Guidelines and Best Practices for Teaching Undergraduate Biomechanics in Kinesiology Programs

AKA Curriculum Guidance Document

This guidance document is the fifth edition of national guidelines for the introductory biomechanics course in kinesiology/exercise science programs in the United States. Previous editions of the guidelines (Kinesiology Academy, 1980, 1992; NASPE, 2003; SHAPE America, 2018)[1] were developed by faculty committees with extensive experience teaching the course, publishing biomechanics research and research on learning biomechanical concepts. The current revision of the guidelines was made by a similar committee of biomechanics scholars representing a variety of institutions and programs. These guidelines were then reviewed and endorsed by the Executive Board of the American Kinesiology Association (AKA) on November 3, 2025. The guidelines are designed to be consistent with the AKA core curriculum in kinesiology [https://americankinesiology.org/the-undergraduate-core/] applicable to undergraduate programs in kinesiology/exercise and sports science (KESS). Cite as:

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Overview

A knowledge of basic and applied biomechanics is essential to the study of human beings engaged in physical activity, exercise, and sports. KESS professionals understand the anatomical and biomechanical factors that underlie human movement and can systematically evaluate and diagnose movement. This knowledge and skill inform evidence-based interventions that are likely to improve technique and reduce the risk of injury. Therefore, it is recommended that all KESS majors complete, at a minimum, one 4 credit hour course in biomechanics with laboratory. These guidelines posit three major goals: 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 movement; and 3) the ability to determine and provide interventions that are likely to improve human movement or reduce the risk of injury. There are 29 specific competencies related to these goals. Many KESS programs in the United States and internationally require 2 or 3 biomechanics courses or modules with additional credits/hours (Breen & Knudson, 2025; Garceau et al. 2011, 2012; Marett et al., 1984) beyond this minimum that reinforce and extend expertise in these important professional skills.

Analytic methods in the course 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 most 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 applying and integrating biomechanics with other kinesiology subdisciplinary knowledge in most professional practice. The guidelines

[1] 5th Edition 2026. First adopted in 1980 and previously revised in 1992 and 2003, and 2018.

conclude with recommendations on faculty qualifications, student learning outcomes, facilities and equipment, and instructional strategies and resources. Instructors 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 lecture in mechanics and biomechanics (Freeman et al., 2014; Haake, 1998; Knudson, 2024), it is recommended that faculty consider using these instructional strategies in the lecture and laboratory experiences in introductory biomechanics courses. Overall, this guidance document is intended for faculty teaching undergraduate biomechanics courses, curriculum committees, program directors, and accrediting bodies in KESS programs. It may be used to guide course design, curricular mapping, program assessment, faculty hiring, and resource allocation.

Prerequisites

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. What mathematics and human anatomy courses are required prior to enrollment in introductory biomechanics should be clearly specified, with waiver opportunity limited only to students who can demonstrate competency in prerequisite courses.

Guidelines (Minimum Exit Outcomes)

Ideally, KESS students will exit their undergraduate studies able to integrate functional anatomy and biomechanical concepts to ask complex questions and solve problems related to human movement in athletic, educational, clinical, or other work settings, using biomechanical analysis of varying levels of complexity and both qualitative and quantitative approaches. 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 and best evidence-based instructional practices for minimum exit learning outcomes of an introductory course in biomechanics follow. The order of learning 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 students in different professional programs. *All learning outcomes are stated to be consistent with the phrase* "**The student is able to**".

Anatomical Bases

Students should exit having met learning 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.

A. Joint Structure and Function

1. identify and describe joint actions, axes of rotation, and planes of motion 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. evaluate flexibility and design stretching routines targeting the primary muscle groups around each joint(s) to improve flexibility.

B. Muscle and Tissue Mechanics

4. identify and explain the roles of muscle groups (i.e., agonist, antagonist, stabilizer, neutralizer), their cooperative actions (i.e., isometric, concentric, eccentric), and key mechanical principles during both simple single joint movements and complex multi-joint motor tasks.
5. explain the Hill muscle model, force-velocity relationship, and length-tension relationship in muscle function, and demonstrate how these relationships influence to dynamic movements.
6. explain the function of the stretch-shortening cycle of muscle in human movement and design effective training exercises that utilize this mechanism.
7. describe the mechanical response of different muscle fiber types, the influence of training upon them, and the potential for muscle fiber type to influence performance.
8. describe how different muscle fiber alignments (architectures) related to tendon orientation and how they influence tension in the muscle-tenson unit and range of motion.
9. explain the types of loading, quantification of loading (i.e., stress), potential effect of loading (i.e. strain), and their relationship to the mechanical strength or tolerance of biological tissues, including the principles of stiffness (i.e. Young's modulus) and viscoelasticity.

C. Neuromuscular Function

10. define the basic structures (e.g., motor unit, Golgi tendon organ, muscle spindle, and other proprioceptors) of the neuromuscular system and explain how reflexes (e.g., stretch reflex, reciprocal inhibition) affect human movement.
11. describe how recruitment and firing rate of motor units regulate muscle force production and is reflected in electromyography (EMG).
12. interpret muscle activation from EMG correctly and explain the various components of the electromechanical delay affecting movement (Vigotsky et al., 2018).

Mechanical Bases

Students should exit the course having met learning 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 anatomical factors to solve human motor performance problems. These outcomes are stated to be consistent with the phrase "**The student is able to**".

A. Basic Considerations

13. define a movement system, relevant biomechanical model, and determine the nature of the system's movement (i.e., linear and angular).
14. describe kinematic and kinetic quantities as vectors and apply vector addition and resolution to enhance the understanding of fundamental mechanical concepts.

B. Movement Kinematics

15. define the basic terms of distance, displacement, speed, velocity, and acceleration as they relate to linear and angular motion in human movements.
16. 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.).
17. explain the relationships between linear and angular motion and apply it to improve motor skill performance (e.g., striking, throwing, kicking) and inform equipment design for sport, rehabilitation, work environments.
18. describe how release height, angle, and velocity influence projectile motion and apply these variables to optimize performance in a projectile activity.

C. Movement Kinetics

19. define basic terms (e.g., force, inertia, mass, and weight) as they relate to linear motion in human movement.
20. define basic terms (e.g., moment of force/torque, moment of inertia, moment arm, radius) as they relate to angular motion.
21. state Newton's laws of motion in the linear and angular forms, and explain how the forces and torques acting on a body relate to its observed linear and angular movements.
22. explain how weight, normal reaction, friction, buoyancy, drag, lift, and Magnus force influence movement in fluid environments.
23. estimate the location of the center of mass of a person in any position and describe how changes in location of the center of mass and other mechanical factors that influence the balance between stability and mobility.
24. identify and explain the importance of impulse-momentum and inertia/ conservation of momentum to the production of effective linear and angular motions of human movements.
25. compare and contrast the scalar variables of mechanical energy, work, and power with the vector quantities of force and moment of force.

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 injuries, chronic disabilities, 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. Courses may emphasize qualitative application of biomechanics [e.g., Qualitative Movement Diagnosis (Knudson, 2013)] and/or quantitative application of biomechanics in human movement. Table 1 illustrates examples of progressive scaffolding from qualitative to quantitative analysis of human movement.

26. observe and describe a variety of movement patterns accurately.
27. determine the anatomical, mechanical, and neuromuscular factors relevant to the performance of a variety of observed movements.
28. evaluate the suitability of a performer's technique with reference to a specific movement goal and context.
29. identify biomechanical factors that limit performance and establish a priority for change in those factors most likely to lead to improvement in performance or lower risk of injury for a variety of movements.

Table 1. Example progression of experience from qualitative to quantitative biomechanical human movement analysis.

Instructional Stage	Primary Mode of Analysis	Student Task(s)	Focus	Learning Outcome
Stage 1	Qualitative Observation	Visually identify joint actions and planes of motion during gait	Functional anatomy, joint kinematics	Accurately describe joint actions and movement patterns
Stage 2	Video-Based Qualitative Analysis	Use 2D video to estimate stride length, cadence, and gait velocity	Temporal–spatial kinematics	Compare movement characteristics across conditions or individuals
Stage 3	Estimation & Simple Quantification	Estimate center of mass displacement and joint moments using simplified models	Mechanical modeling, vector concepts	Explain movement differences using estimated biomechanical variables
Stage 4	Quantitative Kinetics	Interpret ground reaction force data to explain gait asymmetries or loading patterns	Kinetics, force–motion relationships	Apply kinetic data to evaluate movement effectiveness or injury risk

Faculty

Teachers of undergraduate biomechanics in KESS programs should have a doctoral degree with a specialization in biomechanics. Instructors need not earn doctorates under any specific Classification of Instructional Program (CIP) Code [https://nces.ed.gov/ipeds/cipcode/browse.aspx?y=56] like the new (as of 2020) biomechanics CIP code 26.0913. Doctoral degrees in biomechanics may be received from disciplines like biomechanics, biomedical engineering, bioengineering, ergonomics/human factors, and KESS. Preference should usually be given to candidates with degrees, research, and experience in biomechanics within the discipline of KESS. Appropriately trained biomechanics graduate assistants may serve as instructors for laboratory experiences.

Facilities and Equipment

To facilitate achievement of the exit competencies in students, the introductory undergraduate biomechanics course should have separate lecture and laboratory sessions. Effective biomechanics instruction can occur across a range of physical environments when activities are designed with safety and learning objectives in mind. Laboratory activities should take place in a properly equipped biomechanics laboratory space. Other suitable activity areas include gymnasiums, tracks, fields, pools, etc. given there is adequate space for safe movement.

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

A. Minimal Equipment for Laboratory Experiences

1. Anatomical charts, models, medical exam tables, computers, smart devices (e.g. tablet or smartphone) with anatomy software
2. Goniometers, inclinometers, tape measures, and rulers
3. Digital high-speed (≥ 60 Hz) video cameras, smartphones, or iPads/tablets coupled with computers equipped with qualitative/quantitative 2D movement analysis software (e.g., Tracker, Kinovea, or Dartfish)
5. Stop watches, radar guns, and laser timers
6. Medical balance scale (height and weight capabilities), hand grip dynamometers, and portable force platform (e.g., Vernier FP-BTA)
7. Hand-held electrodynamometer and inclinometer/goniometer with interface software
8. Wired surface EMG equipment, amplifiers, computer interface, and analysis software
9. Access to sport, exercise, and rehabilitation implements and equipment (e.g., rackets, bats, balls, protective equipment, golf clubs, dumbbells, therabands, crutches, canes, wheelchairs, medicine balls, swiss/physioballs, etc.)
10. Previously recorded high-speed video movement library (own, free/Youtube) or subscription (DartfishTV)
11. Networked computers or tablets, with wireless internet access to printers

12. Programs with limited funding are encouraged to leverage low-cost technologies (e.g., smartphones, open-source analysis software) to broaden access to biomechanics learning experiences.

B. Desirable Equipment for Laboratory Experiences

1. Complete quantitative 2D/3D movement analysis system, including high-speed video/IR cameras with analysis software for marker or marker-less data collection (e.g. OpenCap).
2. Research quality force platforms, A/D converter, and integrated or other (e.g., Matlab) analysis software
3. Anthropometric kit, biaxial electrogoniometers with wireless computer interface
4. Wireless surface EMG equipment, amplifiers, computer interface, and analysis software
5. Wireless triaxial accelerometers or wearable IMUs with wireless computer interface
6. Reaction boards (1D and 2D)
7. Isokinetic dynamometer (e.g., Biodex or HUMAC NORM)
8. Computers with biomechanical modeling/simulation software (e.g., OpenSim)

Related Guidelines

Related course guidelines for biomechanics instruction in doctor of physical therapy programs have been recently published (Tate et al., 2026).

Instruction

Biomechanics instructors are free to design their course and instructional strategies that best fit their students' needs, curriculum, and facilities. Usually, instruction should emphasize conceptual understanding of mechanical concepts and principles prior to formal mathematical derivation, particularly for students with limited physics backgrounds.

These guidelines strongly recommend that faculty consider using several active learning instructional strategies given overwhelming evidence of their greater effectiveness than traditional lecture and lab instruction in all sciences (Freeman et al., 2014; Haake, 1998). A review of the utility and efficacy of various active learning strategies in science education has been reported (McConnell et al., 2017). Initial national evidence with the Biomechanics Concept Inventory (Knudson et al., 2003) supported the benefit of active learning in classes with active learning in labs learned twice as much as classes with lecture alone (Knudson et al., 2009). Subsequent research has confirmed the superiority of active learning strategies in student learning in biomechanics courses over traditional lecture (see review by Knudson 2024). Importantly, these benefits are likely to accrue to students of all demographics (Riskowski, 2015).

There are several sources for biomechanics faculty seeking ideas for instruction. There are proceedings of past biomechanics teaching conferences (Dillman & Sears, 1978; Shapiro & Marett, 1984; Wilkerson et al., 1997). Teaching and lab activity ideas can be accessed at the kinesiology sections of the California State University System MERLOT project: [https://www.merlot.org/merlot/materials.htm?category=914017]. An extensive bibliography of biomechanics teaching ideas and research on teaching and learning (Knudson, 2026) is available at the Teaching Repository for American Society of Biomechanics members [https://asbweb.org/] or the biography author [dknudson@txstate.edu].

Programs are encouraged to assess student achievement of biomechanics competencies using a combination of formative and summative approaches, including concept inventories, applied problem sets, laboratory reports, movement analysis projects, reflective writing, and performance-based assessments.

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Footnote

[1]Permission to use and revise the previous (4th edition) guidelines (Abraham et al., 2018) was granted by SHAPE America.

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