CHAPTER 1: WHAT IS BIOMECHANICS?

CHAPTER OVERVIEW

The study of human movement, kinesiology, encompasses multiple subdisciplines. Biomechanics is the subdiscipline in which biological systems are studied from a mechanical perspective. Mechanics is often subdivided into kinematics and kinetics. Kinematics is descriptive in nature and explains both static and dynamic motion in terms of displacement, velocity, and acceleration. Kinetics explains the underlying forces that cause and/or result from both static and dynamic motion.

Chapter 1 gives an overview of the relevant questions being answered by today's biomechanist. A basic understanding of mechanical concepts is essential for the practitioner as well as the researcher. Successful physical educators, athletic trainers, physical and occupational therapists, coaches, personal trainers, and physicians apply biomechanical principles daily.

Analysis of human movement may be either quantitative or qualitative and both are important to the practitioner. The chapter presents an introduction to qualitative analysis and a systematic approach for solving formal quantitative problems.

TEACHING TIPS

Develop strategies to help students with math phobia. Determine what resources are available and encourage students early in the term to use the available services. Use cooperative practice during problem solving exercises. In a diverse group, it is important to use examples applicable to specific situations (sport, dance, rehabilitation, etc.) and/or examples applicable to activities common to everyone (walking, climbing stairs, etc.).

ASSESSMENT TECHNIQUE

Goal Ranking and Matching: Ask students to identify two or three learning goals they hope to achieve by participating in the class or lab. Then ask them to rank the goals according to their relative importance. After sharing their goals with the instructor, the students will learn what the instructor hopes to achieve so a comparison can be made. In an elective course, this exercise may help a student determine whether or not to stay. In a required course, the instructor may use this information to tailor the class to a specific population. For example, physical therapy students in a biomechanics class may have different needs and expectations than students preparing to coach. (Angelo, T.A. & Cross, P.K. (1993). *Classroom Assessment Techniques* (2nd ed.). San Francisco: Jossey-Bass.)

YouTube

The internet provides a massive source of content which can be used to supplement the course. Often, students will comprehend a concept much more quickly if they can see a demonstration. YouTube is an excellent source of videos related to many of the biomechanics concepts presented in the text. A couple of samples will be provided for each chapter. As the instructor, you can determine how to best use the videos. For example, you might find applicable videos and assign them for outside viewing or homework. The videos can also be shown during class, to complement the lecture or discussion. Alternatively, you can assign relevant concepts and challenge the students to find appropriate and accurate videos to share with the class. Like other content that is not peer-reviewed, the videos posted on YouTube may or may not be accurate. However, errors can also present "teaching moments".

Here are two concepts presented in Chapter 1.

Biomechanics
http://www.youtube.com/watch?v=x6y70_Hn9SY

Metric System
http://www.youtube.com/watch?v=DQPQ_q59xyw&feature=related

The links are provided as examples of videos which can be used to supplement the content of the course. The authors and publishers do not own or endorse the videos or guarantee the links will remain active. If these samples are not active, accurate or appropriate for your class, please find others that will work better for you.

LABS ON A BUDGET

The inclusion of several laboratory experiences is recommended for all undergraduate biomechanics classes. In the absence of expensive research equipment, there are still many items that can be used to help students experiment with the concepts. The authors and publishers do not own or endorse specific products. However, in select instances, specific vendor examples are provided. Equipment ideas will be presented in Chapters 5, 10 and 12.

There are many examples of biomechanics and/or physics labs online. Several use very low-cost equipment, but are still effective for helping students learn the concepts. Here is an example of a site that has some low-cost experiments, many relevant to the biomechanics concepts presented in the text. It also provides links to other lab sites.

http://www.physicsclassroom.com/lab/

Here is an example of one vendor for low-cost lab equipment.

http://www.arborsci.com/

SOLUTIONS TO SELECTED INTRODUCTORY PROBLEMS

8. Solve for x in each of the equations below. Refer to Appendix A for help if necessary.

a. $x = 5^3$
$x = 5 \text{ X } 5 \text{ X } 5 = 125$

b. $7 + 8 = x/3$
$(7 + 8)3 = (x/3)3$
$45 = x$

c. $4 \text{ X } 3^2 = x \text{ X } 8$
$(4 \text{ X } 9)/8 = (x \text{ X } 8)/8$
$4.5 = x$

d. $-15/3 = x + 1$
$-5 - 1 = x$
$-6 = x$

e. $x^2 = 27 + 35$
$x^2 = 62$
$\sqrt{x^2} = \sqrt{62}$
$x = 7.9$

f. $x = \sqrt{79}$
$x = 8.9$

g. $x + 3 = \sqrt{38}$
$x = 6.2 - 3$
$x = 3.2$

h. $7 \text{ X } 5 = -40 + x$
$35 + 40 = -40 + x + 40$
$75 = x$

i. $3^3 = x/2$
$(3 \text{ X } 3 \text{ X } 3)2 = (x/2)2$
$54 = x$

j. $15 - 28 = x \text{ X } 2$
$-13/2 = (x \text{ X } 2)/2$
$-6.5 = x$

9. Two schoolchildren race across a playground for a ball. Tim starts running at a distance of 15 meters from the ball, and Jan starts running at a distance of 12 meters from the ball. If Tim's average speed is 4.2 m/s and Jan's average speed is 4.0 m/s, which child will reach the ball first? Show how you arrived at your answer. (See Sample Problem 1.) (Answer: Jan reaches the ball first.)

time = distance/speed

t_{Tim} = 15m/4.2m/s t_{Jan} = 12m/4.0m/s

t_{Tim} = 3.6s t_{Tim} = 3.0s

3.6s > 3.0s so Jan reaches the ball first.

10. A 0.5 kg ball is kicked with a force of 40 Newtons. What is the resulting acceleration of the ball? (See Sample Problem 2.) (Answer: 80 m/s^2)

1 Newton = 1 kg m/s^2

Force = mass X acceleration F = ma

a = F/m

a = (40 kg m/s^2)/0.5 kg

a = 80 m/s^2

SOLUTIONS TO SELECTED ADDITIONAL PROBLEMS

3. Sarah goes to the grocery store and spends half of her money. On the way home, she stops for an ice cream cone that costs $0.78. Then, she stops and spends a quarter of the remaining money on a $5.50 bill at the dry cleaners. How much money did Sarah have originally? *($45.56)*

(x/2 - $0.78)/4 = $5.50

x = $45.56

4. Wendell invests \$10,000 in a stock portfolio made up of Petroleum Special at \$30 per share, Newshoe at \$12 per share, and Beans & Sprouts at \$2.50 per share. He places 60% of the money in P.S., 30% in N, and 10% in B&S. With market values changing (P.S. down \$3.12, N up 80%, and B&S up \$.20), what is his portfolio worth 6 months later? *(\$11,856)*

original investment: \$6,000 buys 200 shares of PS
\$3,000 buys 250 shares of N
\$1,000 buys 400 shares of B&S
6 months later:
portfolio value = (200)(\$30.00-\$3.12) + (250)(\$12.00+(0.8)(\$12.00))
+ (400)(\$2.50+\$0.20) = \$11,856

5. The hypotenuse of right triangle ABC (shown in text) is 4 cm long. What are the lengths of the other two sides? *(A = 2 cm, B = 3.5 cm)*

$A = (4\text{ cm})(\sin 30°) = 2\text{ cm}$

$B = (4\text{ cm})(\cos 30°) = 3.5\text{ cm}$

6. In triangle DEF, side E is 4 cm long and side F is 7 cm long. If the angle between sides E and F is 50°, how long is side D? *(5.4 cm)*

$D^2 = E^2 + F^2 - 2BC \cos 50°$

$D^2 = (4\text{ cm})^2 + (7\text{ cm})^2 - (2)(4\text{ cm})(7\text{ cm})\cos 50°$

$D = 5.4\text{ cm}$

7. An orienteer runs 300 m north and then 400 m to the southeast (at a 45° angle to north). If he has run at a constant speed, how far away is he from the starting position? *(283.4 m)*

$d^2 = (300\text{ m})^2 + (400\text{ m})^2 - (2)(300\text{ m})(400\text{ m})\cos 45°$

$d = 283.4\text{ m}$

8. John is out for his daily noontime run. He runs 2 km west, then 2 km south, and then runs on a path that takes him directly back to the place he started. a) How far did John run? b) If he has run at an average speed of 4 m/s, how long did the entire run take? *(a. 6.83 km, b. 28.5 minutes)*

a) Find the length of the hypotenuse of the triangle formed by the path that took him back to the starting place. The sum of all three sides of the triangle is the distance run.

$h^2 = (2\text{ km})^2 + (2\text{ km})^2$

$h = 2.83\text{ km}$

$d = 2.83\text{ km} + 2\text{ km} + 2\text{ km} = 6.83\text{ km}$

b) $t = 6{,}830\text{ m} / 4\text{ m/s}$

$t = 1707.5\text{ s} = 28.5\text{ min}$

9. John and Al are in a 15 km race. John averages 4.4 m/s during the first half of the race, and then runs at a speed of 4.2 m/s until the last 200 m, which he covers at 4.5 m/s. At what average speed must Al run in order to beat John? *(just over 4.3 m/s)*

Total time for John to complete the race:

$t = (7{,}500\text{ m} / 4.4\text{ m/s}) + (7{,}300\text{ m} / 4.2\text{ m/s}) + (200\text{ m} / 4.5\text{ m/s}) = 3487\text{ s}$

John's average speed:

$s = l / t = 15{,}000\text{ m} / 3487\text{ s}$

$s = 4.3\text{ m/s}$ Al must run at an average speed greater than 4.3 m/s to beat John.

10. A sailboat heads north at 3 m/s for 1 hour and then tacks back to the southeast (at 45° to north) at 2 m/s for 45 minutes. a) How far has the boat sailed? b) How far is it at this point from its starting location? *(a. 16.2 km, b. 8.0 km)*

a) $l = (3\text{ m/s})(3600\text{ s}) + (2\text{ m/s})(2700\text{ s})$

$l = 10.8\text{ km} + 5.4\text{ km}$

$l = 16.2\text{ km}$

b) $d^2 = (10.8\text{ km})^2 + (5.4\text{ km})^2 -(2)(10.8\text{ km})(5.4\text{ km})\cos 45°$

$d = 8.0\text{ km}$

CHAPTER 2: KINEMATIC CONCEPTS FOR ANALYZING HUMAN MOTION

CHAPTER OVERVIEW

Communicating specific information about human movement requires specialized terminology that identifies body positions and directions. The anatomical reference position is used as the starting place. The sagittal, frontal, and transverse planes, with their respectively associated mediolateral, anteroposterior, and longitudinal axes provide major frames of reference for the description of body movements. The three general categories of movement are linear motion along a straight or curved line, rotary motion around an axis, and general motion, which is a combination of linear and rotary motion. A body of terminology is presented that describes direction with respect to the human body and the actions that occur at joints. The Cartesian coordinate system is presented as a spatial reference system.

Physical educators, clinicians, and coaches all routinely perform qualitative analyses to assess, correct, or improve human movement. Visual observation is the most commonly used approach for qualitatively analyzing mechanics. To be effective, the analyst must have knowledge of the biomechanics of the movement and must carefully plan and conduct the analysis. This chapter introduces a systematic approach for planning and conducting qualitative analysis and also introduces various tools used for such investigations.

TEACHING TIPS

Physical practice of the various movements will help students learn and remember the terminology. Use movement examples from a variety of activities including those specific to the represented students and those common to all movers. A dancer can demonstrate a pirouette (transverse plane movement around the longitudinal axis), a gymnast can demonstrate a cartwheel (frontal plane movement around the anteroposterior axis), and a student in a wheel chair can demonstrate the action at the elbow during forward propulsion (sagittal plane movement around the mediolateral axis). Begin the practice of qualitative analysis by having students observe (either live demonstration or video demonstration) the more obvious mechanical problems in a movement. Practice analysis throughout the semester to increase familiarity with the techniques.

ASSESSMENT TECHNIQUE

Background Knowledge Probe: Students are asked to answer a few questions about a topic *before* the topic is presented in class. This "pre-test" information can be used to determine whether students have the required background to proceed with certain information. For example, it is helpful to know what background students have in anatomy before proceeding with biomechanics. The information may be used to determine a starting point for the class *or* to determine who needs to be referred for remedial work. (Angelo, T.A. & Cross, P.K. (1993). *Classroom Assessment Techniques* (2nd ed.). San Francisco: Jossey-Bass.)

YouTube

Here are two concepts presented in Chapter 2.

Planes of Motion
http://www.youtube.com/watch?v=fDjCkWKFwj0

Anatomical Directions
http://www.youtube.com/watch?v=CHKFFgxxw1M&feature=related

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CHAPTER 3: KINETIC CONCEPTS FOR ANALYZING HUMAN MOTION

CHAPTER OVERVIEW

The human body generates and resists forces during the course of daily activities. The study of these forces associated with motion is called kinetics. Although the kinematics of motion is what is "seen", kinetics is the underlying cause. A comprehension of kinetics is important to the understanding of both motion production and injury prevention. This chapter introduces basic kinetic concepts and related terminology including mass, inertia, force, weight, pressure, volume, density, torque and impulse.

The effect of a given force (muscle force, gravitational force, impact force) depends on its direction, distribution, duration, and magnitude. Compression, tension, shear, torsion, and bending are examples of various directional forces. Internal distribution of force, known as stress, also impacts the outcome of the application of force. The consequence of duration and magnitude of force can be observed in the aftermath of both repetitive and acute loading. When a force acts on a body, the result will either be acceleration or deformation. The body's response to deformation can either be elastic, if the load is small, or failure, if the load exceeds the elastic limit. In the human body, failure could mean bone fracture or soft tissue rupture. Tools used to study internal and external forces consist of electromyography and dynamography including force and pressure platforms.

Force is a vector quantity and can be represented graphically using an arrow, which has both magnitude and direction. Vector composition is useful for determining the resultant force when two or more forces act on a body. Vector resolution is important to the understanding of the two component forces inherent in a given force. For example, the force of a muscle pulling on a bone has a rotary component, which causes movement at the joint, and either a stabilizing or dislocating component, which pulls the bones together or pulls them apart respectively. Force is one of many vector quantities. For example, vector composition is applicable for determining the resultant of two or more velocities and vector resolution is used to analyze the vertical and horizontal components of projectile motion. A working knowledge of vector algebra will benefit the student in subsequent chapters.

SYMBOLS, UNITS, FORMULAS

Quantity	Symbol	Unit(s)	Formula(s)
Force	F	N	F = ma
Weight	wt	N	wt = ma_g
Pressure	p	Pa, N/m^2, N/cm^2	p = F/A
Volume	V	m^3, cm^3, l	l•w•h
Density	ρ (rho)	kg/m^3	ρ = m/V
Torque	T	N-m	T = $Fd_\perp$
Impulse		N•s	Impulse = Ft

TEACHING TIPS

Comprehension of the effects of the forces produced by the body and the external forces acting on the body is critical to an understanding of movement. Although force cannot be "seen", students can "experience" applications of force and torque using available classroom and laboratory equipment. For example, force composition can be demonstrated by having 2 or more students apply force to a large desk and observe the movement of the desk, the resultant. Vary the application point, direction, and magnitude of the force and observe the effect on the resultant. Simple demonstrations and experiences are important for the student who does not have a physics background and for the visual learner.

ACTIVE LEARNING STRATEGY

Jigsaw: Give students a reading assignment for homework. Ask each student to read the entire assignment and prepare to teach a section of the material (1/4 of the total assignment). When the students arrive for class, they will join an "expert" group (all students who prepared the same material) to compare notes. The instructor will visit each of the four "expert" groups to be sure certain key concepts are emphasized. Students will then join a "jigsaw" group, which will include one student from each of the expert groups. Each student will teach the material to the other 3 students and then listen to the other peer presentations of the rest of the material. *Helpful hint*: Tell students they will not be allowed to use the textbook while they teach. This will help ensure that each student has read the material in advance and has taken notes (Aronson, Blaney, Stephan, Sikes, & Snapp as cited in Johnson, D.W., Johnson, R.T., & Smith, K.A. (1991). *Active Learning: Cooperation in the College Classroom*. Edina, MN: Interaction Book Co.)

YouTube

Here are two concepts presented in Chapter 3.

Weight vs. Mass	http://www.youtube.com/watch?v=gjfLI7aJKmQ
Vectors	http://www.youtube.com/watch?v=xJBGfPfE4fQ

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SOLUTIONS TO SELECTED INTRODUCTORY PROBLEMS

1. William Perry, defensive tackle and part-time running back better known as *The Refrigerator*, weighed in at 1352 N during his 1985 rookie season with the Chicago Bears. What was Perry's mass?

$Wt = ma_g$ $\quad$ $1N = 1kg•m/s^2$

$1352\ N = m(9.81 m/s^2)$

$m = 138\ kg$

2. How much force must be applied to a 0.5 Kg ice hockey puck to give it an acceleration of 30 m/s^2?

$F = ma_g$ $\quad$ $1N = 1kg•m/s^2$

$F = 0.5\ kg\ (30\ m/s^2)$ $\quad$ $F = 15\ N$

6. A gymnastics floor mat weighing 220 N has dimensions of 3 m X 4 m X 0.04 m. How much pressure is exerted by the mat against the floor?

Area = Length X Width

A = 3 m X 4 m

$A = 12\ m^2$

$p = F/A$ $\quad$ $1Pa = 1N/\ m^2$

$p = 220\ N/12\ m^2$

$p = 18.3\ Pa$

7. What is the volume of a milk crate with sides of 25 cm, 40 cm, and 30 cm?

Volume = Length X Width X Height $\quad$ $1l = 1000\ cm^3$

V = 25 cm X 40 cm X 30 cm

$V = 30{,}000\ cm^3$ $\quad$ or $\quad$ 30 l

9. If the contents of the crate described in Problem 7 weigh 120 N, what are the average density and specific weight of the box and contents?

$m = wt/a_g$

$m = 120 \text{ N}/9.81 \text{ m/s}^2$

$m = 12.2 \text{ kg}$

$\rho = m/V$

$\rho = 12.2 \text{ kg}/30{,}000 \text{ cm}^3$

$\rho = 0.0004 \text{ kg/cm}^3$

$\gamma = wt/V$

$\gamma = 120 \text{ N}/30{,}000 \text{ cm}^3$

$\gamma = 0.004 \text{ N/cm}^3$

10. Two children sit on opposite sides of a playground seesaw. Joey, who weighs 220 N, sits 1.5 m from the axis of the seesaw, and Suzy, who weighs 200 N, sits 1.7 m from the axis of the seesaw. How much torque is created at the axis by each child? In which direction will the seesaw tip?

$T = Fd_\perp$

$T_j = 220 \text{ N}(1.5 \text{ m})$

$T_j = 330 \text{ Nm}$

$T_s = 200 \text{ N}(1.7 \text{ m})$

$T_s = 340 \text{ Nm}$

$T_s > T_j$

Seesaw tips toward Suzy

SOLUTIONS TO SELECTED ADDITIONAL PROBLEMS

2. Gravitational force on planet X is 40% of that found on the earth. If a person weighs 667.5 N on earth, what is the person's weight on planet X? What is the person's mass on the earth and on planet X? *(weight on planet X = 267 N; mass = 68 kg on either planet)*

If g_x = 40% g_{earth}, $weight_x$ is 40% of $weight_{earth}$.

$W_x = (0.4)W_{earth} = (0.4)667.5\ N = 267\ N$

weight = mass • gravity

$667.5\ N = m \bullet 9.81\ m/s^2$ or $667.5\ kg \bullet m / s^2 \bullet 9.81\ m/s^2$

m = 68.0 kg (mass will not change when gravity changes)

3. A football player is contacted by two tacklers simultaneously. Tackler A exerts a force of 400 N and tackler B exerts a force of 375 N. If the forces are coplanar and directed perpendicular to one another, what is the magnitude and direction of the resultant force acting on the player? *(548 N at an angle of 43° to the line of action of tackler A)*

The magnitude of the resultant force is calculated using the Pythagorean theorem:

$c^2 = a^2 + b^2$

$R^2 = (400\ N)^2 + (375\ N)^2$

R = 548 N

The direction of the resultant may be calculated using the tangent relationship:

$\tan \theta = B/A = 375\ N / 400\ N$ $\theta = 43°$

4. A 75 kg skydiver in free fall is subjected to a crosswind exerting a force of 60 N and to a vertical air resistance force of 100 N. Describe the resultant force acting on the skydiver. *(638.6 N at an angle of 5.4° to vertical)*

The vertical force acting on the skydiver is equal to his weight minus the air resistance force:

F_v = (75 kg)(9.81 m/s^2) - 100 N = 635.75 N (downward)

The Pythagorean theorem can then be used to find the magnitude of the resultant force:

$R^2 = (635.75\ N)^2 + (60\ N)^2 = 638.6\ N$

The tangent relationship can be used to find the direction of the resultant force:

$\tan\theta = 60 / 635.75$

$\theta = 5.4°$

5. Use a trigonometric solution to find the magnitude of the resultant of the following coplanar forces: 60 N at 90°, 80 N at 120°, and 100 N at 270°. *(49.57 N)*

First the two vertical forces are combined:

60 N - 100 N = -40 N (or 40 N at 270°)

Next, the law of cosines may be used to combine the -40 N force with the remaining force:

$R^2 = (40\ N)^2 + (80\ N)^2 - 2(40\ N)(80\ N)\cos 30°$

R = 49.57 N

6. If 37% of body weight is distributed above the superior surface of the L5 intervertebral disc and the area of the superior surface of the disc is 25 cm^2, how much pressure exerted on the disc is attributable to body weight for a 930 N man? *(13.8 N/cm^2)*

Weight of man's body above L5 disc = 0.37 X 930 N = 344 N

Pressure on disc = F/A = 344 N / 25 cm^2 = 13.8 N/cm^2

7. In the nucleus pulposus of an intervertebral disc, the compressive load is 1.5 times the externally applied load, while in the annulus fibrosus the compressive force is 0.5 times the external load. What are the compressive loads on the nucleus pulposus and annulus fibrosus of the L_5S_1 intervertebral disc of a 930 N man holding a 445 N weight bar across his shoulders, given that 37% of body weight is distributed above the disc? *(1183.7 N acts on the nucleus pulposus, 394.5 N acts on the annulus fibrosus)*

Body weight above disc: (930 N)(0.37) = 344.1 N

Total externally applied load: 344.1 N + 445 N = 789.1 N

Compressive load on the nucleus pulposus: (789.1 N)(1.5) = 1183.7 N

Compressive load on the annulus fibrosus: (789.1 N)(0.5) = 394.5 N

9. Given the mass or weight and the volume of each of the following objects, rank them in the order of their densities. *(B, D, E, A, C)*

Object	Weight or Mass	Volume	Ranking (1 = most dense)
A	50 kg	15 in^3	4
B	90 lb	12 cm^3	1
C	3 slugs	1.5 ft^3	5
D	450 N	0.14 m^3	2
E	45 kg	30 cm^3	3

10. Two muscles develop tension simultaneously on opposite sides of a joint. Muscle A, attaching 3 cm from the axis of rotation at the joint, exerts 250 N of force. Muscle B, attaching 2.5 cm from the joint axis, exerts 260 N of force. How much torque is created at the joint by each muscle? What is the net torque created at the joint? In which direction will motion at the joint occur? *(a. 7.5 N-m; b. 6.5 N-m; net torque equals 1 N-m in the direction of A)*

$T = Fd_{\perp}$

T_A = 250 N X 0.03 m = 7.5 N-m

T_B = 260 N X 0.025 m = 6.5 N-m

Net torque = T_A - T_B = 7.5 N-m - 6.5 N-m = 1.0 N-m in the direction of A

CHAPTER 4: THE BIOMECHANICS OF BONE GROWTH AND DEVELOPMENT

CHAPTER OVERVIEW

Bone is an important biological tissue, which supports and protects other body tissues and acts as a system of rigid levers that can be moved by forces from the attached muscles. The mechanical characteristics of bone are based on its material composition and organizational structure. Minerals contribute to bone's hardness and compressive strength, and collagen provides its flexibility and tensile strength. Cortical bone is stiffer and stronger than trabecular bone, whereas trabecular bone has greater shock absorbing capabilities than cortical bone.

Bones of the axial and appendicular skeletons are categorized according to their shape and function. Although bones grow in length only until the epiphyseal plates close, around the time of adolescence, bones continue to change in diameter throughout a person's lifespan. Bones hypertrophy in response to increased mechanical stress and atrophy in the absence of mechanical stress. Osteoporosis, a condition characterized by excessive loss of bone mineral mass and strength resulting in one or more fractures, is extremely common among the elderly. Although the cause of osteoporosis remains unknown, it is a lifestyle disease related to several risk factors. It has been documented that a program of regular, weight-bearing physical activity can improve bone health and strength.

TEACHING TIPS

Osteoporosis is the result of a lifetime of habits and evidence suggests that it is easier to prevent than to treat. The message of prevention is one of extreme importance to the skeletal wellness of future generations. The importance of lifelong physical activity should be emphasized in *every* kinesiology class and particularly in discussions where the benefits are further confirmed, as in the case of bone health. Have students interview older adults about personal bone health and activity level and share the results with the class.

ACTIVE LEARNING STRATEGY

Think-pair-share: Give students a thought-provoking question and then give them time to *think* about it. Have them write their responses. Then ask them to *pair* with a partner to compare answers and discuss alternatives. They can then *share* either with a larger group or with the class. This is an excellent tool to break up a lecture. It can be done very quickly, with little advance preparation. (Lyman, F. (1981) as cited in Millis, B.J. & Cottell, P. (1998). *Cooperative Learning for Higher Education Faculty*. American Council on Education Series in Higher Education. Phoenix, AZ: Oryx Press.)

YouTube

Here are two concepts presented in Chapter 4.

The Human Skeletal
http://www.youtube.com/watch?v=lsUWOwV9THc

Skeletal System Structure and Function
http://www.youtube.com/watch?v=TnY6l9hMOew

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SOLUTIONS TO SELECTED INTRODUCTORY PROBLEMS

2. In the human femur, bone tissue is strongest in resisting compressive force, approximately half as strong in resisting tensile force, and only about one-fifth as strong in resisting shear force. If a tensile force of 8000 N is sufficient to produce a fracture, how much compressive force will produce a fracture? How much shear force will produce a fracture?

Compressive = 1.0; Tensile = 0.5; Shear = 0.2

$8000\ N_{Tensile}$ (Compressive/Tensile) = Fracture $F_{Compressive}$

$8000\ N_{Tensile}$ (1.0/0.5) = Fracture $F_{Compressive}$

16000 N = Fracture $F_{Compressive}$

16000 N (0.2) = Fracture F_{Shear}

3200 N = Fracture F_{Shear}

8. Approximately 56% of body weight is supported by the fifth lumbar vertebrae. How much stress is present on the 22 cm^2 surface area of that vertebra in an erect 756 N man?

756 N (0.56) = 423.36 N

Stress = F/A

Stress = 423.36 N/22 cm^2

Stress = 19.2 N/cm^2

9. In Problem 8, how much total stress is present on the fifth lumbar vertebra if the individual holds a 222 N weight bar balanced across his shoulders?

423.35 N + 222 N = 645.36 N

Stress = F/A

Stress = 645.36/22 cm^2

Stress = 29.3 N/cm^2

SOLUTIONS TO SELECTED ADDITIONAL PROBLEMS

8. When an impact force is absorbed by the foot, the soft tissues at the joints act to lessen the amount of force transmitted upward through the skeletal system. If an impact force on the foot of 1875 N is reduced 15% by the tissues of the ankle joint and 45% by the tissues of the knee joint, how much force is transmitted to the femur? *(750 N)*

F_{impact} = 1875 N

$F_{transmitted}$ = 1875 N - (1875 N)(0.6) = 750 N

9. How much compression is exerted on the radius at the elbow joint when the biceps brachii, oriented at a 30° angle to the radius exerts a tensile force of 200 N? *(173 N)*

(200 N) cos 30° = 173 N

10. If the anterior and posterior deltoids both insert at an angle of 60° on the humerus and each muscle produces a force of 100 N, how much force is acting perpendicular to the humerus? *(173.2 N)*

(2)(100 N) sin 60° = 173.2 N

CHAPTER 5: THE BIOMECHANICS OF HUMAN SKELETAL ARTICULATIONS

CHAPTER OVERVIEW

The anatomical configurations of the joints of the human body govern the movement capabilities of the articulating body segments. From the perspective of movement permitted, there are three major categories of joints: 1) synarthroses (immovable joints), 2) amphiarthroses (slightly moveable joints), and 3) diarthroses or synovial (freely moveable joints). The number of axes around which movement occurs further categorizes synovial joints. From progressively least mobile and most stable to most mobile and least stable, the joints are 1) non-axial joints (gliding), 2) uniaxial joints (hinge and pivot), 3) biaxial joints (condyloid and saddle), and 4) triaxial joints (ball and socket).

Articular cartilage, which coats the bone ends in synovial joints, reduces stress by increasing surface area and reduces friction to enhance movement. Articular fibrocartilage (the intervertebral discs and menisci of the knee) may serve similar purposes. Tendons and ligaments are passive tissues comprised primarily of collagen and elastic fibers. These tissues, like muscle and bone, appear to respond favorably to regular exercise by increasing in size and strength.

Joint stability or the ability to resist displacement, is influenced by the size and shape of the articulating bone surfaces and the arrangement and strength of the surrounding muscles, tendons, ligaments, and fascia. Joint range of motion is primarily a function of the relative laxity and/or extensibility of the collagenous tissues and muscles crossing the joint (flexibility). If the muscles and ligaments are not stretched, their extensibility usually diminishes. Various approaches for increasing flexibility are presented in the chapter culminating with a discussion of proprioceptive neuromuscular facilitation. PNF is an effective method, which requires a training partner and involves alternating passive static stretches and muscle contractions against resistance.

TEACHING TIPS

When discussing the various categories of joints (amphiarthrosis vs. synovial, uniaxial vs. triaxial), have students move individual joints through their full ROM and compare the varying degrees of movement. For example, a comparison of the motion possible at the shoulder with that at the elbow quickly demonstrates the relationship between ROM and number of axes. In the same discussion, point out the increased stability of the joints with lower ROM (i.e. there is a much greater likelihood of dislocating the shoulder than the elbow). A PNF demonstration is important not only for a better understanding of the technique but also for increased emphasis on the safety issues. This is a great demonstration because after only a few seconds of resisted contraction, increased ROM is almost always visible.

ACTIVE LEARNING STRATEGY

No-fail quiz: The quiz should begin as a traditional quiz, i.e. the students should not know it is a "no-fail" quiz. Monitor the students to determine when they get "stuck" and cannot recall more information. At this point, throw the students the first lifeline, which is "ask a partner for help". After they have worked with a partner for a few minutes, throw the second lifeline, "look in your notes". After a few minutes of using their notes, throw the final lifeline to clear up any material. The final lifeline is "ask the instructor for help". (Smith, D., & McCabe, D. (2001). Active learning and assessment techniques for use in the biomechanics classroom. In J. Blackwell & D. Knudson (Eds.), *Proceedings of the Fifth National Symposium on Teaching Biomechanics in Sports*. University of San Francisco: Exercise & Sport Science Department.)

YouTube

Here are two concepts presented in Chapter 5.

Types of Joints
    http://www.youtube.com/watch?v=SOMFX_83sqk&feature=related

Tendons and Ligaments of the Knee
    http://www.youtube.com/watch?v=0YZeQxAftvg

The links are provided as examples of videos which can be used to supplement the content of the course. The authors and publishers do not own or endorse the videos or guarantee the links will remain active. If these samples are not active, accurate or appropriate for your class, please find others that will work better for you.

LABS ON A BUDGET

The inclusion of several laboratory experiences is recommended for all undergraduate biomechanics classes. In the absence of expensive research equipment, there are still many items that can be used to help students experiment with the concepts. The authors and publishers do not own or endorse specific products.

Suggested lab items for laboratories related to anatomical concepts (Chapters 5, 6, 7, 8, 9)

Under $100

Skeletons – there are a variety of skeletal models available for under $100 including some full skeletons. Partial models, such as the vertebral column, are also quite useful.

Musculoskeletal models – some muscle models can also be found for under $100, such as the knee or shoulder complex.