe the mechanical properties of cortical bone and cancellous bone.
8	Give the characteristics of any two biological materials.
9	Explain the biomechanics of hip joints.
10	Give an account of biomechanics of shoulder

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DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – V – BIOMECHANICS – SBMA1403

KINESIOLOGY OF SPORTS

5.1 Biomechanics to Neuromuscular Fitness

Neuromuscular control is defined as the unconscious trained response of a muscle to a signal regarding dynamic joint stability. The movements of the lower extremity, including the knee joint, are controlled through this system, which needs to provide the correct messaging for purposeful movement. Neuromuscular training programs should address several aspects of sensorimotor function and functional stabilization to improve objective function and alleviate symptoms. Neuromuscular exercise has effects on functional performance, biomechanics, and muscle activation patterns of the surrounding joint musculature.

A lag in the neuromuscular reaction time can result in dynamic joint instability with recurrent episodes of joint subluxation and deterioration. Therefore, both mechanical stability and neuromuscular control are probably important for long-term functional outcome, and both aspects must be considered in the design of a neuromuscular rehabilitation program

The neuromuscular training method that is described is based on biomechanical and neuromuscular principles and aims to improve sensorimotor control and achieve compensatory functional stability. Unlike conventional strength training, neuromuscular exercise addresses the quality of movement and emphasizes joint control in all three biomechanical/movement planes.

The muscular system can be mechanically or metabolically overloaded. These mechanisms result in specific and different adaptations that enhance performance.

The magnitude of these adaptations is dependent on:

The type of exercise

The intensity of exercise

The frequency of exercise

The duration of exercise

The mode of exercise (e.g. strength training or endurance training) influences the type and magnitude of adaptation in the neuromuscular system. For example if endurance training (high repetition, low load contractions) is undertaken the muscular system will undergo specific changes that targets aerobic metabolism and improved fatigue resistance. Strength training (low repetitions with high load contractions), in contrast, will cause muscle adaptations such as increased myofibrillar protein synthesis. As a result muscle size, strength and power may increase and improve.

5.2 Biomechanics to Gymnastics

Gain an understanding of the techniques used in gymnastics skills from a perspective of sports biomechanics and motor control research. Such investigations can explain, for example, how a twist may be introduced into a somersault after takeoff, can quantify the contributions of various twisting techniques to actual performances, and can determine the extent to which twisting somersaults can be controlled by means of in-flight corrections.

Major applications are on twisting somersaults, swinging on rings, swinging on high bar, uneven bars and parallel bars, vaulting and tumbling.

Tumbling

Tumbling is a dynamic activity performed in both gymnastics and tumbling disciplines. Linear and angular momentum produced during the approach phase is used during the final takeoff phase along with appropriate muscle activation time histories to produce the necessary linear and angular momentum at takeoff to perform a particular skill.

Fig 5.1 Tumbling

Twisting somersaults in gymnastics

somersaults form the main elements of the floor exercise and apparatus dismounts in Artistic Gymnastics.Twisting somersaults in gymnastics

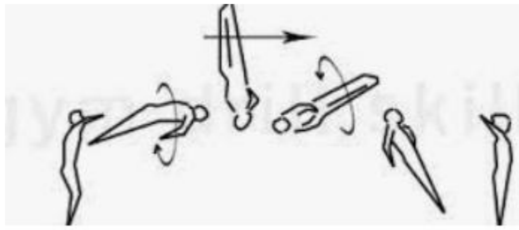

Fig 5.2 Sommersaults

High Bar

A routine on high bar comprises circling skills, release and regrasp skills and a dismount. The giant circle is a fundamental skill on this piece of apparatus since it is used to link the circling skills and to generate the required linear and angular momentum for the complex release skills.

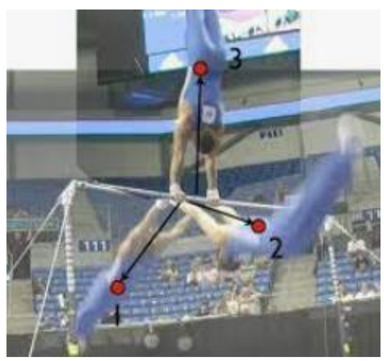

Fig 5.3 High bar jumping

Parallel Bars

Routines are performed on two parallel bars and consist of a mount, swinging skills, some with flight, held elements, and a dismount. Many of the swinging elements on parallel bars are similar to movements performed on the high bar, with the main difference being the shape and orientation of the bars and their effect on grasp and point of rotation.

Fig 5.4 Parallel Bar

Vaulting

Vaulting is a dynamic activity performed in both mens and womens artistic gymnastics. Linear and angular momentum generated during the approach and the takeoff from the springboard are used during the contact with the vaulting table to produce the flight and rotation necessary for a particular vault.

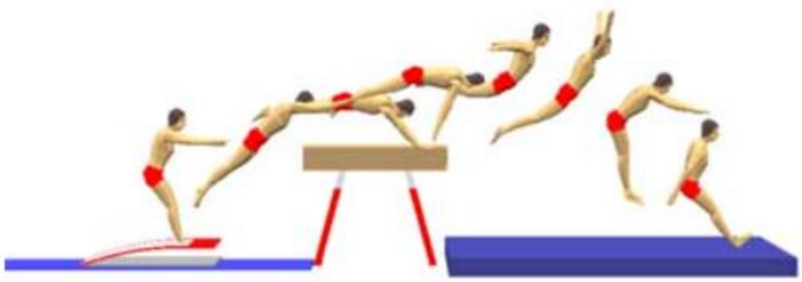

Fig 5.5 Vaulting

Rings

The long swing to still handstand is a key element of a competitive rings exercise. The forces on the gymnast are around twice those in a giant circle on high bar but are limited because of the elasticity of the rings equipment and the technique used by the gymnast. The difficulty in reaching a completely motionless handstand is a consequence of the marked sensitivity to timing the joint angle changes in the second half of the movement.

Fig 5.6 Ring movements

5.3 Aerodynamics in sports

The basic aerodynamic and hydrodynamic principles that govern most sports are identified. In turn, each concept is applied to a wide variety of individual sports, demonstrating how surface textures, form and shape of the equipment or athlete govern speed and motion and how performance can be enhanced.

SPORTS BALL AERODYNAMICS

Lateral deflection in flight, known as swing, swerve or curve, is well recognized in baseball, golf, tennis, cricket, volleyball and soccer. In most of these sports, the deflection is produced by spinning the ball about an axis perpendicular to the line of flight which generates the Magnus effect. It has long been known that the aerodynamics of sports balls is strongly dependent on the detailed development and behavior of the boundary layer on the ball's surface

BASEBALL AERODYNAMICS

For a pitch such as the curveball, the ball is released with topspin about the horizontal axis. This results in a Magnus force that makes the ball curve faster towards the ground than it would under the action of gravity alone.

GOLF BALL AERODYNAMICS

In golf ball aerodynamics, apart from the lift force, the drag and gravitational forces are also important, since the main objective is to "tailor" the flight path of the ball. The lift force is generated due to the Magnus effect and the role of the dimples is to lower the critical

TENNIS BALL AERODYNAMICS

Studies of tennis ball aerodynamics have revealed the very important role that the felt cover plays. The first observation is that the boundary layer over the top and bottom of the ball separates relatively early, thus suggesting a laminar boundary layer separation. However, since the flow field did not change with Re, it was presumed that transition had already occurred and that a turbulent boundary layer separation was obtained over the whole Re range tested, thus putting the ball in the transscritical flow regime.

CRICKET BALL AERODYNAMICS

Fast bowlers in cricket make the ball swing by a judicious use of the primary seam (six rows of prominent stitching). The ball is released with the seam at an angle to the initial line of flight

VOLLEYBALL AND SOCCER BALL AERODYNAMICS

In volleyball, two main types of serves are employed: a relatively fast spinning serve (generally with topspin), which results in a downward Magnus force adding to the gravitational force or the so-called “floater” which is served at a slower pace, but with the palm of the hand so that no spin is imparted to it.

5.4 Hydrodynamics in swimming

Swimming is a sport that relies on hydrodynamic principles. Also known as fluid dynamics, this branch of science deals with the study of liquids in motion. Swimmers engage in hydrodynamics every time they set foot in the water. Competitive swimmers, especially, work with basic hydrodynamic principles to reduce drag, streamline their forms and optimize their strokes for the best possible performance.

Water Resistance

Water resistance plays an important role in understanding the hydrodynamics of swimming. Because water offers 1000 times more resistance than moving through air, most of the energy in the water is lost when acting against resistance forces. If a person walks the length of a pool, the resistance force of water because water is over 700 times more dense than air.

Buoyancy

Another aspect of hydrodynamics and swimming is the principle of buoyancy. Buoyancy is the upward force which causes the pressure below a person to be greater than the pressure above the person, resulting in the ability to float on top of the water rather than be pushed to the bottom. The closer a person is to the top of the water, the greater the buoyancy. Competitive swimmers establish greater buoyancy by trying to keep their shoulders above the water, which improves their ability to move through the water with greater buoyancy.

Propulsion Forces

When a person swims, they propel themselves through the water with their legs and arms due to the high density of water. The arms perform a levering action to propel through the water while the legs typically perform a kicking motion. Forward power of the body through water deals with two main forces of hydrodynamics: the resistance, or drag force, and the lift force of water. When a person swims, they work with lift force by swimming as closely to the surface of the water as possible. However, to overcome the drag, or resistance, of water, they must produce a propulsion force greater than the opposing resistance force of water. To maximize forward motion, fingers are pressed together and hands are moved in a pulling motion, taking advantage of the water density. Kicking the legs also reduces drag force, although kicking produces less force than the arms do when they swim.

The water resistance, i.e. drag, is generated mainly due to the collision of the water molecules with the athlete and to the friction between the water and the surface of the body. In swimming, a third form of drag is created due to the waves generated by the motion of the athlete, wave drag. The appearance of waves will obstruct the efforts of the athlete. In open water events this form of drag is greater than in swimming pools that are designed so as to minimize the effect.

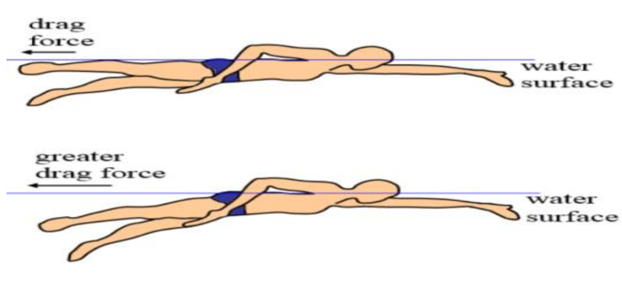

Fig 5.7 Drag during swimming

Streamlining Form

Because water acts as a resistance force on the body, it has to streamline the form to reduce drag. For example, a larger body moves more slowly through the water than a smaller person because of the difference in surface area. Because resistance force is proportional to surface area, a person can decrease drag if he can make himself smaller in the water. Competitive swimmer's bathing suits do not resemble the typical bathing suit you might find at a store; instead, they are designed to cover the entire body, compressing the swimmer as much as possible. These suits tighten the body to achieve a torpedo shape, which reduces drag and contributes to faster swimming. Swim caps also reduce drag, which is why they are worn in competitions.

5.5 Analysis of throw and push patterns

Push-and-Pull Motions

A segment motion that involves moving an object, either directly by part of the body or by means of implement, in pushing and pulling pattern. For example, a pitcher throws a baseball or a tennis player serves a tennis or a worker lifts a box from the floor onto an overhead rack an archer shoots an arrow from a bow

A segmental motion that all forces are continuously applied onto an external object (continuous application pattern of sequential movement)

Joint Action Patterns

In pushing and pulling patterns of motion, the basic joint actions are flexion and extension in one or more of the extremities. The joint actions in the upper extremities are characterized by flexion and extension in the elbow while the opposite movement is occurring in the shoulder. In the lower extremities, extension occurs simultaneously in the hip, knee, and ankle. This simultaneous and opposite joint action is a primary characteristic of push-pull patterns. All joint motions occur at the same time or very near the same time.

The simultaneous nature of the joint motions in push and pull patterns produces a rectilinear path of motion at the distal end point of the segments involved, as opposed to a curvilinear path. Such a rectilinear path means that all forces produced by segmental motion are applied directly to the object and that this force is applied in the direction of motion. Keeping this in mind makes it apparent that the primarily simultaneous push-pull patterns are of greatest value when it is important to apply a large force (overcome a large resistance) or to apply a force with maximum accuracy. All the forces involved are applied directly in line with the object being moved. There are no large-magnitude tangential forces.

Ball Throwing

Stage 1- ball thrown primarily with elbow extension – no rotation of thorax or arm

Stage 2 - Thoracic rotation accompanies backward motion of the arm. The throw is initiated by the arm swing forward. Some arm rotation as well as forearm extension at various times

Stage 3 - step is taken with same side foot to initiate throw

Stage 4 – step is taken with contralateral foot, thoracic rotation, arm rotation, elbow extension

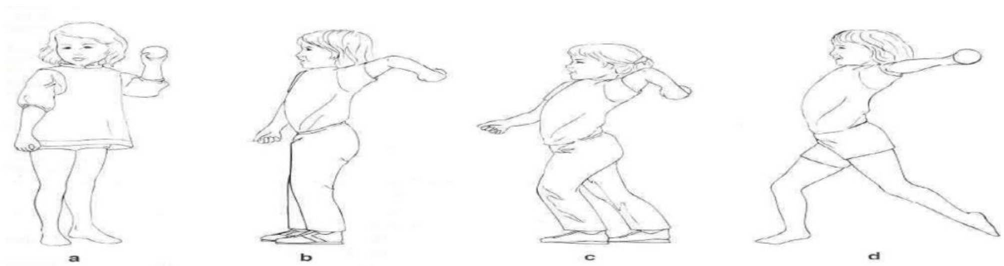

Fig 5.8 Phases of ball throwing

5.6 Sports Medicine

Sports medicine focuses on helping people improve their athletic performance, recover from injury and prevent future injuries. Sports medicine professionals treat amateur athletes, those who want better results from their exercise program, people who have suffered injuries and are trying to regain full function and those with disabilities who are trying to increase mobility and capability. The goal of sports medicine is to help people engage in exercise safely and effectively in order to achieve their training goals.

Sports medicine specialists treat a wide range of physical conditions, including acute traumas such as fractures, sprains, strains, and dislocations. They also treat chronic overuse injuries, including tendonitis, degenerative diseases, and overtraining syndrome.

Sports medicine combines general medical education with the specific principles of sports science, exercise physiology, orthopedics, biomechanics, sports nutrition, and sports psychology. A sports medicine team may involve medical and non-medical specialists, including physicians, surgeons, athletic trainers, sports psychologists, physical therapists, nutritionists, coaches, and personal trainers. Most sports medicine healthcare providers are certified in internal medicine, emergency medicine, family medicine, or another specialty. They then get additional training. There are other non-physician medical professionals who are critical to delivering care in sports medicine. They include: physical therapists, certified athletic trainers and nutritionists. They each play an important role in your care:

Physical therapists help you rehabilitate and recover from injuries.

Certified athletic trainers offer rehabilitative exercises to help you regain strength and develop programs to prevent future injury.

Registered Dietitians help you with needed weight loss or weight gain, and they offer dietary advice to help you improve how well your body is functioning.

Sports psychology is a specific branch of psychology that focuses on the mental and emotional needs of athletes and sports enthusiasts.Because athletes face unique stresses, a sports psychologist can help regulate anxiety and improve focus in a way that is specific to their sport. They will use a variety of psychology tools and skills (including psychotherapy, stress management, and goal-setting) to help athletes maintain a strong emotional balance during competition or recovery from a severe sports injury.

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Question Bank

PART A

S.No.	Questions
1	What is the resistance devices used in neuromuscular training?
2	Define muscular strength.
3	What are the methods of stretching?
4	List the different floating positions of the human body.
5	List the different gymnastics techniques.
6	What factors distinguish a push like pattern from a throw like pattern.
7	Define wave drag.
8	What are the factors that influence the swimming efficiency?
9	How is a gill ball aerodynamics work?
10	Differentiate between active and passive flexibility

PART B

S.No.	Questions
1	Elaborate on the aaplication of biomechanics
2	Explain the conditions occurring in aerodynamic lift force.
3	What are the movements that propel the human body while swimming? Explain.
4	Discuss on sports medicine.
5	Write notes on: a) Movement pattern b) Skill c) Throw like patterns d) Push like patterns with examples
6	Write in detail about the resistive forces in swimming.
7	How do you apply the principles of biomechanics to gymnastics?