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Guidance Document

Guidelines for Undergraduate Biomechanics

This fourth-edition guidance document provides national guidelines for the introductory biomechanics course in kinesiology, exercise science, and health, physical education, recreation and dance (HPERD) programs in the United States. Previous editions of the guidelines (Kinesiology Academy, 1980, 1992; National Association for Sport and Physical Education [NASPE], 2003) were developed by faculty committees with extensive experience teaching the course and publishing research on learning biomechanical concepts. Previous guidelines were approved by the full Kinesiology Academy or Biomechanics Academy, and then by NASPE. The current revision of the guidelines was approved by SHAPE America on April 26, 2018.

A knowledge of basic and applied biomechanics is essential to the study of human beings engaged in motor performance. A person who understands the anatomical and mechanical phenomena that underlie human movement can systematically analyze movement and determine evidence-based interventions that aim to improve technique and reduce the risk of injury. Therefore, we recommend that all students of human movement complete at least one course in biomechanics. Specifically, this coursework should provide students with: 1) a basic knowledge of the biomechanical foundations of human movement; 2) the knowledge and skills necessary to complete a systematic analysis and evaluation of human motor performance; and 3) the ability to determine and provide interventions that are likely to improve movement or reduce the risk of injury.

Analytic methods can range on a continuum from qualitative to quantitative, and students may benefit from developing a repertoire of analytic methods along with a sense of when each is appropriate. Progressive development, repetition, integration and application of biomechanical concepts are important in facilitating learning. Higher-order thinking skills (e.g., synthesis and evaluation) are necessary in applied biomechanics. The instructor can facilitate the development of these skills through modeling and guided practice in various scenarios. Given the greater effectiveness of active-learning instructional strategies over traditional lectures, particularly in physics and biomechanics (Freeman et al., 2014; Haake, 1998; Knudson et al., 2003; Riskowski, 2015), it is recommended that faculty consider using these instructional strategies and laboratories in introductory biomechanics courses.

Prerequisites

The minimum prerequisites for an introductory undergraduate biomechanics course should typically include: a) the ability to use basic algebraic operations to solve problems that use words, formulas, equations and graphs (Meltzer, 2002); and b) foundational knowledge about the organization and description of the skeletal, articular, muscular and nervous systems.

Guidelines (Minimum Exit Outcomes)

Ideally, students of human movement would exit their undergraduate studies able to integrate functional anatomy and mechanical concepts to ask complex questions and solve multilevel problems related to human movement in athletic, educational, clinical or other work settings. The completion of a full semester course with a lab is the minimum recommendation. However, completion of additional courses in biomechanics and the infusion of biomechanical concepts into other courses is desired.

Guidelines for minimum exit outcomes of an introductory course in biomechanics follow. The order of outcome presentation is not suggestive of the order for planning a course. Course concepts should be presented in an order that meets the unique needs of the students in different professional programs.

Application of Biomechanics Competencies to Human Movement

As a minimum, introductory undergraduate biomechanics classes should expose students to the continuum of qualitative to quantitative human movement analysis techniques. Instructors may elect to stress different levels of student mastery for different modes of movement analysis. Throughout the course, students should be given the opportunity to observe and ask questions about movement, then analyze and evaluate the movement to answer their questions. This process should require the application and integration of anatomical and biomechanical concepts to a wide variety of activities. These may include improving motor skills, assessing the safety and effectiveness of exercise activities, selecting and adapting sport and exercise equipment, and evaluating movement patterns for the purposes of injury prevention. Activities should be examined across performers of varied age, skill, acute injury, chronic disability, and fitness levels. At the conclusion of the course, students should demonstrate basic competence in a systematic approach to the observation, analysis and evaluation of human movements in athletic, clinical, educational and other work environments.

These outcomes are stated to be consistent with the phrase “The student is able to:”

1. observe and describe a variety of movement patterns accurately;
2. determine the basic anatomical and mechanical factors associated with the performance of a variety of observed movements;
3. evaluate the suitability of a performer’s technique with reference to the task at hand; and
4. identify factors that limit performance and establish a priority for change in those factors most likely to lead to improvement in performance for a variety of movements.

Anatomical Bases

Students should exit having met outcomes related to joint structure and function, muscle mechanics, and neuromuscular function. These competencies should be applied to a variety of human movement settings and integrated with the mechanical bases to solve human motor performance problems. These outcomes are stated to be consistent with the phrase "The student is able to".

A. Joint Structure and Function

1. identify and describe joint actions, axes of rotation, and planes of movement in simple single-joint activities, and more complex multi-joint motor performances.
2. observe human movement and explain the reasons for different joint actions and ranges of motion using knowledge of joint structure, stability and mobility.
3. assess flexibility and create safe and effective stretches for the major muscle groups surrounding each joint.

B. Muscle Mechanics

1. identify and describe the roles that muscle groups play (i.e., agonist, antagonist, stabilizer, neutralizer) and their cooperative actions (i.e., isometric, concentric, eccentric) during simple single-joint activities and complex multi-joint motor performances.
2. explain the force-velocity and length-tension relationships of muscle and recognize their application in static positions and dynamic movements.
3. recognize the use of the stretch-shortening cycle of muscle in human movement and create effective training exercises that utilize this phenomenon.
4. describe the mechanical response of different muscle fiber types, how training influences them, and the potential for muscle fiber type to influence performance.

C. Neuromuscular Function

1. define the basic structures (e.g., motor unit, muscle spindle, and proprioceptors) of the neuromuscular system and explain how reflexes (e.g., stretch reflex, reciprocal inhibition) affect human movement.
2. describe how recruitment and firing rate of motor units regulate muscle force production.

Mechanical Bases

Students should exit having met outcomes related to basic considerations of human movement and the kinematics and kinetics of motion. These competencies should be applied to a variety of human movement settings and integrated with the anatomical bases to solve human motor performance problems. These outcomes are stated to be consistent with the phrase “The student is able to”.

A. Basic Considerations

1. define a movement system and determine the nature of the system’s movement (i.e., linear or angular).
2. appropriately represent kinematic and kinetic quantities as vectors and use vectors, vector addition, and vector resolution to enhance the understanding of basic mechanical concepts.

B. Movement Kinematics

1. define the basic terms of distance, displacement, speed, velocity and acceleration as they relate to linear and angular motion in human movements.
2. use kinematic variables to compare the quality of various motor performances (e.g., across skill level, fitness level, gender, age, body size and type, etc.).
3. explain the kinematic relationships between linear and angular motion and apply this relationship to improve motor skill performance (e.g., striking, throwing, kicking) and equipment design (e.g., sport, rehabilitation, work environment).
4. describe how the variables of release height, angle and velocity affect projectile motion and apply these variables to a projectile activity to optimize performance.

C. Movement Kinetics

1. define basic terms (e.g., force, inertia, mass, weight) as they relate to linear motion in human movement.
2. define basic terms (e.g., moment of force/torque, moment of inertia, moment arm, radius) as they relate to angular motion.
3. state the linear and angular forms of Newton’s laws of motion and explain the relationship between the observed movements of a body experiencing linear or angular motion and the forces/torques responsible for that motion.
4. explain the effects of weight, normal reaction, friction, buoyancy, drag and lift on motor performance.

5. estimate the location of the center of mass of persons in any position and describe how changes in location of the center of mass and other mechanical factors influence stability.

6. identify and explain the importance of impulse-momentum, work-energy, and the conservation of momentum in the production of effective human movements.

Faculty

Teachers of undergraduate biomechanics should have a doctoral degree with a specialization in biomechanics. Preference should usually be given to candidates with degrees, research and experience in biomechanics within the discipline of kinesiology or sport and exercise science.

Facilities and Equipment

To facilitate achievement of the exit competencies in the introductory undergraduate biomechanics course, students should have separate lecture and laboratory sessions. The active learning experiences in biomechanics laboratories have been shown to double the mastery of biomechanics concepts over lecture alone (Knudson, Bauer, & Bahamonde, 2009). Preferably, laboratory activities should take place in a properly equipped biomechanics laboratory space. Other suitable activity areas include gymnasiums, tracks, fields, pools, etc. Laboratory activity ideas can be obtained through biomechanics-related web sites like the ASB Teaching Repository (http://asbteachingrepository.herokuapp.com/) or the "Biomechanics of Physical Activity" section of the AKA kinesiology MERLOT project (https://www.merlot.org/merlot/materials.htm?category=914017)

Minimal and desirable equipment to facilitate laboratory experiences is listed below.

A. Minimal Equipment for Laboratory Experiences

1. Anatomical charts, models or computers with anatomy software

2. Goniometers, tape measures and rulers

3. High-speed digital video cameras and computers equipped with qualitative movement analysis software (e.g., Dartfish, siliconcoach, Simi Scout, Spark Motion, video4Coach)

5. Stop watches

6. Medical balance scale (height and weight capabilities)

7. Sport, exercise and rehabilitation implements and equipment (e.g., rackets, bats, balls, protective equipment, golf clubs, dumbbells, therabands, crutches, canes, physioballs, etc.)

8. Previously recorded high-speed video movement library

9. Networked computers and printers with Internet access

B. Desirable Equipment for Laboratory Experiences

1. Complete computer-based quantitative 2D/3D movement analysis system, including high-speed video cameras with playback and analysis software
2. Force platform, A/D converter and analysis software. When research-quality force platforms are not available in dedicated labs, portable force platforms like the Vernier FP-BTA force plate should be substituted.
3. Electrogoniometer with a computer interface
4. EMG equipment with amplifiers, computer interface and analysis software
5. Reaction board
6. Electrodynamometer with a computer interface (e.g., Vernier DGS-BTA force sensor) and hand dynamometer
7. Isokinetic dynamometer (e.g., Biodex)
8. Computers with biomechanical modeling/simulation software

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