INTRODUCTION

What are biomechanics and biofluids?

1. **Biomechanics.**

Biomechanics is the science of movement of a living body, including how muscles, bones, tendons, and ligaments work together to produce movement. Biomechanics is part of the larger field of kinesiology, specifically focusing on the mechanics of the movement. It is both a basic and applied science, encompassing research and practical use of its findings. This 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 a branch of biophysics. Biomechanics includes not only the structure of bones and muscles and the movement they can produce, but also the mechanics of blood circulation, renal function, and other body functions. Biomechanics studies not only the human body but also animals and even extends to plants and the mechanical workings of cells. For example, the biomechanics of the squat includes consideration of the position and/or movement of the feet, hips, knees, back, and shoulders, and arms.

Etymology

The word "biomechanics" and the related "biomechanical" come from the Ancient Greek βίος – *bios* - "life" and *mēchanikē* "mechanics", to refer to the study of the mechanical principles of living organisms, particularly their movement and structure.

Bio – Living organism mechanics – Law of mechanics applied to human movement.
Mechanics – Study of physical actions and forces
Kinematics – description of motion (fast, high)
Biomechanics – study of living mechanism
Kinesiology – study of motion kines (Latin) – motion logos – study

Sub -categories

Biofluid mechanics

Biological fluid mechanics, or biofluid mechanics, is the study of both gas and liquid fluid flows in or around biological organisms. An often-studied liquid biofluid problem is that of blood flow in the human cardiovascular system. Under certain mathematical circumstances, blood flow can be modelled by the Navier–Stokes's equations. *In vivo* whole blood is assumed to be an incompressible Newtonian fluid. However, this assumption fails when considering forward flow within arterioles. At the microscopic scale, the effects of individual red blood cells become significant, and whole blood can no longer be modelled as a continuum. When the diameter of the blood vessel is just slightly larger than the diameter of the red blood cell the Fahraeus–Lindquist effect occurs and there is a decrease in wall shear stress. However, as the diameter of the blood vessel decreases further, the red blood cells have to squeeze through the vessel and often can only pass in a single file. In this case, the inverse Fahraeus–Lindquist effect occurs and the wall shear stress increases.

An example of a gaseous biofluids problem is that of human respiration. Recently, respiratory systems in insects have been studied for bioinspiration for designing improved microfluidic devices.

Bio tribology.

Bio tribology is the study of friction, wear and lubrication of biological systems especially human joints such as hips and knees. In general, these processes are studied in the context of Contact mechanics and tribology. When two surfaces rub against each other, the effect of that rubbing on either surface will depend on friction, wear and lubrication at the point of contact. For example, the femoral and tibial components of knee implants routinely rub against each other during daily activity such as walking or stair climbing. If the performance of the tibial component needs to be analysed, the principles of contact mechanics and tribology are used to determine the wear performance of the implant and the lubrication effects of synovial fluid. Additional aspects of bio tribology include analysis of subsurface damage resulting from two surfaces coming in contact during motion, i.e., rubbing against each other, such as in the evaluation of tissue-engineered cartilage

Comparative biomechanics

Comparative biomechanics is the application of biomechanics to non-human organisms, whether used to gain greater insights into humans (as in physical anthropology) or into the functions, ecology and adaptations of the organisms themselves. Common areas of investigation are Animal locomotion and feeding, as these have strong connections to the organism's fitness and impose high mechanical demands. Animal locomotion, has many manifestations, including running, jumping and flying. Locomotion requires energy to overcome friction, drag, inertia, and gravity, though which factor predominates varies with environment. Comparative biomechanics overlaps strongly with many other fields, including ecology, neurobiology, developmental biology, ethology, and palaeontology. Comparative biomechanics is often applied in medicine (with regards to common model organisms such as mice and rats) as well as in biomimetics, which looks to nature for solutions to engineering problems

Computational biomechanics

Computational biomechanics is the application of engineering computational tools, such as the Finite element method to study the mechanics of biological systems. Computational models and simulations are used to predict the relationship between parameters that are otherwise challenging to test experimentally, or used to design more relevant experiments reducing the time and costs of experiments. Mechanical modelling using finite element analysis has been used to interpret the experimental observation of plant cell growth to understand how they differentiate, for instance. In medicine, over the past decade, the Finite element method has become an established alternative to in vivo surgical assessment. One of the main advantages of computational biomechanics lies in its ability to determine the endo-anatomical response of an anatomy, without being subject to ethical restrictions.

Experimental biomechanics

Experimental biomechanics is the application of experiments and measurements in biomechanics

Continuum biomechanics

The mechanical analysis of biomaterials and biofluids is usually carried forth with the concepts of continuum mechanics. This assumption breaks down when the length scales of interest approach the order of the micro structural details of the material. One of the most remarkable characteristics of biomaterials is their hierarchical structure. In other words, the mechanical characteristics of these materials rely on physical phenomena occurring in multiple levels, from the molecular all the way up to the tissue and organ levels.

Biomaterials are classified in two groups, hard and soft tissues. Mechanical deformation of hard tissues (like wood, shell and bone) may be analysed with the theory of linear elasticity. On the other hand, soft tissues (like skin, tendon, muscle and cartilage) usually undergo large deformations and thus their analysis rely on the finite strain theory and computer simulations. The interest in continuum biomechanics is spurred by the need for realism in the development of medical simulation.

Plant biomechanics

The application of biomechanical principles to plants, plant organs and cells has developed into the subfield of plant biomechanics. Application of biomechanics for plants ranges from studying the resilience of crops to environmental stress to development and morphogenesis at cell and tissue scale, overlapping with mechanobiology.

Elements of Biomechanics

These are the key areas that biomechanics focuses on:

- **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

Sports biomechanics

In sports biomechanics, the laws of mechanics are applied to human movement in order to gain a greater understanding of athletic performance and to reduce sport injuries as well. It focuses on the application of the scientific principles of mechanical physics to understand movements of action of human bodies and sports implements such as cricket bat, hockey stick and javelin etc. Elements of mechanical engineering (e.g., strain gauges), electrical engineering (e.g., digital filtering), computer science (e.g., numerical methods), gait analysis (e.g., force platforms), and clinical neurophysiology (e.g., surface EMG) are common methods used in sports biomechanics. Biomechanics in sports can be stated as the muscular, joint and skeletal actions of the body during the execution of a given task, skill and/or technique. Proper understanding of biomechanics relating to sports skill has the greatest implications on: sport's performance, rehabilitation and injury prevention, along with sport mastery. The best athlete is the one that executes his or her skill the best.

Sports biomechanics studies human motion during exercise and sports. Physics and the laws of mechanics are applied to athletic performance. Here are some various uses for biomechanics:

- **Equipment**: Biomechanics can be used in the design of sports equipment, clothing, shoes, and the fields and facilities where sports are played. For example, a shoe can be designed for the best performance for a middle-distance runner or a racket for the best grip.
- **Individuals**: Biomechanics can be applied to individuals, analysing their movements and coaching them for more effective movement during exercise and sports movement. For example, an individual's running gait or golf swing can be filmed and recommendations made for them to change and improve it.
- **Injuries**: Biomechanics can be applied to studying the causes, treatment, and prevention of sports injuries. The research can analyze the forces at work that can lead to an ankle sprain and how shoe design or the playing surface might reduce the risk of injury.
- **Training**: Biomechanics can study sports techniques and training systems and develop ways to make them more efficient. This can include basic research into how hand position affects propulsion in swimming. It can propose and analyze new training techniques based on the mechanical demands of the sport, aimed at resulting in better performance.

Careers in Biomechanics

Specialties within biomechanics include:

- **Biological science**: Studies of human, animal, cell, and plant biomechanics

- **Engineering and applied science**: Applying the research of biomechanics to various situations
- **Ergonomics and human factors**: Using biomechanics in human-machine interfaces, workplace, and functional designs and processes
- **Exercise and sports science**: Applying biomechanics to human performance in athletics
- **Health sciences**: Researching causes, treatment, and prevention of injury and using biomechanics to design rehabilitation programs and equipment

A master of science or doctorate in kinesiology can lead to a career in a biomechanics field, such as research and design by sports companies, athletic research and testing, workplace testing, and design of interfaces between humans and equipment.

A student of biomechanics will do coursework in physics, biology, anatomy, physiology, mathematics, and statistics. Laboratory equipment used includes force plates, electromyography, high-speed video motion analysis systems, digitizing equipment, accelerometers, pressure sensors, potentiometers, computer analysis programs, and modelling programs.

Applications

The study of biomechanics ranges from the inner workings of a cell to the movement and development of limbs, to the mechanical properties of soft tissue, and bones. Some simple examples of biomechanics research include the investigation of the forces that act on limbs, the aerodynamics of bird and insect flight, the hydrodynamics of swimming in fish, and locomotion in general across all forms of life, from individual cells to whole organisms. With growing understanding of the physiological behavior of living tissues, researchers are able to advance the field of tissue engineering, as well as develop improved treatments for a wide array of pathologies including cancer. Biomechanics is also applied to studying human musculoskeletal systems. Such research utilizes force platforms to study human ground reaction forces and infrared videography to capture the trajectories of markers attached to the human body to study human 3D motion. Research also applies electromyography to study muscle activation, investigating muscle responses to external forces and perturbations.

Biomechanics is widely used in orthopaedic industry to design orthopaedic implants for human joints, dental parts, external fixations and other medical purposes. Bio tribology is a very important part of it. It is a study of the performance and function of biomaterials used for orthopaedic implants. It plays a vital role to improve the design and produce successful biomaterials for medical and clinical purposes.

2. Biofluids

Biofluid: A biological fluid. Biofluids can be excreted (such as urine or sweat), secreted (such as breast milk or bile), obtained with a needle (such as blood or cerebrospinal fluid), or develop as a result of a pathological process (such as (such as blister or cyst fluid). The term biofluid is employed as both a noun (as in the aforementioned biofluids) and an adjective (as in biofluid dynamics and biofluid mechanics).

Biofluid dynamics (An introduction)

Biofluid dynamics may be considered as the discipline of biological engineering or biomedical engineering in which the fundamental principles of fluid dynamics are used to explain the mechanisms of biological flows and their interrelationships with physiological processes, in health and in diseases/disorder. It can be considered as the conjuncture of mechanical engineering and biological engineering. It spans from cells to organs, covering diverse aspects of the functionality of systemic physiology, including cardiovascular, respiratory, reproductive, urinary, musculoskeletal and neurological systems etc. Biofluid dynamics and its simulations in computational fluid dynamics (CFD) apply to both internal as well as external flows. Internal flows such as cardiovascular blood flow and respiratory airflow, and external flows such as flying and aquatic locomotion (i.e., swimming). Biological fluid Dynamics (or Biofluid Dynamics) involves the study of the motion of biological fluids (e.g., blood flow in arteries, animal flight, fish swimming, etc.). It can be either circulatory system or respiratory systems. Understanding the circulatory system is one of the major areas of research. The respiratory system is very closely linked to the circulatory system and is very complex to study and understand. The study of Biofluid Dynamics is also directed towards finding solutions to some of the human body related diseases and disorders. The usefulness of the subject can also be understood by seeing the use of Biofluid Dynamics in the areas of physiology in order to explain how living things work and about their motions, in developing an understanding of the origins and development of various diseases related to human body and diagnosing them, in finding the cure for the diseases related to cardiovascular and pulmonary systems.

Sir Isaac Newton' s three physical laws, the basic of classic mechanism: these laws describe relationship of forces, objects, motion.

1. *Law of inertia* – an object in a state of constant velocity tends to remain in that state of motion unless an unbalanced force is applied to it.

2. *Law of acceleration* – when a force acts on an object the rate of change of momentum experienced by the object is proportional to the size of force and takes place in the direction in which the force acts. F= m x a (a=F/m)

3. *Action reaction law* – for every action there is an equal and opposite reaction.

<u>Mechanical Stress</u> – Force / area

When any number of a structure be it a bridge, aircraft or a bone plate or a human tibia, is subjected to external force or number of forces the body will try to resist such forces by developing internal resistance forces to contract it.

Applications of Biofluid Dynamics

Biofluid Dynamics refers to the study of fluid Dynamics of basic biological fluids such as blood, air etc. and has immense applications in the field of diagnosing, treating and certain surgical procedures related to the disorders/diseases which originate in the body relating to cardiovascular, pulmonary, synovial systems etc. The different types of cardiovascular diseases include Aneurysms, Angina, Atherosclerosis, Stroke, Different types of Cerebrovascular disease, Heart Failure, Coronary Heart diseases and Myocardial infarction or Heart attacks. The Computational Fluid dynamics (CFD) models prepared through software, of the arteries, veins etc. not only lead to the identification of properties of flowing blood inside arteries but also changes in viscosity can be identified which may be the result of certain underlying disease/disorder. Moreover, the stress concentration and the distribution of stresses in different biological systems carrying fluids can also be identified. This has led to a greater degree of assistance to biomedical engineers in recognizing the cause of certain diseases and thus they can easily search for the method of cure for that disease/disorder. Also, this has led to a greater degree of good research in the fields of biotechnology, Bio-Mechanics etc

References.

Cowin, Stephen C., ed. (2008). Bone mechanics handbook (2nd ed.). New York: Informa Healthcare. ISBN 978-0-8493-9117-0.

Fischer-Cripps, Anthony C. (2007). Introduction to contact mechanics (2nd ed.). New York: Springer. ISBN 978-0-387-68187-0.

Fung, Y.-C. (1993). Biomechanics: Mechanical Properties of Living Tissues. New York: Springer-Verlag. ISBN 978-0-387-97947-2.

Gurtin, Morton E. (1995). An introduction to continuum mechanics (6 ed.). San Diego: Acad. Press. ISBN 978-0-12-309750-7.

Humphrey, Jay D. (2002). Cardiovascular solid mechanics: cells, tissues, and organs. New York: Springer. ISBN 978-0-387-95168-3.

Mazumdar, Jagan N. (1993). Biofluids mechanics (Reprint 1998. ed.). Singapore: World Scientific. ISBN 978-981-02-0927-8.

Mow, Van C.; Huiskes, Rik, eds. (2005). Basic orthopaedic biomechanics & mechano-biology (3 ed.). Philadelphia: Lippincott Williams & Wilkins. p. 2. ISBN 978-0-7817-3933-7.

Peterson, Donald R.; Bronzino, Joseph D., eds. (2008). Biomechanics : principles and applications (2. rev. ed.). Boca Raton: CRC Press. ISBN 978-0-8493-8534-6.

Temenoff, J.S.; Mikos, A.G. (2008). Biomaterials : the Intersection of biology and materials science (Internat. ed.). Upper Saddle River, N.J.: Pearson/Prentice Hall. ISBN 978-0-13-009710-1.

Totten, George E.; Liang, Hong, eds. (2004). Mechanical tribology : materials, characterization, and applications. New York: Marcel Dekker. ISBN 978-0-8247-4873-9.

Waite, Lee; Fine, Jerry (2007). Applied biofluid mechanics. New York: McGraw-Hill. ISBN 978-0-07-147217-3.

Young, Donald F.; Bruce R. Munson; Theodore H. Okiishi (2004). A brief introduction to fluid mechanics (3rd ed.). Hoboken, N.J.: Wiley. ISBN 978-0-471-45757-2.

White, Frank M. (2011). Fluid Mechanics (7th ed.). McGraw-Hill. ISBN 978-0-07-352934-9.

Tu, Jiyuan; Yeoh, Guan Heng; Liu, Chaoqun (Nov 21, 2012). Computational Fluid Dynamics: A Practical Approach. ISBN 978-0080982434.

Batchelor, C. K., & Batchelor, G. K. (2000). An introduction to fluid dynamics. Cambridge University Press.

Bonde-Petersen, Flemming (1975). A simple force platform. European Journal of Applied Physiology, 34(1):51-54. doi:10.1007/BF00999915

"ForceDecks Force Platform Testing Systems | Force Decks". www.forcedecks.com. Retrieved 2018-09-07.

Hawkin Dynamics Staff. "So what exactly is a force plate?". www.hawkindynamics.com. Retrieved 2020-06-30.

Robertson DGE, et al., Research Methods in Biomechanics. Champaign IL:Human Kinetics Pubs., 2004.

Clark, R. A., Bryant, A. L., Pua, Y., McCrory, P., Bennell, K., & Hunt, M. (2010). Validity and reliability of the Nintendo Wii Balance Board for assessment of standing balance. Gait & posture 31(3): 307-310.

Rheology of the circulation, by R.L. Whitmore. Oxford, Pergamon Press, [1968] English : [1st ed.]