International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13 Number 9 (2018) pp. 205-210

Biomechanics- Basics and Applications

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Abstract: Biomechanics is the application of principles of mechanics to biological systems. It has huge scope which can be utilized to study and further to use the same for causes of societal upliftment, prevention of sports injuries, medical care and towards a better rehabilitation of human beings. In this era of artificial things, biomechanics studies give a variety of artificial organs and systems which are beneficial to mankind. To give this discussion on the applications of biomechanics a more understanding platform, we'll be discussing the biomechanics of heart, lungs, joints, blood and gait in this paper.

Key words: Biomechanics, Rehabilitation

Introduction: As the name suggests, Biomechanics is the application of principles of Mechanics to Biological systems. Since the mechanical principles are universal and apply to all entities, including the living beings, their basics, mathematical equations, relations, laws, etc. have huge applications in biological systems too. But, there are some distinguishing features between the mechanics of living and non living things. In addition to the inertia owned by a non-living system, a living entity generates energy inside the system by virtue of metabolism of food inside the body. Similarly, in addition to the Newton's third law which is followed in non-living systems, living entities have nervous system to control the reaction to an action. Another difference of equations applicability comes due to the establishment of principles in ideal controlled lab environment whereas living systems exist and exhibit their properties outside lab away from ideal conditions, and that is what is to be incorporated as slight modifications in the universal laws and mathematical relations. Though each and every, simple or complex, body system has a well documented and accepted mechanics, the area needs wider involvements for applications point of view. We see diverse applications of the principles of mechanics in the areas of sports biomechanics, soft tissue mechanics, hard tissue mechanics, human gait, prosthesis and orthosis, rehabilitation, blood flow mechanics, lung mechanics, heart mechanics, etc. The application of fluid mechanics in the blood flow inside blood vessels is a typical example of Bernoulli's theorem. The flow and exchange of gases inside lungs and inside body tissues through capillaries network is another typical example of gaseous fluid mechanics. The fracture in bones, sprain in muscles and ligaments are examples of the stress-strain relationships being exhibited in the loading of human body. Sports mechanics and exercise physiology is the most recent application area of mechanics in biology due to increasing health issues and deteriorating living styles. The studies of mechanics of body organs, in addition to material properties, has been the key to the design and development of many artificial body parts leading to the treatment and rehabilitation of individuals with lost capabilities of one kind or another. We'll be discussing a few prominent applications of biomechanics in this paper for elaborating the same. The basic of the discussion underneath is to emphasize that we have been able to study the biomechanics of the visceral organs of human body in true compliance to the mechanics principles and techniques. Too much references have been avoided because of the nature of the paper, which is a discussion stuff and differs from a review paper.

Biomechanics of Heart: The heart pumps blood and nutrients to all organs to support their normal function. Synchronized contraction of the heart muscles generates pressure to drive the blood flow to distal organs through arteries and the constant repetitive pumping action maintains the circulation to all organs. Biomechanical principles play an important role in governing heart/ cardiac function. The heart is a multiscale system that functions at the organ, tissue, cellular, and protein levels. Therefore, cardiac function can be evaluated at the cellular, tissue and organ levels, and at each level mechanical stress plays an important role in regulating function. In terms of mechanics, the best way to depict the heart/ cardiac cycle is using a pressure-volume diagram/ graph. The Pressure-Volume graph depicts the cardiac cycle as a counterclockwise loop. The heart is capable of adjusting the amount of work it does in order to match the metabolic demands of the body. Though ECG, ie, the study of electrical activity of heart is the most commonly known and may be the most extensively studied parameter, the mechanics remains an unpopular version of the same. LIke all the physical material things, heart is a muscular structure and follows the mechanical principles of contraction, expansion, volumetric flow, pressure built-up on its walls, chambers and valves. The energy and work done calculations are a matter of open research.

Biomechanics of Blood: Blood is a connective tissue of our body and like all fluids flowing in closed chambers follow certain principles, blood circulates in the blood vessels and follows the principles and properties of fluid mechanics, like laminar and turbulent flow, Reynolds Number, mazwell Models, viscoelasticity, Newtonian and non-newtonian nature, resistance and pressure in blood flow vascular system, Bernaulli's theorem, work, energy, etc. Blood, here, is a fluid with suspended particles like cells and platelets, proteins, and other tiny molecules, which flow through blood vessels of varying cross-sectional areas, differing membrane structures and thickness. Blood pressure measurement is atypical example of variations in the parameter due to fluid flow properties. Even the laws of thermodynamics are well justified because the increased flow of blood causes an increase in temperature at a site.

Biomechanics of Lungs: The lungs are highly elastic organs, composed of a variety of structures: vasculature, airways and parenchyma. The unique mechanical properties of each of these structures form the composite material of the lung. Medical imaging modalities such as computed tomography and magnetic resonance imaging can be used to observe lung morphology. It would be helpful to be able to correlate regional morphological changes with changes in pulmonary function. Conventional registration methods, as exemplified by a finite element implementation of the classic elastic matching technique, have shown to perform well over a set of vascular landmarks in the measurement of lung motion. This performance is maintained in an augmented system, which combines inhomogeneous material properties with the use of domain discretizations tailored to reflect the apparent geometry within the image and to reduce background effects. These adaptations lay the groundwork for biomechanical modeling of the lung using the finite element method. The mechanics of respiration through lungs involve the measurements and calculation of numerous lung volumes and capacities, Boyle’s law, pressure, air-way resistance measurements, etc.

Biomechanics of Joints: The site where two or more bones come together irrespective of whether there is any movement or not, is called a joint. Depending upon the structural arrangements at the joint site, the joints vary in their degrees of movement, their mechanics, motion produced by them, problems and their corrective measures. The study of biomechanics of joints becomes more important to solve the joint problems of elderly, amputees, paralysis patients, for better mobility to them. Joints follow the principles of motion, vectors, levers, force, torque, pressure, Stress-strain relationships, tension, compression, equilibrium, etc. Muscles, tendons and ligaments act as stabilizers, co-stabilizers and anti-stabilizers for the joints and also act as traction-pulley arrangements. Motion continuum is vast field which incorporates the applications of joints mechanics in all the complex movements, sports activities, which explain the stability of joints during complex body movements.

Biomechanics of Gait: Gait is the “Pattern of Walking”. Gait of a person depends upon their gender, sex, age, region, etc. Though walking is something easily visible action, still the most common activity done subconsciously. To understand the seemingly simple exercise, the complexity of the same is necessary to be understood for the upliftment of those who have locomotory issues and need alternatives or corrective measures. Besides the study strategies, which involve dividing the gait cycle into parts and sub-parts, the mechanics principles of Newton’s laws, Ground reaction force, three-point pressure, anthropometry, ergonomics, mechanical loading, fatigue, etc. are also studied in this. The applications of prosthetics and orthotics for lower limbs are additional responsibilities of the field experts to take care for physical rehabilitation purposes.

Conclusion: The paper is an exercise to bring the readers in the domain of biomechanics from a mechanical perspective. Similarly, another intention is to bridge a gap between the biomechanical engineers and clinical personnel for better coorelation for a more fruitful research work. Readers are encouraged to study the details of the above discussions as per their interest area and requirements for various research proposals. Besides, the main or directly related mechanics issues to a body organ, it is important to mention here that human body or body part cannot be taken as a subject in an ideal experimental set up because of the vast complexity involved. Each and every tissue should be given due time and laborious reading for understanding the interdependence of various working mechanisms and parallel processing of large number of electrical and mechanical things.

Acknowledgements: My sincere acknowledgements to the organizers of the conference for giving us the opportunity to share such an interesting field on an open platform.

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