

Introduction to Biomechanics of Human Movement

Most people are extremely skilled in many everyday movements like standing, walking, or climbing stairs. By the time children are two, they are skilled walkers with little instruction from parents aside from emotional encouragement. Unfortunately, modern living does not require enough movement to prevent several chronic diseases associated with low physical activity (USDHHS, 1996). Fortunately, many human movement professions help people to participate in beneficial physical activities. Physical Educators, coaches, athletic trainers, strength & conditioning coaches, personal trainers, and physical therapists all help people reap the benefits of physical activity. These human movement professions rely on undergraduate training in kinesiology, and typically require coursework in biomechanics. **Kinesiology** is the term referring to the whole scholarly area of human movement study, while **biomechanics** is the study of motion and its causes in living things. Biomechanics provides key information on the most effective and safest movement patterns, equipment, and relevant exercises to improve human movement. In a sense, kinesiology professionals solve human movement problems every day, and one of their most important tools is biomechanics. This chapter outlines the field of biomechanics, why biomechanics is such an important area to the kinesiology professional, and where biomechanics information can be found.

WHAT IS BIOMECHANICS?

Biomechanics has been defined as *the study of the movement of living things using the science of mechanics* (Hatze, 1974). Mechanics is a branch of physics that is concerned with the description of motion and how forces create motion. Forces acting on living things can create motion, be a healthy stimulus for growth and development, or overload tissues, causing injury. Biomechanics provides conceptual and mathematical tools that are necessary for understanding how living things move and how kinesiology professionals might improve movement or make movement safer.

Most readers of this book will be majors in departments of Kinesiology, Human Performance, or HPERD (Health, Physical Education, Recreation, and Dance). Kinesiology comes from two Greek verbs that translated literally means “the study of movement.” Most American higher education programs in HPERD now use “kinesiology” in the title of their department because this term has come to be known as the academic area for the study of human movement (Corbin & Eckert, 1990). This change in terminology can be confusing because “kinesiology” is also the title of a foundational course on applied anatomy that was commonly required for a physical education degree in the first half of the twentieth century. This older meaning of kinesiology persists even today, possibly

because biomechanics has only recently (since 1970s) become a recognized specialization of scientific study (Atwater, 1980; Wilkerson, 1997).

This book will use the term kinesiology in the modern sense of the whole academic area of the study of human movement. Since kinesiology majors are pursuing careers focused on improving human movement, you and almost all kinesiology students are required to take at least one course on the biomechanics of human movement. It is a good thing that you are studying biomechanics. Once your friends and family know you are a kinesiology major, you will invariably be asked questions like: should I get one of those new rackets, why does my elbow hurt, or how can I stop my drive from slicing? Does it sometimes seem as if your friends and family have regressed to that preschool age when every other word out of their mouth is “why”? What is truly important about this common experience is that it is a metaphor for the life of a human movement professional. Professions require formal study of theoretical and specialized knowledge that allows for the reliable solution to problems. This is the traditional meaning of the word “professional,” and it is different than its common use today. Today people refer to professional athletes or painters because people earn a living with these jobs, but I believe that kinesiology careers should strive to be more like true professions such as medicine or law.

People need help in improving human movement and this help requires knowledge of “why” and “how” the human body moves. Since biomechanics gives the kinesiology professional much of the knowledge and many of the skills necessary to answer these “what works?” and “why?” questions, biomechanics is an important science for solving human movement problems. However, biomechanics is but one of

many sport and human movement science tools in a kinesiology professional's toolbox. This text is also based on the philosophy that your biomechanical tools must be combined with tools from other kinesiology sciences to most effectively deal with human movement problems. Figure 1.1a illustrates the typical scientific subdisciplines of kinesiology. These typically are the core sciences all kinesiology majors take in their undergraduate preparations. This overview should not be interpreted to diminish the other academic subdisciplines common in kinesiology departments like sport history, sport philosophy, dance, and sport administration/management, just to name a few.

The important point is that knowledge from all the subdisciplines must be integrated in professional practice since problems in human movement are multifaceted, with many interrelated factors. For the most part, the human movement problems you face as a kinesiology professional will be like those “trick” questions professors ask on exams: they are complicated by many factors and tend to defy simple, dualistic (black/white) answers. While the application examples discussed in this text will emphasize biomechanical principles, readers should bear in mind that this biomechanical knowledge should be integrated with professional experience and the other subdisciplines of kinesiology. It is this **interdisciplinary** approach (Figure 1.1b) that is essential to finding the best interventions to help people more effectively and safely. Dotson (1980) suggests that true kinesiology professionals can integrate the many factors that interact to affect movement, while the layman typically looks at things one factor at time. Unfortunately, this interdisciplinary approach to kinesiology instruction in higher education has been elusive (Harris, 1993). Let's look at some examples of human movement problems where it is particularly important to

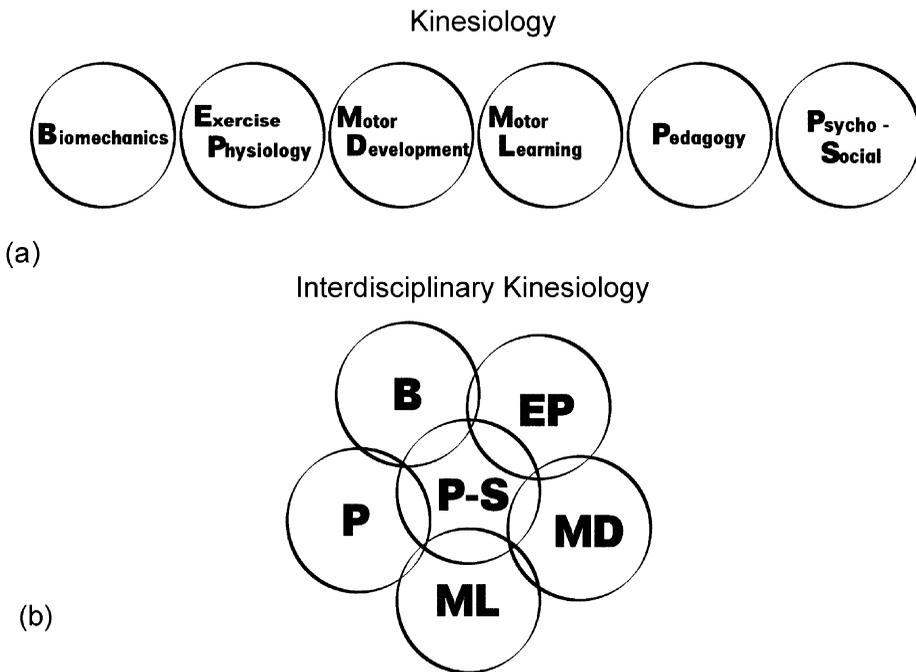


Figure 1.1. (a) The major academic subdisciplines or sciences of kinesiology. (b) Schematic of the integration of all the sciences in an interdisciplinary approach to solving human movement problems in kinesiology.

integrate biomechanical knowledge into the qualitative analysis.

WHY STUDY BIOMECHANICS?

Scientists from many different areas (e.g., kinesiology, engineering, physics, biology, zoology) are interested in biomechanics. Why are scholars from so many different academic backgrounds interested in animal movement? Biomechanics is interesting because many people marvel at the ability and beauty in animal movement. Some scholars have purely theoretical or academic interests in discovering the laws and principles that govern animal movement. Within kinesiology, many biomechanists have been interested in the application of biomechanics to sport and exercise. The applications of biomechanics to human

movement can be classified into two main areas: the improvement of performance and the reduction or treatment of injury (Figure 1.2).

Improving Performance

Human movement performance can be enhanced many ways. Effective movement involves anatomical factors, neuromuscular skills, physiological capacities, and psychological/cognitive abilities. Most kinesiology professionals prescribe technique changes and give instructions that allow a person to improve performance. Biomechanics is most useful in improving performance in sports or activities where technique is the dominant factor rather than physical structure or physiological capacity. Since biomechanics is essentially the

Applications of Biomechanics

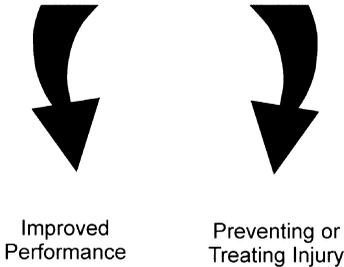


Figure 1.2. The two major applications of biomechanics are to improve human movement and the treatment or prevention of injury.

science of movement technique, biomechanics is the main contributor to one of the most important skills of kinesiology professionals: the qualitative analysis of human movement (Knudson & Morrison, 2002).

Imagine a coach is working with a gymnast who is having problems with her back handspring (Figure 1.3). The coach observes several attempts and judges that the angle of takeoff from the round off and

body arch are performed poorly. The coach's experience tells him that this athlete is strong enough to perform this skill, but they must decide if the gymnast should concentrate on her takeoff angle or more back hyperextension in the block. The coach uses his knowledge of biomechanics to help in the qualitative analysis of this situation. Since the coach knows that a better arch affects the force the gymnast creates against the mat and affects the angle of takeoff of the gymnast, he decides to help the gymnast work on her "arch" following the round off.

Biomechanics research on sports techniques sometimes tends to lag behind the changes that are naturally occurring in sports. Athletes and coaches experiment with new techniques all the time. Students of biomechanics may be surprised to find that there are often limited biomechanical

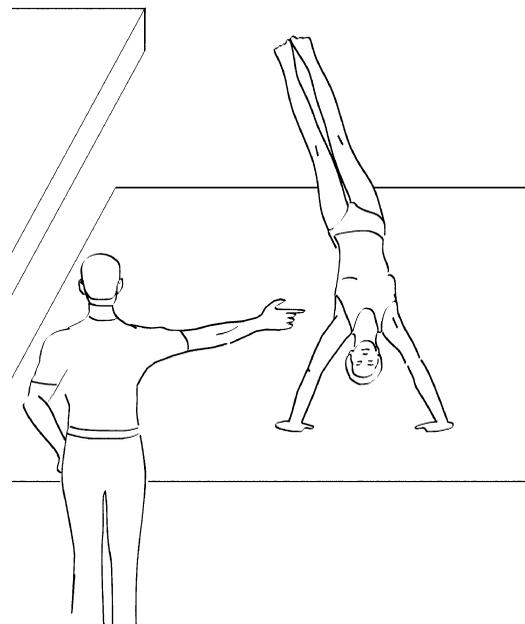


Figure 1.3. Biomechanics principles must be integrated with other kinesiology sciences to solve human movement problems, like in the qualitative analysis a round off and back handspring.

studies on many techniques in many popular sports. The vast number of techniques, their variations, and their high rates of change and innovation tend to outdistance biomechanics research resources. Sport biomechanics research also lags behind the coaches and athletes because scientific research takes considerable time to conduct and report, and there is a lack of funding for this important research. There is less funding for biomechanical studies aimed at improving performance compared to studies focused on preventing and treating injuries. Students looking for biomechanical research on improving sports technique often will have fewer sources than students researching the biomechanics of injury.

While technique is always relevant in human movement, in some activities the psychological, anatomical, or physiological factors are more strongly related to success. Running is a good example of this kind of movement. There is a considerable amount of research on the biomechanics of running so coaches can fine tune a runner's technique to match the profile of elite runners (Cavanagh, Andrew, Kram, Rogers, Sanderson, & Hennig, 1985; Buckalew, Barlow, Fischer, & Richards, 1985; Williams, Cavanagh, & Ziff, 1987). While these technique adjustments make small improvements in performance, most of running performance is related to physiological abilities and their training. Studies that provide technique changes in running based on biomechanical measurements have found minimal effects on running economy (Cavanagh, 1990; Lake & Cavanagh, 1996; Messier & Cirillo, 1989). This suggests that track coaches can use biomechanics to refine running technique, but they should only expect small changes in performance from these modifications.

Human performance can also be enhanced by improvements in the design of equipment. Many of these improvements are related to new materials and engineer-

ing designs. When these changes are integrated with information about the human performer, we can say the improvements in equipment were based on biomechanics. Engineers interested in sports equipment often belong to the International Sports Engineering Association (<http://www.sportsengineering.org/>) and publish research in ISEA proceedings (Subic & Haake, 2000) or the *Sports Engineering* journal. Research on all kinds of equipment is conducted in biomechanics labs at most major sporting goods manufacturers. Unfortunately, much of the results of these studies are closely guarded trade secrets, and it is difficult for the layperson to determine if marketing claims for "improvements" in equipment design are real biomechanical innovations or just creative marketing.

There are many examples of how applying biomechanics in changing equipment designs has improved sports performance. When improved javelin designs in the early 1980s resulted in longer throws that endangered other athletes and spectators, redesigns in the weight distribution of the "new rules" javelin again shortened throws to safer distances (Hubbard & Alaways, 1987). Biomechanics researchers (Elliott, 1981; Ward & Groppe, 1980) were some of the first to call for smaller tennis rackets that more closely matched the muscular strength of young players (Figure 1.4). Chapter 8 will discuss how changes in sports equipment are used to change fluid forces and improve performance.

While breaking world records using new equipment is exciting, not all changes in equipment are welcomed with open arms by sport governing bodies. Some equipment changes are so drastic they change the very nature of the game and are quickly outlawed by the rules committee of the sport. One biomechanist developed a way to measure the stiffness of basketball goals, hoping to improve the consistency of



Figure 1.4. The design of sports equipment must be appropriate for an athlete, so rackets for children are shorter and lighter than adult rackets. Photo used with permission from Getty Images.

their response but found considerable resistance from basketball folks who liked their unique home court advantages. Another biomechanist recently developed a new “klap” speed skate that increased the time and range of motion of each push off the ice, dramatically improving times and breaking world records (de Koning, Hou-dijk, de Groot, & Bobbert, 2000). This gave quite an advantage to the country where these skates were developed, and there was controversy over the amount of time other skaters were able to practice with the new skates before competition. These dramatic equipment improvements in many sports have some people worried that winning Olympic medals may be more in the hands

of the engineers than athletes (Bjerklie, 1993).

Another way biomechanics research improves performance is advances in exercise and conditioning programs. Biomechanical studies of exercise movements and training devices serve to determine the most effective training to improve performance (Figure 1.5). Biomechanical research on exercises is often compared to research on the sport or activity that is the focus of training. Strength and conditioning professionals can better apply the principle of specificity when biomechanical research is used in the development of exercise programs. Computer-controlled exercise and testing machines are another example of how biomechanics contributes to strength and conditioning (Ariel, 1983). In the next section the application of biomechanics in the medical areas of **orthotics** and **prosthetics** will be mentioned in relation to preventing injury, but many prosthetics are now being designed to improve the performance of disabled athletes.



Figure 1.5. A computerized testing and exercise dynamometer by Biodex. The speed, muscle actions (isometric, concentric, eccentric), and pattern of loading (isokinetic, isotonic) can be selected. Image courtesy of Biodex Medical Systems.

Preventing and Treating Injury

Movement safety, or injury prevention/treatment, is another primary area where biomechanics can be applied. Sports medicine professionals have traditionally studied injury data to try to determine the potential causes of disease or injury (epidemiology). Biomechanical research is a powerful ally in the sports medicine quest to prevent and treat injury. Biomechanical studies help prevent injuries by providing information on the mechanical properties of tissues, mechanical loadings during movement, and preventative or rehabilitative therapies. Biomechanical studies provide important data to confirm potential injury mechanisms hypothesized by sports medicine physicians and epidemiological studies. The increased participation of girls and women in sports has made it clear that females are at a higher risk for anterior cruciate ligament (ACL) injuries than males due to several biomechanical factors (Boden, Griffin, & Garrett, 2000). Continued biomechanical and sports medicine studies may help unravel the mystery of this high risk and develop prevention strategies (see Chapter 12).

Engineers and occupational therapists use biomechanics to design work tasks and assistive equipment to prevent overuse injuries related to specific jobs. Combining biomechanics with other sport sciences has aided in the design of shoes for specific sports (Segesser & Pforringer, 1989), especially running shoes (Frederick, 1986; Nigg, 1986). Since the 1980s the design and engineering of most sports shoes has included research in company biomechanics labs. The biomechanical study of auto accidents has resulted in measures of the severity of head injuries, which has been applied in biomechanical testing, and in design of many kinds of helmets to prevent head injury (Calvano & Berger, 1979; Norman, 1983; Torg, 1992). When accidents result in

amputation, **prosthetics** or artificial limbs can be designed to match the mechanical properties of the missing limb (Klute Kallfelz, & Czerniecki, 2001). Preventing acute injuries is also another area of biomechanics research. Forensic biomechanics involves reconstructing the likely causes of injury from accident measurements and witness testimony.

Biomechanics helps the physical therapist prescribe rehabilitative exercises, assistive devices, or orthotics. **Orthotics** are support objects/braces that correct deformities or joint positioning, while assistive devices are large tools to help patient function like canes or walkers. Qualitative analysis of gait (walking) also helps the therapist decide whether sufficient muscular strength and control have been regained in order to permit safe or cosmetically normal walking (Figure 1.6). An athletic trainer might observe the walking pattern for signs of pain and/or limited range of motion in an athlete undergoing long-term conditioning for future return to the field. An athletic coach might use a similar quali-



Figure 1.6. Qualitative analysis of gait (walking) is of importance in physical therapy and the treatment of many musculoskeletal conditions.

tative analysis of the warm-up activities of the same athlete several weeks later to judge their readiness for practice or competition. Many biomechanists work in hospitals providing quantitative assessments of gait function to document the effectiveness of therapy. The North American group interested in these quantitative assessments for medical purposes is the Gait and Clinical Movement Analysis Society (GCMAS) at <http://www.gcmas.net/cms/index.php>. Good sources for the clinical and biomechanical aspects of gait are Kirtley (2006), Perry (1992), Whittle (1996), and the clinical gait analysis website: <http://guardian.curtin.edu.au/cga/>.

Dramatic increases in computer memory and power have opened up new areas of application for biomechanists. Many of these areas are related to treating and preventing human injury. Biomechanical studies are able to evaluate strategies for preventing falls and fractures in the elderly (Robinovitch, Hsiao, Sandler, Cortez, Liu, & Paiement, 2000). Biomechanical computer models can be used to simulate the effect of various orthopaedic surgeries (Delp, Loan, Hoy, Zajac, & Rosen, 1990) or to educate with computer animation. Some biomechanists have developed software used to adapt human movement kinematic data so

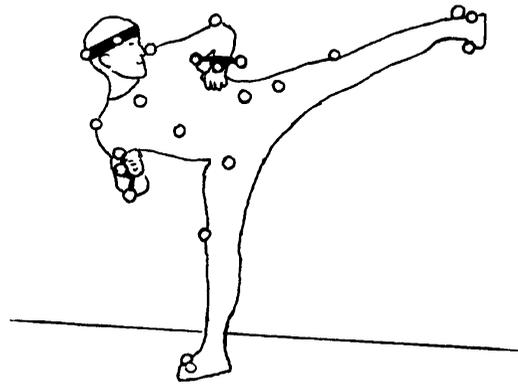


Figure 1.7. Biomechanical measurements and software can be used to make accurate animations of human motion that can be used for technique improvement, cinema special effects, and computer games. Drawing based on image provided by Vicon Motion Systems.

that computer game animations have the look of truly human movement, but with the superhuman speed that makes games exciting (Figure 1.7). Some people use biomechanics to perform forensic examinations. This reconstruction of events from physical measurements at the scene is combined with medical and other evidence to determine the likely cause of many kinds of accidents.

Application

A variety of professions are interested in using biomechanics to modify human movement. A person that fabricates prosthetics (artificial limbs) would use biomechanics to understand the normal functioning of joints, the loadings the prosthetic must withstand, and how the prosthetic can be safely attached to the person. List possible questions biomechanics could answer for a(n):

- Athletic Coach?
- Orthopaedic Surgeon?
- Physical Educator?
- Physical Therapist?
- Athletic Trainer?
- Strength & Conditioning Professional?
- Occupational Fitness Consultant?

You? What question about human movement technique are you curious about?

Qualitative and Quantitative Analysis

Biomechanics provides information for a variety of kinesiology professions to analyze human movement to improve effectiveness or decrease the risk of injury. How the movement is analyzed falls on a continuum between a qualitative analysis and a quantitative analysis. **Quantitative analysis** involves the measurement of biomechanical variables and usually requires a computer to do the voluminous numerical calculations performed. Even short movements will have thousands of samples of data to be collected, scaled, and numerically processed. In contrast, **qualitative analysis** has been defined as the “systematic observation and introspective judgment of the quality of human movement for the purpose of providing the most appropriate intervention to improve performance” (Knudson & Morrison, 2002, p. 4). Analysis in both quantitative and qualitative contexts means identification of the factors that affect human movement performance, which is then interpreted using other higher levels of thinking (synthesis, evaluation) in applying the information to the movement of interest. Solving problems in human movement involves high levels of critical thinking and an interdisciplinary approach, integrating the many kinesiology sciences.

The advantages of numerical measurements of quantitative over those of qualitative analysis are greater accuracy, consistency, and precision. Most quantitative biomechanical analysis is performed in research settings; however, more and more devices are commercially available that inexpensively measure some biomechanical variables (e.g., radar, timing lights, timing mats, quantitative videography systems). Unfortunately, the greater accuracy of quantitative measures comes at the cost of technical skills, calibration, computational

and processing time, as well as dangers of increasing errors with the additional computations involved. Even with very fast modern computers, quantitative biomechanics is a labor-intensive task requiring considerable graduate training and experience. For these reasons and others, qualitative analysis of human movement remains the main approach kinesiology professionals use in solving most human movement problems. Qualitative analysis will be the main focus of the applications of biomechanics presented in this book. Whether your future jobs use qualitative or quantitative biomechanical analysis, you will need to be able to access biomechanical knowledge. The next section will show you many sources of biomechanical knowledge.

Activity: Videotape Replay

Tape a sporting event from a TV broadcast on a VCR. Find a sequence in the video where there is a movement of interest to you and where there is a good close-up shot of the action. You could also video yourself performing a movement using a camcorder. Watch the replay at real-time speed and try to estimate the percentage of time taken up by the major phases of the movement. Most skills can be broken down into three phases—preparation, action, and follow-through—but you can have as many phases as you think apply to the movement of interest. Rewind the tape and use the “pause” and “frame” advance functions to count the number of video frames in the skill and calculate the times and percentages for each phase of the skill. Most VCRs show every other field, giving you a video “clock” with 30 pictures per second. Note, however, that some VCRs show you every field (half of interlaced video) so your clock will be accurate to 1/60th of a second. How could you check what your or the classes’ VCR does in frame advance mode? How close was your qualitative judgment to the more accurate quantitative measure of time?

Application

Even though qualitative and quantitative analyses are not mutually exclusive, assume that qualitative-versus-quantitative biomechanical analysis is an either/or proposition in the following exercise. For the sports medicine and athletics career areas, discuss with other students what kind of analysis is most appropriate for the questions listed. Come to a consensus and be prepared to give your reasons (cost, time, accuracy, need, etc.) for believing that one approach might be better than another.

Sport Medicine

1. Is the patient doing the lunge exercise correctly?
2. Is athlete "A" ready to play following rehab for their injured ACL?

Athletics

1. Should pole vaulter "B" change to a longer pole?
2. Is athlete "A" ready to play following rehab for their injured ACL?

WHERE CAN I FIND OUT ABOUT BIOMECHANICS?

This text provides a general introduction to the biomechanics of human movement in kinesiology. Many students take advanced courses in biomechanics and do library research for term projects. This text will provide quite a few references on many topics that will help students find original sources of biomechanical data. The relative youth of the science of biomechanics and the many different academic areas interested in biomechanics (among others, biology, engineering, medicine, kinesiology, physics) makes the search for biomechanical knowledge challenging for many students. This section will give you a brief tour of some of the major fields where biomechanics research is of interest.

Where you find biomechanics research depends on the kind of data you are interested in. Many people are curious about human movement, but there are also many scholars who are interested in the biomechanics of a wide variety of animals. An excellent way to study the theoretical aspects of biomechanics is to study animals that

have made adaptations to be good at certain kinds of movements: like fish, kangaroos, or frogs. Much of this biomechanical research on animals is relevant to the study of human movement.

Professionals from many fields are interested in human movement, so there is considerable interest and research in human biomechanics. As a science biomechanics is quite young (infant), but biomechanics is more like the middle child within the subdisciplines of kinesiology. Biomechanics is not as mature as Exercise Physiology or Motor Learning but is a bit older than Sport Psychology and other subdisciplines. Basic biomechanics research on many popular sport techniques will have been conducted in the early to mid-20th century. Biomechanics research in kinesiology since the 1970s has tended to become more narrowly focused and specialized, and has branched into areas far beyond sport and education. As a result, students with basic sport technique interests now have to integrate biomechanics research over a 50-year period.

Depending on the depth of analysis and the human movement of interest, a stu-

dent of biomechanics may find himself reading literature in biomechanical, medical, physiological, engineering, or other specialized journals. The smaller and more narrow the area of biomechanical interest (for example, specific fibers, myofibrils, ligaments, tendons), the more likely there will be very recent research on the topic. Research on the effect of computerized retail check-out scanners would likely be found in recent journals related to engineering, human factors, and ergonomics. A student interested in a strength and conditioning career might find biomechanical studies on exercises in medical, physical education, physiology, and specialized strength and conditioning journals. Students with clinical career interests who want to know exactly what muscles do during movement may put together data from studies dealing with a variety of animals. Clues can come from classic research on the muscles of the frog (Hill, 1970), the cat (Gregor & Abelew, 1994) and turkeys (Roberts, Marsh, Weyand, & Taylor, 1997), as well as human muscle (Ito, Kawakami, Ichinose, Fukushima, & Fukunaga, 1998). While muscle force-measuring devices have been im-

planted in humans, the majority of the invasive research to determine the actions of muscles in movement is done on animals (Figure 1.8).

Scholarly Societies

There are scholarly organizations exclusively dedicated to biomechanics. Scholarly societies typically sponsor meetings and publications to promote the development of their fields. Students of sport biomechanics should know that the International Society of Biomechanics in Sports (ISBS) is devoted to promotion of sport biomechanics research and to helping coaches apply biomechanical knowledge in instruction, training, and conditioning for sports. The ISBS publishes scholarly papers on sports biomechanics that are accepted from papers presented at their annual meetings and the journal *Sports Biomechanics*. Their website (<http://isbs.org/>) provides links to a variety of information on sport biomechanics. The websites for the societies discussed in this section are listed at the end of this chapter and in a file on the CD.

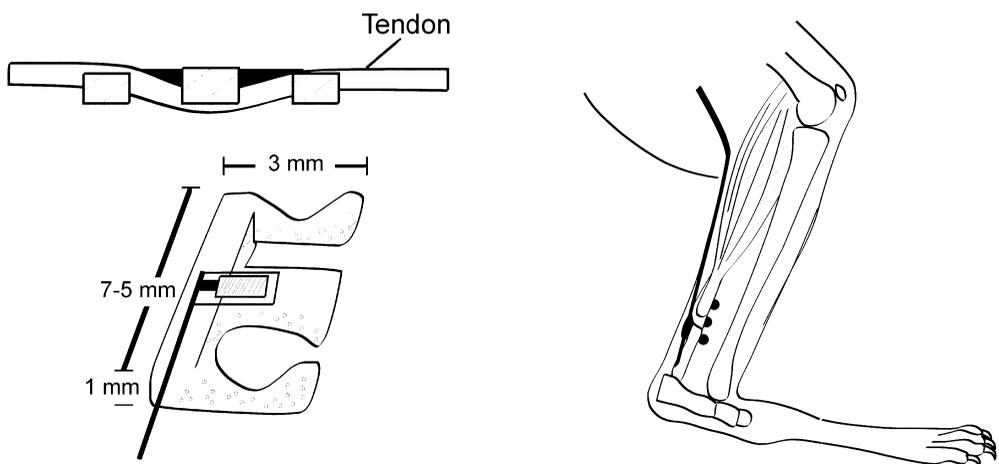


Figure 1.8. Schematic of a buckle transducer for *in vivo* measurement of muscle forces in animal locomotion. Adapted with permission from Biewener and Blickhan (1988).

The International Society of Biomechanics (ISB) is the international society of scholars interested in biomechanics from all kinds of academic fields. The ISB hosts international meetings and sponsors journals. Some examples of regional biomechanics societies include the American Society of Biomechanics (ASB), the Canadian Society of Biomechanics, and the European Society of Biomechanics. The ASB website has several links, including a list of graduate programs and papers accepted for presentation at ASB annual meetings. Another related scholarly society is the International Society for Electrophysiology and Kinesiology (ISEK), which promotes the **electromyographic** (EMG) study of human movement. Engineers interested in equipment design, sport, and human movement have founded the ISEA mentioned earlier. There are other scholarly organizations that have biomechanics interest groups related to the parent disciplines of medicine, biology, or physics.

Aside from the many specialized biomechanics societies, there are biomechanics interest groups in various scholarly/professional organizations that have an interest in human movement. Two examples are the American Alliance for Health, Physical Education, Recreation, and Dance (AAHPERD) and the American College of Sports Medicine (ACSM). AAHPERD is the original physical education scholarly/professional organization, founded in 1885. Biomechanists in HPERD can be active in the Biomechanics Academy of the National Association for Sport and Physical Education (NASPE is one of the HPERD associations within the alliance). The American College of Sports Medicine was founded in 1954 by physicians and exercise scientists to be a scholarly society interested in promotion of the study and application of exercise, sports medicine, and sports science. The ACSM substructure interested in biomechanics is

the biomechanics interest group (BIG). Other professional organizations in medicine, physical therapy, athletic training, and/or strength and conditioning sponsor biomechanics programs related to their unique interests. Whatever career path you select, it is important that you join and participate in the related scholarly and professional organizations.

Computer Searches

One of the best ways to find information on human biomechanics is to use computerized bibliographies or databases of books, chapters, and articles. Some of the best electronic sources for kinesiology students are *SportDiscus*, *MEDLINE*, and *EMBASE*. *SportDiscus* is the CD-ROM version of the database compiled by the Sport Information Resource Center (SIRC) in Ontario, Canada (<http://www.sirc.ca/>). SIRC has been compiling scholarly sources on sport and exercise science since 1973. Many universities buy access to *SportDiscus* and *Medline* for faculty and student research. *SportDiscus* is quite helpful in locating research papers in the ISBS edited proceedings.

Medical literature has been well cataloged by Index Medicus and the searchable databases *MEDLINE* and *EMBASE*. These databases are quite extensive but do not list all published articles so a search of both is advisable (Minozzi, Pistotti, & Forni, 2000) for literature searches related to sports medicine. Besides access from your university library, the national library of medicine provides free searching of *Medline* at <http://www.ncbi.nlm.nih.gov/entrez/query.fcgi>. Very large databases like *SportDiscus*, *Medline*, and *EMBASE* are great research tools if searched intelligently. These databases and others (e.g., *Biological Abstracts*, *Science Citation Index*) should be

searched by the careful linking of keywords and Boolean (logic: and, or) operators. Remember that much of the power of indexing is the cross-referencing as well as the direct listings for your search items.

Many journals now publish keywords with articles to facilitate the searching for the articles with similar terms. The search request for “biomechanics” in some databases will return all items (probably too many) beginning with these letters in the title, abstract, or keywords including biomechanics or biomechanical. Searching for “kinematic and ankle” will find sources documenting the motion at the ankle joint. Even better would be “kinematic or ankle or subtalar,” because any one of the three search terms matching would select a resource. You miss very little with this search, but it is necessary to go through quite a few sources to find the most relevant ones. Be persistent in your search and let your readings refine your search strategy. A student interested in occupational overuse injuries (sports medicine term) will find that the human factors field may refer to this topic as “cumulative trauma disorder,” “work-related musculoskeletal disorders,” or “occupational overuse syndrome” just to name a few (Grieco, Molteni, DeVito, & Sias, 1998).

There are bibliographies of literature that are in print that list sources relevant to

biomechanics. The President's Council on Physical Fitness and Sports publishes *Physical Fitness/Sports Medicine*. The *Physical Education Index* is a bibliographic service for English language publications that is published quarterly by BenOak Publishing. The *PE Index* reviews more than 170 magazines and journals, provides some citations from popular press magazines, and this index can be used to gather “common knowledge.” Early sport and exercise biomechanics research has been compiled in several bibliographies published by the University of Iowa (Hay, 1987).

Biomechanics Textbooks

Good sources for knowledge and links (not hyperlinks) to sources commonly missed by students are biomechanics textbooks. Biomechanics students should look up several biomechanics textbooks and review their coverage of a research topic. Scholars often write textbooks with research interests that are blended into their texts, and many authors make an effort to provide extensive reference lists for students. Remember that writing books takes considerable time, so references in a particular text may not be totally up-to-date, but they do give students leads and clues on many good

Interdisciplinary Issue: Collaborative Biomechanics

Finding biomechanics information is like a scavenger hunt that will lead students all over a library. We have seen that biomechanics research can be found in biology, engineering, medical, and other specialized journals. “Interdisciplinary” means using several different disciplines simultaneously to solve a problem. Do some preliminary research for sources (journals and edited proceedings/books) on a human movement of interest to you. Do the titles and abstracts of the sources you found suggest scholars from different disciplines are working together to solve problems, or are scholars working on a problem primarily from their own area or discipline? What have other students found in their research?

sources. The quality of a biomechanical source will be difficult for many students to judge, so the next section will coach you in evaluating biomechanical sources.

BIOMECHANICAL KNOWLEDGE VERSUS INFORMATION

Knowledge is different from information. **Knowledge** is contextual, theory-based, and data-supported ideas that make the best current explanation for reality. Scientific knowledge is a theoretical structure of laws and principles that is built on the consensus of experimental evidence by scientists in that field. Students often fail to realize that knowledge is a structure that is constantly being constructed and remodeled as new theories and evidence are examined, and transitions in the structure are often controversial.

Biomechanical knowledge is built by a consensus of scientists from a variety of disciplines interested in human movement (e.g., biology, engineering, kinesiology, medicine). Most real-world human movement problems have only partial answers because of limited biomechanical research or knowledge that is specifically related to the context of the person and problem of interest. Although the stack of biomechanical knowledge is not perfect, a critical review of this will be the best guide and closest to the truth.

The modification of human movement based on biomechanical knowledge is difficult because movement is a multifaceted problem, with many factors related to the performer and activity all interacting to affect the outcome. The next chapter will present nine general principles of biomechanical knowledge that are useful in applying biomechanics in general to improve human movement. There will be a few bits of the knowledge puzzle that are well

known and rise to the level of scientific law. While most biomechanical knowledge is not perfect and can only be organized into some general principles, it is much better at guiding professional practice than merely using information or trail and error.

Living in an information age, it is easy for people to become insensitive to the important distinction between information and knowledge. The most important difference is that information has a much higher chance of being incorrect than knowledge. **Information** is merely access to opinions or data, with no implied degree of accuracy. Information is also much easier to access in the age of the Internet and wireless communications. Do not confuse ease of access with accuracy or value. This distinction is clearer as you look at the hierarchy of the kinds of sources used for scholarly research and a simple strategy for the evaluation of the quality of a source.

Kinds of Sources

When searching for specific biomechanical knowledge it is important to keep in mind the kind of source you are reading. There is a definite hierarchy of the scholarly or academic rigor of published research and writing. Figure 1.9 illustrates typical examples of this hierarchy. Although there are exceptions to most rules, it is generally true that the higher up a source on the hierarchy the better the chance that the information presented is closer to the current state of knowledge and the truth. For this reason professionals and scholars focus their attention on peer-reviewed journals to maintain a knowledge base for practice. Some publishers are now “publishing” electronic versions of their journals on the world wide web (WWW) for subscribers or make papers available for free after a certain waiting period.

Most scholarly journals publish original research that extends the body of

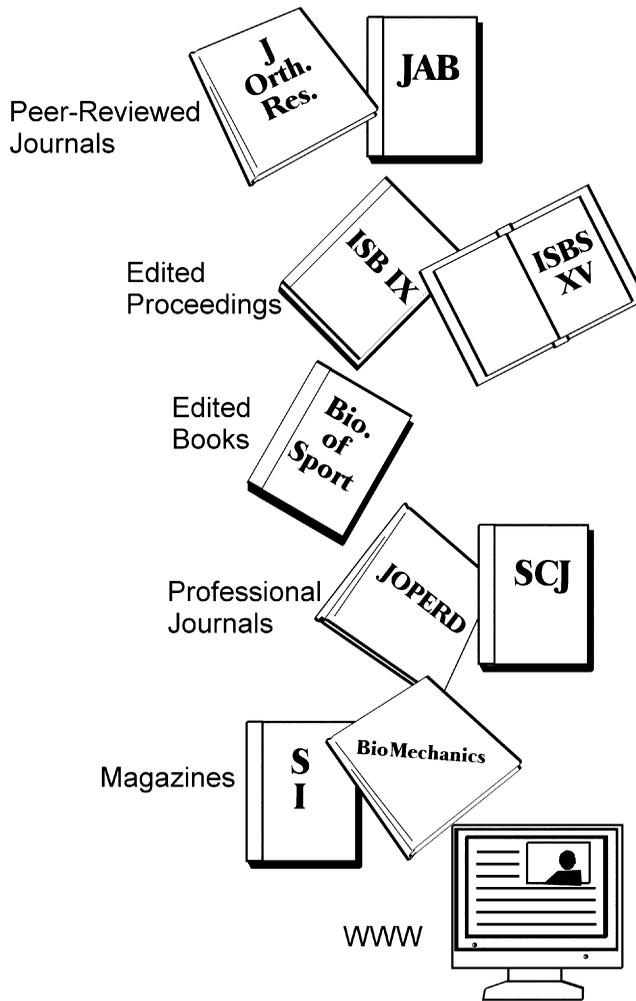


Figure 1.9. The many kinds of biomechanics sources of information and the hierarchy of their academic rigor.

knowledge, or review papers that attempt to summarize a body of knowledge. Many journals also publish supplements that contain abstracts (short summaries of a research study) of papers that have been accepted for presentation at a scholarly meeting or were published in another journal. While the review of these abstracts is not as rigorous as a full journal article, abstracts do provide students with clues about what the most recent research is fo-

cusing on. Reading biomechanics research will be challenging for most undergraduates. Appendix A provides a comprehensive glossary of biomechanics terms that will help you when reading the biomechanics literature related to your professional interests.

In the middle of academic rigor are edited proceedings, edited books, and professional journals. These publications have varying degrees of peer review before pub-

lication, as well as varying rules on what constitutes acceptable evidence. At the bottom of the credibility chain are popular press publications (magazines/newspapers) and hypertext on the worldwide web. While these sources are appropriate for more subjective observations of laypersons, there are serious threats to the validity of the observations from these sources. The major problems with webpages are their impermanence (unlike archival research literature) and the lack of review (anyone can post a webpage). Another good example is the teaching and coaching tips published by the *Physical Education Digest* (<http://www.pedigest.com>). Most of tips and cues are opinions of coaches and teachers in popular press magazines that have not been tested by scientific research. It is possible that some of these opinions are correct and useful, but there is little evidence used to verify the advice, so kinesiology professionals should verify with other primary sources before using the advice. The next section will summarize a quick method for checking the credibility of various sources for biomechanical knowledge.

Evaluating Sources

The previous section clearly suggests that certain sources and kinds of evidence are more likely to be accurate. When evaluating the credibility of sources that fall at similar levels of rigor, the “me” test can be easily applied to judge the chance of the advice being a good and balanced representation of reality. The “m” stands for motivation. What is the motivation for the person or source providing the information? Sources with little financial interest in to making the observations/claims and who are dedicated to advancing a body of knowledge or human potential (scholarly journals) are much more likely to provide accurate information. The motivation of the popular press (TV, newspapers, magazines) and the

internet (WWW) involves profit and self-promotion based on numbers of viewers and, therefore, is more prone to sensationalize and to not weigh all the evidence.

The “e” in the acronym stands for the key element of all science: evidence. Science is based on logical analysis and the balance of many controlled studies. This weighing of all the evidence stands in stark contrast to the more emotional claims of the popular press. The more emotional and sensational the language, even if it talks about “the latest study,” the more likely you are reading only part of the whole picture. Remember that the structure of knowledge is a complicated structure built over time using many small pieces. The “latest” piece of the knowledge puzzle may be in error (see the next section) or will be rejected by most scholars as having flaws that make it less valuable as other research.

This simple “me” strategy is just the first step in learning more professional strategies for weighing evidence. In medicine and allied health there are formal methods for classifying the strength of scientific evidence called “evidence-based practice” to assist in diagnosis and treatment (Hadorn *et al.*, 1996; Sackett *et al.*, 1996). Authors have called the sports medicine and kinesiology professions to more consistently focus on using critical review of evidence to support practice (Faulkner *et al.*, 2006; Knudson, 2005; Shrier, 2006).

One formidable barrier to a kinesiology professional's ability to weigh biomechanical evidence is the technical and specialized terminology employed in most studies. Throughout this text many of these measurement systems and mechanical terms are covered. Appendix A provides an extensive glossary of biomechanical terms and quantitative measurement systems. Two papers that provide good summaries of biomechanical and exercise science terms are available (Knuttgen & Kraemer, 1987; Rogers & Cavanagh, 1984). Students re-

Application

On your next trip to a physician or other medical professional's waiting room, evaluate the nature of the articles and advertisements in the magazines and displays you encounter. Do advertisements related to claims in the articles appear near the article? Do the articles talk about several studies, their relative merits, as well as the percentage of subjects with various responses? Does the professional you are visiting sell supplements or products to patients? If so, what does this tell you about motivation and potential conflicts of interest between practice and profits? The biomechanics of most health and human performance problems in human movement are classic examples of complicated problems, with many interrelated factors and variability in the response of individuals to treatment.

viewing biomechanical studies should ask their instructor for assistance when the text or these sources do not clear up their understanding.

A Word About Right and Wrong Answers

The increasing amount and complexity of research and technology tends to give many people a false sense of the correctness of numbers. Few people will question a measurement if some machine output numbers on a printout, unless they are very familiar with the measurement. Like our knowledge-versus-information discussion, it is very important for kinesiology professionals to understand that the process of reviewing and weighing the evidence is often more important than finding the perfect or “right” answer. Such absolutes in a complicated world are quite rare, usually only occurring when a technique change would run against a law of physics or one of our principles of biomechanics. These principles (and laws) of mechanics are the application tools developed throughout this book.

So the good news is that biomechanics helps kinesiology professionals solve problems, while the bad news is that most of

these everyday questions/problems do not have easy, dichotomous (right/wrong) answers. There are many factors that affect most phenomena and there is variation in nearly all phenomena. In fact, all true science is written using statistics to account for this variation. Statistics use estimates of data variation to attach a probability to any yes/no decision about the data. If you read a study that says an observation was significant at the 0.05 level, this only means that the result is not likely a fluke or observation due to chance variation alone. It is possible that chance alone created this “difference,” and $p < 0.05$ means that in the long run there is about a 1-in-20 chance that the observation or decision about the data is wrong. Since most studies use this error standard ($p < 0.05$), this means that, out of twenty studies on a particular topic, one likely reports an incorrect observation from chance variation alone. A common misconception among laypersons is that statistics in a scientific study “proves” things. Statistics only provide tools that allow scientists to place probability values about yes/no decisions on the numbers observed in their research. Proof is a long-term process requiring critical review of the whole body of research on the issue. Remember this when television news broadcasts sensationalize the results of the “latest” study on some health issue or you are tempted to believe

Interdisciplinary Issue: Too Much Performance?

Recent controversies about sport performance enhancement through steroids and genetics parallel the issues related to biomechanics and improvements in equipment. Engineers and biomechanists have used advances in technology to improve the materials and design of sports equipment, although the use of tools in sport has a long history (Minetti, 2004). Jenkins (2004) presents a nice review of how improvements in equipment materials has dramatically affected performance in several sports. These are truly interdisciplinary controversies because there are ethical, safety, athlete, coaching, and sport/historical perspectives on performance. One example of technology correcting too much performance is the new rules for the javelin in the mid-1980s. The center of gravity of the the javelin was moved forward to decrease throwing distances because many athletes were throwing the old javelin over 100 m. Advances in biomechanics and computer technologies have also been used to modify technique, training, and equipment for the Olympics (Legwold, 1984; Sheppard, 2006).

that one biomechanical study settles a particular issue.

Biomechanical knowledge is constantly changing and usually cannot be easily classified into always right or wrong answers, so there are two important professional tools you must not forget to use. These tools will work quite well with the biomechanical tools (nine principles) developed in this text. These two tools are the Swiss Army Knives™ or Leathermen™ of your professional toolbox because of they are so flexible and important. One is your *ability to*

access biomechanical knowledge, and the other is the *critical thinking* necessary to evaluate and integrate knowledge so it can be applied in solving human movement problems. You are not likely going to remember everything in this book (though you would be wise to), but you should have the knowledge to access, and critical thinking tools that allow you to find, evaluate, and apply biomechanics to human movement. The rest of this text will illustrate and explicate the nine principles of biomechanics, which are tools you would do well to never forget when helping people improve their movement.

SUMMARY

Kinesiology is the scholarly study of human movement. A core science in the academic discipline of kinesiology is biomechanics. Biomechanics in kinesiology is the study of motion and its causes in human movement. The field of biomechanics is relatively new and only has a few principles and laws that can be used to inform professional practice. Kinesiology professionals often use biomechanical knowledge in the qualitative analysis of human movement to decide on how to intervene to improve movement and prevent or remediate injury. Applying biomechanics in qualitative analysis is most effective when a professional integrates biomechanical knowledge with professional experience and the other subdisciplines of kinesiology. Biomechanical knowledge is found in a wide variety of journals because there are many academic and professional areas interested in the movement of living things. Students studying human biomechanics might find relevant biomechanical knowledge in books and journals in applied physics, biology, engineering, ergonomics, medicine, physiology, and biomechanics.

REVIEW QUESTIONS

1. What is biomechanics and how is it different from the two common meanings of kinesiology?
2. Biomechanical knowledge is useful for solving what kinds of problems?
3. What are the advantages and disadvantages of a qualitative biomechanical analysis?
4. What are the advantages and disadvantages of a quantitative biomechanical analysis?
5. What kinds of journals publish biomechanics research?
6. What is the difference between knowledge and information?
7. Why should biomechanical knowledge be integrated with other sport and exercise sciences in solving human movement problems?

KEY TERMS

biomechanics
 electromyography (EMG)
 information
 interdisciplinary
 kinesiology
 knowledge
 orthotics
 prosthetics
 qualitative analysis
 quantitative analysis

SUGGESTED READING

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WEB LINKS

AAHPERD—American Alliance for Health, Physical Education, Recreation, and Dance is the first professional HPERD organization in the United States.

<http://www.aahperd.org/>

Biomechanics Academy—A biomechanics interest area within AAHPERD and NASPE (National Association for Sport and Physical Education).

<http://www.aahperd.org/naspe/template.cfm?template=specialinterests-biomechanics.html>

AAKPE—American Academy of Kinesiology and Physical Education is the premier, honorary scholarly society in kinesiology.

<http://www.aakpe.org/>

ACSM—American College of Sports Medicine is a leader in the clinical and scientific aspects of sports medicine and exercise. ACSM provides the leading professional certifications in sports medicine.

<http://acsm.org/>

ISB—International Society of Biomechanics was the first biomechanics scholarly society.

<http://www.isbweb.org/>

ASB—American Society of Biomechanics posts meeting abstracts from a variety of biomechanical scholars.

<http://www.asbweb.org/>

ISEA—International Sports Engineering Association hosts international meetings and publishes the journal *Sports Engineering*.

<http://www.sportsengineering.co.uk/>

ISBS—International Society of Biomechanics in Sports hosts annual conferences and indexes papers published in their proceedings and journal (*Sports Biomechanics*).

<http://www.isbs.org/>

ISEK—International Society of Electrophysiological Kinesiology is the scholarly society focusing on applied electromyography (EMG) and other electrophysiological phenomena.

<http://isek-online.org/>

ISI—The Institute for Scientific Information (Thompson Scientific) provides a variety of services, including rating scholarly journals and authors.

<http://www.isinet.com/isi/>

Medline—Free searching of this medical database provided by the National Library of Medicine.

<http://www.ncbi.nlm.nih.gov/entrez/query.fcgi/>

SIRC—The Sport Information Resource Center provides several database services for sport and kinesiology literature like *SportDiscus*. Many college libraries have subscriptions to *SportDiscus*.

<http://www.sirc.ca/>