Biomechanics Curriculum: Its Content and Relevance to Movement Sciences

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While the National Association for Sport and Physical Education (NASPE) has outlined a number of learning outcomes for undergraduate biomechanics, there are a number of factors that can influence the curriculum in such courses. These factors create a situation that indeed can influence students and their attitude towards these classes. Undergraduate students generally avoid the required biomechanics course for a number of reasons, some of which deal with the methods used to teach those classes. In most situations, we teach “applied physics” rather than biomechanics and this emphasis on the physics of movement may have little interest to our students. The emphasis on the mechanics of movement is a concern that must be addressed to create interest in undergraduate biomechanics.

Biomechanics, as a sub-discipline within movement science, is a relative “newcomer.” The field has developed largely in the last 35 to 40 years emerging from other disciplines such as kinesiology, anthropometry, and physiology. Biomechanics has been defined by the American Society of Biomechanics as “the application of the laws of mechanics to animate motion” (see www.asbweb.org/aboutasb.htm). Another definition proposed by the European Society of Biomechanics is “the study of forces acting on and generated within a body and the effects of these forces on the tissues, fluid or materials used for the diagnosis, treatment or research purposes” (see www.esbiomech.org/current/about_esb/index.htm). From these definitions, it is clear that the sub-discipline of biomechanics has a strong mechanics content area.

Most non-biomechanics academics associate this sub-area with the kinematics and kinetics of human movement, particularly in sport situations. However, this view of biomechanics is no longer entirely appropriate. Biomechanics has become more and more diverse in its areas of study and thus more specialized since its early days. Within the sub-discipline, one can find multiple areas that include, for example, tissue engineering, clinical biomechanics, dental biomechanics, reproductive biomechanics, fluid mechanics, muscle mechanics and modeling, human factors, etc. as well as the kinematics and kinetics of sport techniques. At the most recent World Congress of Biomechanics held in Munich, Germany in 2006, there

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were over 2,500 participants at the congress that included 27 parallel sessions. It is clear, therefore, that the term biomechanics now means many different things to different audiences. This diversity of meaning has impacted both the undergraduate and graduate curricula at universities around the world. This paper will only deal with the undergraduate curriculum.

Therefore, the purpose of this paper is to attempt to answer the following questions: (1) What is the content taught in an undergraduate biomechanics curriculum? (2) How does the diversity in the focus of biomechanics affect what is taught? and (3) How relevant is the material that is taught to the movement sciences?

Guidelines for Undergraduate Biomechanics Courses

In 2003, the Biomechanics Academy of the National Association for Sport and Physical Education (NASPE) presented guidelines for the material that should be taught in an undergraduate biomechanics course (see www.aahperd.org/NASPE/pdf_files/Guidelines_Biomechanics_Approval for details). These guidelines advocated exit outcomes organized into three major goals (see Table 1). These goals included: (1) application of biomechanics competencies to human movement, (2) anatomical bases, and (3) mechanical bases.

Table 1 Competencies in the Guidelines for Undergraduate Biomechanics (approved by the Biomechanics Academy of the National Association for Sport and Physical Education)

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<th>Application of Biomechanics Competencies to Human Movement</th>
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<td>1. Observe and describe a movement technique adequately.</td>
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<td>2. Determine the anatomical and mechanical factors basic to the performance of an observed movement.</td>
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<td>3. Evaluate the suitability of a performer’s technique with reference to the task at hand.</td>
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<td>4. Identify those factors that limit performance and establish a priority for change in those factors most likely to lead to improvement in performance.</td>
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<th>Anatomical Bases</th>
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<td>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.</td>
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<td>2. Observe human movement and explain the reasons for different joint actions and ranges of motion using knowledge of joint structure, stability and mobility.</td>
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<td>3. Assess flexibility and create safe and effective stretches for the major muscle groups surrounding each joint.</td>
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<td>4. Identify and describe the roles that muscle groups play and their cooperative actions during simple joint activities and complex multi-joint motor performances.</td>
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<td>5. Explain the force-velocity and length-tension relationships of muscle and recognize their application in static positions and dynamic movements.</td>
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(continued)
6. Recognize the use of the stretch-shortening cycle of muscle in human movement and create effective training exercises that utilize this phenomenon.
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. Define the basic structures of the neuromuscular system and explain how reflexes affect human movement.

**Mechanical Bases**

1. Define a movement system and determine the nature of the system’s movement.
2. Appropriately represent kinematic and kinetic quantities as vectors and use this knowledge to understand the basic mechanical concepts of internal and external forces.
3. Define the terms of distance, displacement, speed, velocity, and acceleration as they relate to linear and angular motion in human movements.
4. Use kinematic variables to compare the quality of various motor performances.
5. Explain the kinematic relationships between linear and angular motion and apply this relationship to improve motor skill performance and equipment design.
6. Describe how the variables of release height, angle, and velocity affect projectile motion and apply these variables to a projectile activity to optimize performance.
7. Define the basic terms of force, inertia, mass and weight as they relate to linear motion in human movement.
8. Define the basic terms of torque, moment, moment of inertia, moment arm, and radius as they relate to angular motion in human movement.
9. State the linear and angular forms of Newton’s Laws of Motion and explain the relationship between the observed movement and for forces and torques responsible for that motion.
10. Explain the effect of weight, normal reaction, friction, buoyancy, drag, and lift on motor performance.
11. Estimate the location of the center of gravity of persons in any position and describe how changes in the location of the center of gravity and other mechanical factors that affect stability.
12. Identify and explain the importance of impulse-momentum, work-energy, and the conservation of momentum to the production of effective human movements.

While these goals and their respective outcomes would indeed create a worthy biomechanics curriculum, there are questions that must be addressed concerning these guidelines. The outcomes themselves are very global in nature and open to interpretation as to the depth of treatment each is given. We must therefore ask these questions: How are these guidelines implemented? Are they viewed equally? Are they used at all? and, finally, can they be used? Using the example of the undergraduate course taught at the University of Massachusetts Amherst, it is clear that many of the outcomes that deal with mechanics are emphasized while others that deal with application are either ignored or minimized in importance. I do not believe that this course is unique and the same is true at other institutions with possibly slightly different emphases.
Factors Affecting Implementation of the NASPE Guidelines

In looking at a number of syllabi of various undergraduate courses at various institutions, it is obvious that there are a number of factors that influence the content taught in these courses. Essentially, the question of how the guidelines are implemented is answered with “it depends.” The factors that influence the implementation of the NASPE guidelines are: (1) the instructor, (2) the prerequisites for the course, (3) the type of department/college in which the course is taught, and (5) the year in which the course is taught.

The Instructor

The NASPE guidelines suggest that instructors of undergraduate biomechanics classes should have a doctoral degree and a specialization in biomechanics. However, because biomechanics was a relative newcomer to the field of movement science, the content of the curriculum was poorly understood by the department in which the course was taught. Thus, the qualifications of the instructor teaching a biomechanics course was either ignored or neglected. Quite often, biomechanics was a secondary requirement for qualifying for faculty positions. Therefore, faculty trained in exercise physiology or pedagogy or motor control were given the task of teaching the undergraduate biomechanics course. Fortunately, this practice is not as frequent as it once was. Now the problem is that we have many individuals trained in biomechanics but not necessarily trained in movement science or kinesiology departments.

Biomechanists are now trained at the graduate level in departments of physical education, exercise science, engineering (mechanical or biomedical), or physical therapy. In addition, graduate programs in biomechanics generally have specializations that further narrow the focus of their graduates. For example, even if a graduate program has multiple faculty members in biomechanics, each faculty member will have a particular focus (e.g., muscle mechanics) and the future faculty member will be trained in that focus. Thus, that particular area of specialization may be emphasized in the undergraduate class that is taught.

The instructor and their academic background will also influence the textbook used for the class. Undergraduate biomechanics textbooks range from a qualitative approach (Knudson, 2002) to a more quantitative approach (Hamill & Knutzen, 2003) to a combination of both (Hall, 2006). None of these approaches are wrong and all can be taught using the NASPE guidelines but the teaching method of the instructor can be affected by the book used.

Prerequisites

Within the Biomechanics Academy guidelines, undergraduate biomechanics classes may have a focus that is qualitative, clinical, or quantitative. The prerequisites for the courses will necessarily emphasize the focus. The guidelines suggest that the students should have the ability to use basic algebraic operations to solve problems and the foundational knowledge of anatomy. In a national survey conducted every 10 years by the Biomechanics Academy, Satern (1999) presented
information gathered from those teaching undergraduate biomechanics. There appeared to be a large variance in the prerequisites for undergraduate courses (see Figure 1). Clearly, students have been required to have a foundation in anatomy and physiology. The necessity of a physics class has neither increased nor decreased in importance although it is required by less than 20% of instructors. However, since 1977, it appears that a required mathematics course has become more prevalent as a prerequisite. For the survey, it is not clear as to the depth of the mathematics course. Although, in looking at syllabi of selected institutions, it appears that these courses range from college algebra to calculus. It seems intuitive that the need for multiple prerequisites including anatomy, physiology, mathematics, and physics can be related to the focus of the course, the depth of the course content, the training of the instructor and the department in which the course resides.

The Department/College

Certainly what is emphasized in the course will depend on the type of department and/or college. Even though departments/colleges with different teaching goals can still adhere to the NASPE guidelines, there can be a wide discrepancy in the curriculum. For example, an exercise science department may emphasize a purely quantitative approach while a department of physical education may emphasize a qualitative approach. Further, the narrowness of focus of the department will also affect what is taught. Using the example of the Departments of Kinesiology at the University of Massachusetts Amherst and at the Pennsylvania State University, we see that the former is a relatively narrow department in terms of movement sciences and the latter a rather broadly based department. The Department of Kinesiology at the University of Massachusetts has four basic areas of study: motor control,
biomechanics, exercise physiology, and metabolism. The Department of Kinesiology at the Pennsylvania State University includes the aforementioned movement science areas with additional sub-disciplines such as psychology, history, pedagogy, etc. With different emphases, these departments may have different depths of focus in the undergraduate class.

The Year the Course is Taught

There appears to be no consistency as to whether the introductory course in biomechanics is taught in the sophomore, junior, or senior years of the undergraduate degree program. The year in which the course is taught will affect the prerequisites for the course and possibly constrain the depth of knowledge imparted in the course. In surveying different institutions, courses taught at the sophomore, junior, or senior years each appeared, for the most part, to follow the NASPE guidelines but it would be difficult to argue that the depth of the course was the same. What did appear to be different with courses taught in the different years was the focus/narrowness of the departments. Some departments (i.e., broadly based) viewed the course as purely an introductory course while others (i.e., more narrow) viewed the course as an essential foundation course.

Another factor that emerges from the view of the course is the number of courses that are taught within each department (see Figure 2). The previous discussion centered on a single undergraduate course. Since 1977, it appears that the majority of institutions have offered a single biomechanics course and relatively fewer offer two or three courses. It does appear, however, that institutions offering two courses at the undergraduate level are increasing. This may be due to the separation of functional anatomy from the mechanical aspects of movement.

![Figure 2](image-url)
Relevancy of the Biomechanics Curriculum

The third question that was posed as a purpose of this paper was: How relevant is the material that is taught to the movement sciences? I hope it is obvious that the material that is taught in an undergraduate biomechanics course is relevant to movement sciences and thus relevant to the department goals. Without knowledge of the mechanics of human movement, it is difficult to explain many of the phenomena that we see. However, this may be a tough case to argue. In a paper that has been accepted for publication, Ives and Knudson (in press) argue that the movement sciences emphasize the physiological bases of movement at the expense of other sub-disciplines such as biomechanics. They cite the example of the American College of Sports Medicine certification programs that include only a few biomechanical terms. Ives and Knudson also point out that NASPE omits biomechanics as a scientific basis for professional preparation in exercise science.

The more important question is the relevancy of the material to students. More appropriately, the question should be rephrased to include the appropriateness of the content material to the students. This is particularly important because there are indicators that most students do not see or appreciate the relevancy of the materials. In the Department of Kinesiology at the University of Massachusetts Amherst, the required undergraduate class is usually taken in the last semester of the senior year. That is, it is avoided until the last possible moment. This situation is probably not unique. The question is why this is so. In addition, the situation may be present in other core classes (i.e., motor control and exercise physiology) in the human movement curriculum.

It is my view that the way in which the curricular content is presented to students may be the answer. Indeed, students appear to have a great deal of trepidation regarding the mathematics necessary for understanding biomechanics. Added to this is that the content is presented as “applied physics” rather than as biomechanics. That is, in the biomechanics course we teach mostly the concepts of physics (e.g., the derivation of velocity and acceleration from position) rather than why the concepts are important to human movement and how they may be applied to human movement. We, as biomechanics instructors, seem to emphasize the physics rather than the biomechanical aspects of movement.

Further, little attempt has been made to integrate anatomical/biological factors of human movement into biomechanics. For example, one outcome that has been observed in running is that individuals have a preferred running speed and a preferred stride length at that speed (Hamill et al., 1995). Some runners also tend to either over-stride (stride length is greater than the preferred) or under-stride (stride length is less than preferred). While this is an interesting finding in itself, it becomes more valuable when we integrate this finding with physiological outcomes. At the preferred stride length for a given speed, the individual operates at a minimum oxygen cost. By either increasing or decreasing their stride length at that speed, oxygen consumption will increase.

In general, undergraduate classes in biomechanics often lack a multi-disciplinary view. Essentially, we have taken “silos” that are the sub-areas at the graduate level and created “silos” at the undergraduate level. The undergraduate course simply becomes a version of the graduate level so, for every graduate course in a sub-area, we have a corresponding undergraduate course. While I am specifically
speaking of biomechanics, I can make the same argument for all sub-areas of the movement sciences.

What Is the Future?

To alleviate the problem of the relevancy of undergraduate biomechanics curriculum to the department and to the students, I see two possible solutions. The first is to keep things as they are now with some modification. That is, we continue to instruct biomechanics classes with the content strictly based on the mechanics of movement. This is the simplest solution for departments but it may not satisfy my concerns about the students. They will still feel the trepidation of the mathematics and physics content of the classes. Knudson (2005) argued for evidence-based practice in biomechanics addressing the theory to practice gap. This type of approach along with a more qualitative approach may address some of the dissatisfaction of students with their undergraduate biomechanics courses.

Ives and Knudson (in press) suggested some preliminary changes in requirements for biomechanics. They suggested that kinesiology departments should require an applied biomechanics course that is at least four semester hours and includes a laboratory component. This first course should be based on the NASPE standards for introductory biomechanics that includes a “how to” in addition to biomechanics theory. This is similar to what is now taught in most departments. They further suggested another advanced biomechanics course that could be an elective. Their second biomechanics course could be tailored to specific career interests such as injury prevention/treatment, elite performance, ergonomics, or special populations. However, the problem in the method of teaching the introductory course would still have to be addressed.

A second approach, as Rikli (2006) suggested, would be to refocus attention on the big picture of the field. What this would entail is a complete restructuring of the undergraduate biomechanics curriculum in movement science. Rikli (2006) stated that “most questions of significance are best addressed through cross-disciplinary approaches involving input from a combination of biological, behavioral and social sciences.” In terms of research questions, we do this almost automatically yet at the level where we are trying to capture the interest of students, we do not do this. At the undergraduate level, we still teach classes related to a sub-discipline rather than presenting concepts and integrating the information from a number of different perspectives.

To pose an example, an undergraduate movement science course (or half course) would consist of a specific topic such as obesity. Within the class, obesity could be discussed, with pertinent background material presented, from a number of perspectives. From a physiology/metabolism viewpoint, energy balance could be presented with the relative physiological concepts. Biomechanists could add concepts dealing with shock attenuation, stride length variance, and the potential for injuries resulting from the obese condition (e.g., osteoarthritis). Motor control specialists could provide information on balance issues during quiet standing, during locomotion, or getting up from a seated position.

I believe this integration of information of material would better serve our undergraduate students and possibly pique their interest for further study. By illustrating the potential use of the integrated information removes us from the
“silo” structure of undergraduate programs. While this paper deals particularly with undergraduate biomechanics courses and the problems that face the students in that class, I do feel the integrated approach has much potential for the undergraduate movement science curriculum as a whole.

**Conclusions**

The purpose of this paper was to attempt to answer the following questions: (1) What is the content taught in an undergraduate biomechanics curriculum? (2) How does the diversity in the focus of biomechanics affect what is taught? and (3) How relevant is the material that is taught to the movement sciences? There are a number of factors that affect what is taught in an undergraduate biomechanics class. It appears that undergraduate biomechanics courses, as presently taught at most institutions, are not particularly relevant to our students. These courses are too “physics” oriented. To capture the interest of students I suggest that we follow one of two approaches. We may alleviate these problems by offering an introductory biomechanics class that includes basic principles followed by a more applied course. However, this approach simply models the undergraduate program on the graduate program in which the sub-areas of the movement sciences are structured as “silos” of knowledge. I believe a more comprehensive and appropriate approach would be an integrative one in which specific topics would be addressed from a number of perspectives that cut across the sub-areas of the movement sciences.

**References**


