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Biomechanics: A Primer

Matthew N. O. Sadiku[1], Tolulope J. Ashaolu[2], and Sarhan M. Musa[1]
[1]*Roy G. Perry College of Engineering Prairie View A&M University Prairie View, TX 77446*
[2]*College of Food Science, Southwest University, 2 Tiansheng road, Beibei 400715 Chongqing, P.R. China*

ABSTRACT: *Biomechanics is the application of mechanical engineering principles to the biological systems. It is the study of human movement and interaction with the environment. It applies mechanical principles to the human body in order to understand the mechanical influences on bone and joint. A basic understanding of these principles is beneficial for medical professionals. This paper provides a brief introduction to biomechanics.*

KEY WORDS: *biomechanics, mechanics, biology*

I. INTRODUCTION

Biomechanics is an emerging discipline where engineering mechanics principles are applied to the study of biological systems such as humans, plants, organs, and cells. It is the study of human movement and the forces which cause the movement. The main objective of biomechanics is the analysis of the structure of humans, animals, and plants by applying the basic principles of mechanics. Biomechanics focuses on the mechanics of movement of a living body, including how muscles, bones, tendons, and ligaments work together to produce movement. Different disciplines such as continuum mechanics, structural analysis, kinematics, and dynamics play prominent roles in biomechanics [1]. Studying the biomechanics of human cells is important for a number of reasons. First, our human body is constantly subjected to physical stresses and strains. For example, impact biomechanics can be done to study the injuries suffered by the human being in extreme situations such as car accidents. Second, biomechanical study can provide quantitative investigation on the change in the physical properties of cells [3]. Aristotle is often regarded as the first bio-mechanic because of his work with animal anatomy. The modern era of biomechanics began in the mid-1960s. The study of biomechanics existed in the US within the realm of physical education long before it became a separate discipline in the 1960s.

II. ELEMENTS OF BIOMECHANICS

Biomechanics is the science of the physical properties of biological systems and their response to the application of physical forces. Mechanics is based on Newton's three laws of motion. There are two major areas within mechanics: statics and dynamics. Biomechanics consists of the following areas [3].

- *Statics*: This deals with systems that are in equilibrium, stationary or fixed posture.
- *Dynamics*: This describes systems that are in motion with acceleration and deceleration.
- *Kinematics*: This deals with the motion of objects, including displacement, velocity, and acceleration. It describes the motion of human body without consideration of the causes of the motion.
- *Kinetics*: This deals with the relationships between the force system acting on a body and the changes it produces in body motion. It studies the cause of motion in the human body.

III. COMPUTATIONAL BIOMECHANICS

Computational techniques are applied in almost every biomechanical research. They provide an alternative means that has the advantage of being non—invasive. The finite element method is by far the most well-known numerical technique in computational biomechanics for calculating stresses and strains in all materials including living tissues. Computational modeling, computer simulation, and CAD software are used to predict the relationship between parameters that are otherwise challenging to test experimentally. Computational models can help model the real world with sufficient accuracy. They can also provide visualization of certain biomechanical aspects under study. Verification and validation are important in computational biomechanics in order to increase peer acceptance of computational biomechanics models. Computational modeling have offered significant utility in biomechanics with applications ranging from rigid body dynamics-based musculoskeletal modeling of locomotion to finite element analysis of medical devices [4].

IV. APPLICATIONS

Biomechanics has myriad applications in daily life. It is popular in sports and athletics, in studying animals and plants, nanostructures, fruit biomechanics, and ergonomics.

- **Sports Biomechanics:** A popular application of biomechanics is in the field of sports and physical education. Biomechanical principles are being applied to sports medicine and the prevention of sports-related injuries and injuries due to falls. The main objective is finding effective instructional cues that help the athlete achieve correct mechanical technique. Sports biomechanics studies human motion during exercise and in sports. In sports biomechanics, the laws of mechanics are applied to human movement in order to gain a greater understanding of athletic performance. Studies from biomechanics are critical for the study of speed, timing, technique, coordination, and strategy during sports events or training. Sport biomechanics can help improve the physical capacity of the athletes, enable them reach better performance, develop innovative techniques in a given sport, and help athletes interact with the environment more effectively [5]. Biomechanics can help one predict what changes should be made to improve athletic performance.

  Fruit biomechanics: This applies biomechanical principles to plants. It is needed for quality determination and engineering design of fruit processes and equipment. Fruits are usually the seed-associated structures of plants that are sweet and edible in the raw state, such as apples, pears, peaches, oranges, grapes, strawberries, tomatoes and bananas. Fruit biomechanics is the mechanical behavior of fruits under applied external forces [6].

- **Ergonomics:** Ergonomics involves the analysis of a human being performing a task and the design of appropriate tools. It aims at providing a safe working environment for industrial workers. It deals low-back pain and hand and wrist disorders that often occur in industry. Workers are often required to lift, lower, push, pull, carry, and hold heavy materials. To be safe, the following guidelines are recommended [7]:

- Use pallets and devices to avoid lifting loads manually.
- Provide workers with enough space to access to loads without awkward postures.
- Reduce lifting frequencies and durations by job rotation with other workers and non-lifting task
- Wear proper shoes to avoid slips, trips, falls, and excessive grip force.
- Wear proper gloves during the use of hand tools to protect against heat, cold, and vibration.

Biomechanics is used in orthopedic industry to design orthopedic patient-specific implants for human joints, dental parts, and other medical purposes. Other applications include physical education, dance, plant biomechanics, plant biomechanics, animal locomotion, robotics, footwear industry, and bone tissue engineering.

V. BENEFITS AND CHALLENGES

Biomechanics can benefit athletes of all ages and skill levels. It is a tool that can be used in sport biomechanics to identify forces and mechanical energy that cause injuries and thus to increase the quality of life. Teachers and coaches may use the principles of mechanics to correct actions of a student or athlete. One limitation in biomechanics is that we cannot, with current technology, measure muscle forces in a noninvasive way. Reproducibility of scientific studies, particularly using computational strategies, has been challenged. Students often have a difficult time learning Newtonian mechanics. This is a major problem for biomechanics instructors because undergraduate biomechanics course utilizes these concepts [8].

VI. CONCLUSION

Biomechanics deals with the structure and function of the mechanical aspects of biological systems, at any level using the methods of mechanics. It remains in an emerging state. It has yet to fully breakthrough into our society's consciousness. It will be the breakthrough science of the 21st century [9]. As new techniques are developed, biomechanics will continue to grow. More information about biomechanics can be found in books [10-14] and more books available on Amazon.com. One may also consult with the two journals exclusively devoted to biomechanics: *Journal of Biomechanics* and Journal *of Biomechanical Engineering*.

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AUTHORS

Matthew N.O. Sadiku is a professor in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interests include computational electromagnetics and computer networks. He is a fellow of IEEE.

Tolulope J. Ashaolu is a postdoctoral research fellow at Southwest University, Chongqing, China. He is the author of several papers and a book. His research interests include functional foods and food microbiology.

Sarhan M. Musa is a professor in the Department of Engineering Technology at Prairie View A&M University, Texas. He has been the director of Prairie View Networking Academy, Texas, since 2004. He is an LTD Sprint and Boeing Welliver Fellow.

A Primer of Biomechanics is an excellent book for any podiatrist interested in tissue stress biomechanics, even though it is actually directed toward the orthopedic surgery resident. The book is clear, concise, full of practical explanations of important physics and biomechanics terminology and concepts that directly apply to the tissue stress podiatrist and today's current biomechanics research.