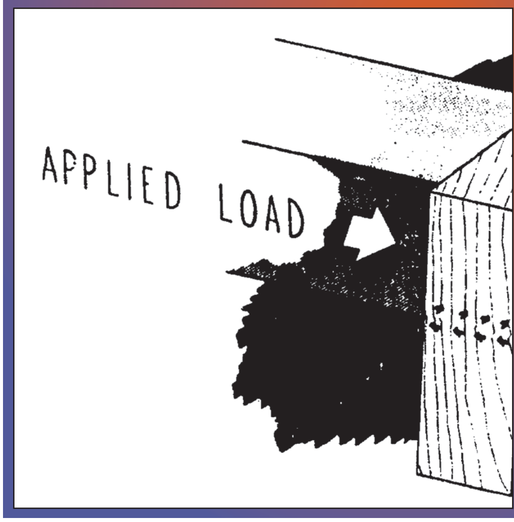
Understanding Biomechanical Forces



Here's a refresher on the basics of this science.

BY J. DAVID SKLIAR, DPM

Goals and Objectives

1) To familiarize podiatrists with a basic review and/or introduction to biomechanical forces.

2) To be able to associate biomechanical effects on patients and their mechanical problems.

3) To be able to treat biomechanical problems mechanically and surgically in accord with established mechanical principles.

4) To have an understanding of biomechanical forces that influence the use of surgical implants and to be able to minimize destructive forces during and after surgical procedures.

Welcome to Podiatry Management's CME Instructional program. Our journal has been approved as a sponsor of Continuing Medical Education by the Council on Podiatric Medical Education.

You may enroll: 1) on a per issue basis (at $23.00 per topic) or 2) per year, for the special rate of $179 (you save $51). You may submit the answer sheet, along with the other information requested, via mail, fax, or phone. You can also take this and other exams on the Internet at www.podiatrym.com/cme.

If you correctly answer seventy (70%) of the questions correctly, you will receive a certificate attesting to your earned credits. You will also receive a record of any incorrectly answered questions. If you score less than 70%, you can retake the test at no additional cost. A list of states currently honoring CPME approved credits is listed on pg. 180. Other than those entities currently accepting CPME-approved credit, Podiatry Management cannot guarantee that these CME credits will be acceptable by any state licensing agency, hospital, managed care organization or other entity. PM will, however, use its best efforts to ensure the widest acceptance of this program possible.

This instructional CME program is designed to supplement, NOT replace, existing CME seminars.** The goal of this program is to advance the knowledge of practicing podiatrists. We will endeavor to publish high quality manuscripts by noted authors and researchers. If you have any questions or comments about this program, you can write or call us at: **Podiatry Management, P.O. Box 490, East Islip, NY 11730, (631) 563-1604 or e-mail us at bblock@podiatrym.com.

*Following this article, an answer sheet and full set of instructions are provided (pg. 180).—**Editor***

A force is defined as that which can cause acceleration of matter, or the resistance of matter to acceleration. If a force causes no visible acceleration, it must be because an equal but opposite force exists which cancels the first one. In biomechanics, we differentiate two categories of forces. Those that come from outside a structure are called loads. Those that are generated within a structure are called stresses (Figure 1).

Loads

A load is any force applied to the outside of a structure, and thus sustained by the structure. The body's weight on the foot bones and the reactive force of the ground pushing up

Continued on page 174

Biomechanical (from page 173)

on the foot structures are examples of loads. The pull of a muscle on a bone is a load on the bone. However, it is equally valid to consider the bone's resistance to the muscle as a load on the muscle.

Specification of Stresses and Loads

There are two ways in which forces can be expressed.

The forces generated in a substance in response to the load applied to it are known as stresses.

1) Total Force: The total weight of forces regardless of the area, such as body weight. This is employed in determining joint reactive forces.

2) Unit Force: This is the force per unit area, such as pounds per square inch. This specification is most significant in dealing with biomechanical forces (Figure 2).

Stress

In accordance with Newton's third law, when a force is exerted, it causes an equal and opposite force on the substance acted upon. The forces generated in a substance in response to the load applied to it are known as stresses. It is the resistance of the intermolecular bonds in a substance to deformation by external loads. Note, we are talking about mechanical stress, which is unrelated to physiological stress (Figure 3).

1) Tension Stress: A force in matter which resists its being pulled apart or stretched. When a muscle contracts, its tendon develops tension stress at its bony insertion.

2) Compression Stress: A force in matter which resists its being pushed together. It is also referred to as pressure. Body weight on the foot bones produces compression stress.

3) Shear Stress: A force in matter which resists its being torn (scissored) apart. The resistance of a substance to motion (friction) is a shear stress. Friction makes the underlying surface a point of firm application. Without it, there would be no locomotion.

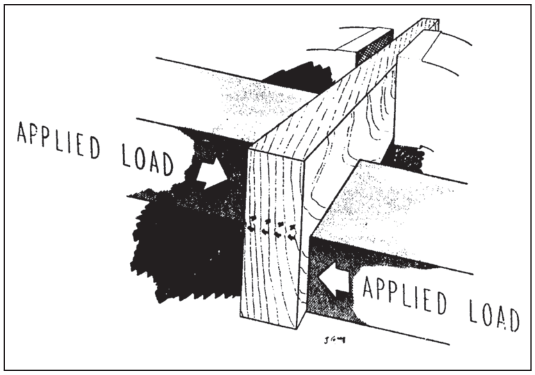


Figure 1: The force applied to the bars is the load. The force resisting the shearing force is the stress.

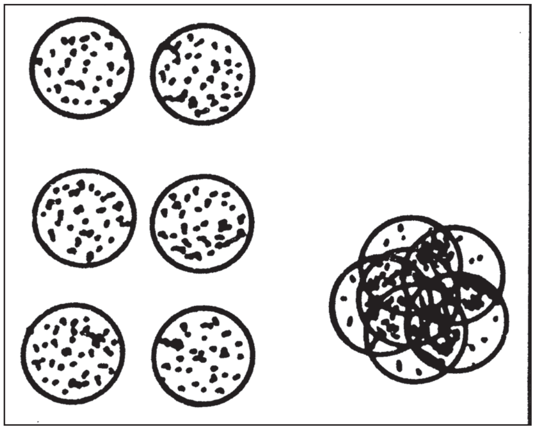


Figure 2: Total loads are the same in both halves, but unit loads are greater on the right side.

Strain

Strain is the deformation of an object when a load is applied to it. All deformations are a combination of the three principal strains, analo-

Continued on page 175

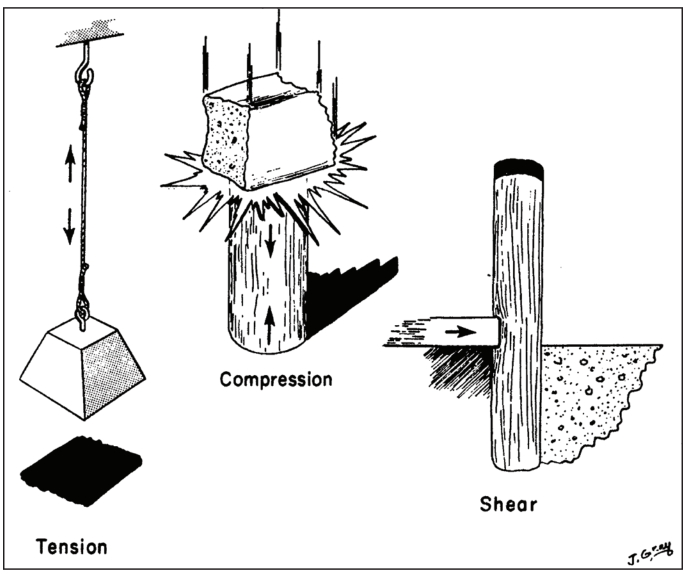


Figure 3: The three principal stresses.

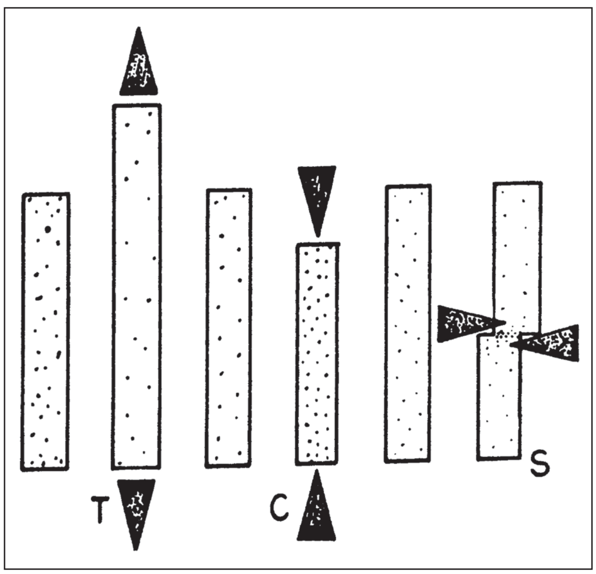


Figure 4: The three principal strains.

Biomechanical (from page 174)

gous to the stresses.

1) Tension Strain: Elongation of an object to which tension stress is applied (Figure 4).

2) Compression Strain: Shortening or squashing of an object to which compression stress is applied.

3) Shear Strain: Displacement or delamination of an object to which a shear stress is applied.

used in orthotics), but it is considered 100% elasticity even though it lacks resilience. Such materials are termed viscoelastic (Figure 5). They are characterized by a partial instantaneous deformity with the application of a load followed by a time-related continued deformation.

Upon removal of the load, the process is reversed with a partial instantaneous rebound followed by a time-related return to the original shape. The instantaneous deforma-

When material is loaded, the strain will be proportional to the stress for a while. Eventually, the strain begins to increase faster than the stress.

when the force is removed. In pathology, its ability to stretch is increased (lowered elastic modulus), and its elastic limit is reduced, resulting in permanent deformation, e.g., osteomalacia.

Young's Modulus (Elastic Modulus)

This is a measure of the stiffness, or rigidity, of a material. It is mathematically arrived at by dividing the stress by the resulting strain (deformation). The larger the modulus, the stiffer the material. Note that strength (toughness, the resistance to fracture) and stiffness are not the same. For example, wet bone has an elastic modulus of 2 x 106 psi and an ultimate tensile strength of 12,000 psi. Glass has an elastic modulus of 10 x 106 (5 times the resistance to de-

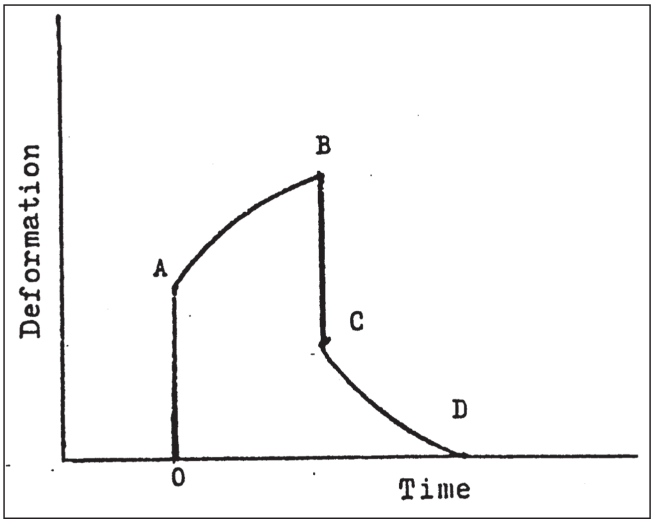


Figure 5: Viscoelastic Stress-Strain Relations
OA: Instantaneous deformation
AB: Time-related deformation
BC: Instantaneous return
CD: Time-related return

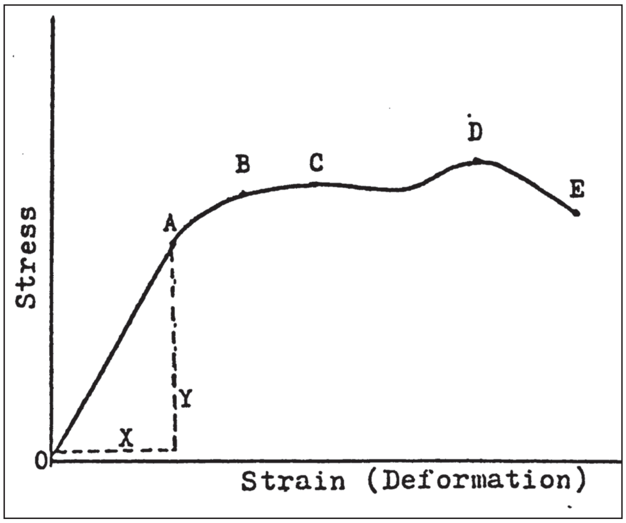


Figure 6: Solids Stress-Strain Relationship
A: Proportional limit. OA: Proportional range. B: Elastic limit.
0B: Elastic range. C: Yield point. D: Ultimate strength. E. Rupture point.
CE: Plastic range. YIX: Slope for Young's modulus.

Stress-Strain Relationship

1) Solids: a) Elasticity: All materials have some elastic properties. It is the ability to return to its original size and shape after having been deformed, following removal of the load. If the return to the original state is instantaneous, the material is said to be resilient, (e.g., a new tennis ball or a billiard ball). In some materials, the return to the original state may be time-delayed (e.g., some plastic polyethylenes tion can be likened to the action of a spring, and materials which do so are known as Hookian Bodies. The gradual deformation can be likened to a dash pot. In mechanics, such materials are known as Newtonian bodies. Thus, any biologic material that displays both Newtonian and Hookian properties is termed viscoelastic.

Tissues other than bone (soft tissues) possess viscoelasticity. Bone, although slightly elastic, does not always return to its original form formation, or stiffness, as bone) and an ultimate tensile strength of only 5,000 psi (about 2.5 times weaker than bone).

Some materials have the same moduli in compression and tension. These are homogeneous solids like plastics and metals. Biological structural materials like bone, cartilage, and tendon, have a "grain" and thus have different moduli in different directions.

Continued on page 176

Biomechanical (from page 175)

Proportional Limit

When material is loaded, the strain will be proportional to the stress for a while. Eventually, the strain begins to increase faster than the stress. That is the point known as the proportional limit. The proportional range (from start to proportional limit) is the area of the stress-strain curve from which Young's modulus is determined (Figure 6).

Elastic Limit

This is the ultimate point to which a material can be deformed and still return to original shape with removal of the load.

Yield Point

This is the point on a stress-strain curve from which progressive deformation occurs without increasing the load on the part. This is the start of the plastic range. Some materials (like plastics) will have large plastic ranges, i.e., ductility, and may not even reach a fracture point. Materials that have a yield point take impact well and are said to be tough. Materials that lack a yield point take impact poorly and are called brittle.

Ultimate Strength

This is the maximum stress a material will sustain. With brittle materials, this is usually at or near the yield point. With ductile materials the ultimate strength may be substantially higher than the rupture point. It is any additional load necessary to further deform a substance after its yield point.

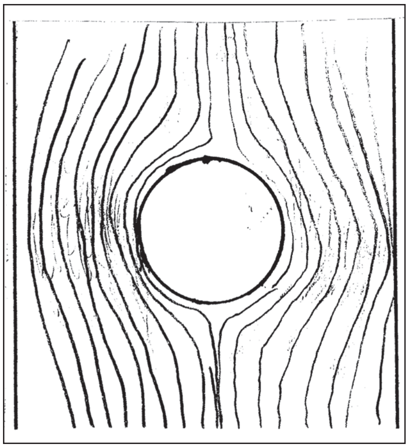


Figure 7: Stress gradient caused by a defect in the structure.

Rupture Strength

Following a material's yield point, it continues to deform so that less external load is necessary to produce additional strain. Elongation will continue until the material ultimately breaks. Materials may differ in their rupture strength according to the type of stress applied.

The rupture strength of typical wet bone is 12,000 psi in tensile strength, 15,000 psi in compressive strength, and 8,000 psi in shear strength. This difference can be correlated to the site of fracture of a bone.

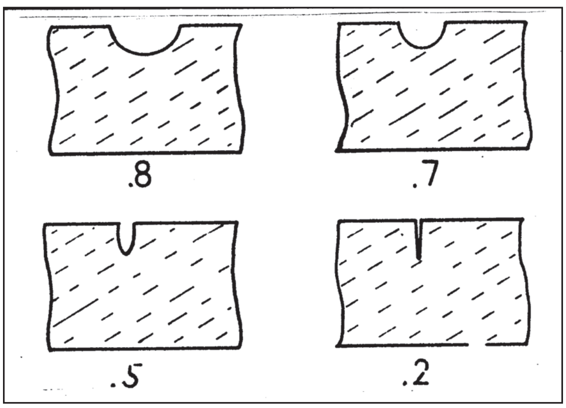


Figure 8: The number below each surface notch is the fraction of the original strength of the material that is left. The sharper the curve, the more the structure is weakened. This is the notch effect. A notch is a stress riser that locally concentrates stresses above the surrounding average value.

Fluids

Viscosity

This is a measure of resistance of fluid to flow. Flow is a form of shearing strain. Low viscosity fluids flow quickly. High viscosity fluids are better lubricants for joints to protect them from wear and seizure.

Stress Gradient

When a tension load is applied to an object, the lines of stress are in an opposite direction and all stress lines are parallel to each other. If a hole is placed in the object, the stress lines will branch out around the hole causing the lines to become concentrated in that area. This concentration of stress lines is known as the stress gradient (Figure 7). If the hole is less than 20% of the diameter, it will have minimal effect on the structural strength of the part. Holes greater than 20% of the diameter of a bone will lead to bone failure.

If a bone is to be drilled for screws or a plate, multiple holes should be kept twice the diameter of the hole from each other. If this is not possible, it is best to stagger the holes. The purpose of a pin or screw in a bone hole is not to keep the parts together, but rather to remove the stress from the fracture site.

Fatigue damage takes time to develop. Early stages are almost impossible to detect.

Stress Risers

Surface scratches, even microscopic ones, sharp angles, and grooves weaken structures and are called stress risers. They cause an increase in stress concentrations that start and cause the propagation of surface cracks (Figure 8). The ability of a scratch or groove to cause a local increase in surface stress is called the notch effect. The sharper the curve at the root of the defect, the more the structure is weakened. Rounding the edges of holes drilled in bone for screws reduces some of the notch effect.

Factors Influencing Bone Failures

Bone Diameter

As the cross-sectional area of a

Continued on page 177

Biomechanical *(from page 176)*

bone decreases, stresses increase.

Sex

There is no apparent difference in the behavior and properties of human bone on the basis of sex. There are differences, however, in males and females in the frequency of types of bone injuries.

Age

Because of the frequency of tibial injury in the sport of skiing, that bone has been intently studied. It was found that the strength properties of the tibia in individuals over the age of 70 were approximately half those at age 20. In those under 17 years of age, strength limits of bones were also about half those of adults. This is attributed to the smaller cross-section of the tibia in children. Between 20 and 60 years, the strength properties of the tibia remain constant.

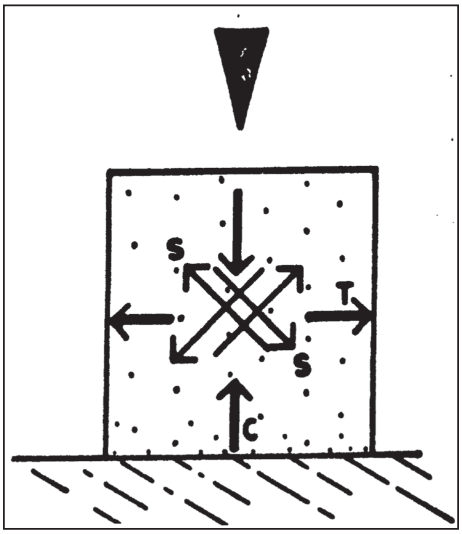


Figure 9: Stresses and strains loaded vertically in uniaxial compression. C: compression. T: tension. S: shear.

Fatigue

Breakage caused by repeated loading and unloading within the normal elastic limits of a substance is called fatigue. All solids are susceptible to fatigue failure. Much of the breakage of plates, pins, screws, plastic arteries, sutures, etc., or any device implanted in the body is due to fatigue failures. Unlike inorganic implants, living structures rarely fail in fatigue. This is because they are self-repairing, not because they have an inherent resistance to fatigue. Fatigue failures of bone are usually secondary to something that impairs the repair system.

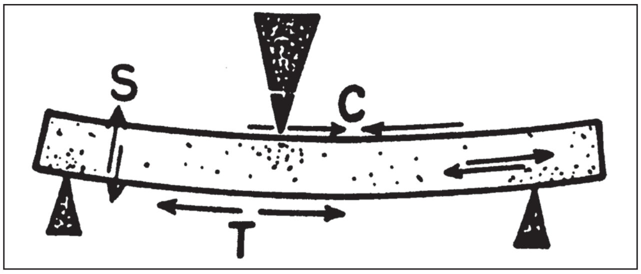


Figure 10: A beam loaded in static bending. C: compression. T: tension. S: shear.

Bending generates unequal stresses in material, the greatest stresses occurring at surfaces, and the least at some region inside the structure.

Fatigue damage takes time to develop. Early stages are almost impossible to detect. Factors that increase the possibility of bone fatigue are the condition of the surface (scratches), changes in surface contour (functional adaptation of bone), and stress risers.

External Loads

In a study of the influence of force on the body in skiing, it was determined that the acceleration at the leg increased geometrically with increase in ski velocity, whereas the acceleration at the hip and head only increased linearly. Moreover, the accelerations at the tibia are about seven times larger in skiing than in running.

Static Forces

These involve stresses and strains in structures in which external loads are balanced so that the structure stays still.

Uniaxial Loads

If a load is centered exactly over a structure, thus acting in line with the axis of the structure, it is known as a uniaxial load. Stresses would be generated perfectly evenly throughout the material in the structure (Figure 9).

Compression Stress and Strain: These forces develop greatest when parallel to the line of action of the load.

Tension Stress and strain: They develop greatest at right angles to the load direction, and at equal magnitude to the compression stress.

Shear Stress and strain: These develop along a line of action that is 45 degrees to the lines of greatest compression and tension. The shear stress is half the magnitude of the compression or tension stress.

The above forces are true for structurally homogeneous materials. Biological substances—bone, tendon,

Continued on page 178

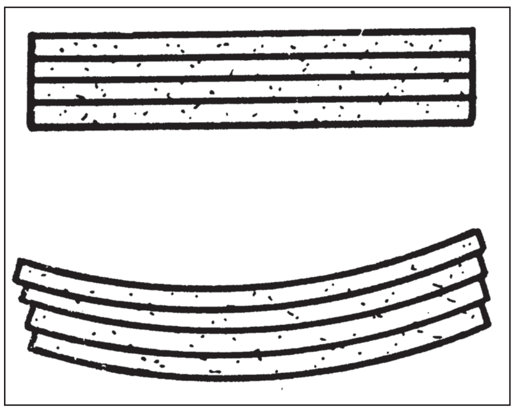


Figure 11: Horizontal shearing stress in a structure loaded in bending can be shown by bending a stack of boards. Top: no load. Bottom: Loaded in static bending. Note that if this were a solid structure like bone, the various layers would try to slide on each other. The resistance to sliding would develop a horizontal shearing stress.

Biomechanical (from page 177)

and cartilage—are grained materials and as such respond variably, dependent upon the type of stress considered. Bone, for example, has greater resistance to compression than to distention.

Eccentric Loads

Uniaxial loads, although ideal, are rarely encountered in the body. Usually, there is some eccentricity to the line of action of the load with respect to the line of resistance by the structure. As a result, bending forces occur which have to be added to those due to the compression.

Bending

Bending generates unequal stresses in material, the greatest stresses occurring at surfaces, and the least at some region inside the structure. Tension stress and strain develop on the convex surface. Compression stress and strain develop on the concave and horizontal plane. The vertical forces are equal throughout the surface; the horizontal forces of shear are greatest at the central part (neutral plane) of the structure, and least at the outer surfaces (Figure 10).

The horizontal shearing stress and strain may be visualized by bending a stack of boards. When a beam made in this way is bent, the boards at the end displace (Figure 11). In solid beams and bones, this slippage cannot occur, but tries to, and the resistance to this strain is the horizontal shearing stress.

Failure (fracture) occurs primarily on the convex surface. Long bones are essentially tubular in structure. A tube in proportion to the amount of material composing it resists bending, better than does a solid rod of the same kind and amount of material.

Torque (torsion)

Torque is a twist or rotation-like bending. It results in unequal stresses in material. It is produced by two couples of forces acting in parallel planes at right angles to the axis, and working in opposite directions. Tension and compression are zero when the forces are parallel, opposite, and at right angles to the bone. Tension and compression stresses are maximal when the two forces are parallel with the long axis of the bone. This is very significant in functional adaptation of bone, and explains why devices such as a Denis-Browne Bar are ineffectual in correcting a femoral or tibial torsion.

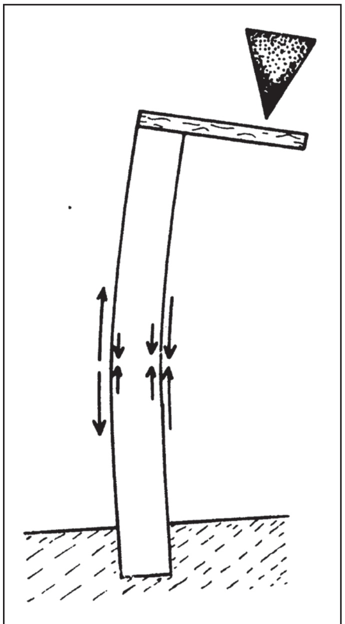


Figure 12: Cantilever bending and the distribution of compression (converging arrows) and tension (diverging arrows) stress produced.

Cantilever Bending

This is a situation wherein a bending force is put on an erect beam. There is a uniaxial compression load on the beam equal to the load, causing a similar compression stress, distributed evenly (as shown by the arrows inside the beam). There is also a bending force creating tension stress on the external side (convex), subtracting from the compression there (Figure 12).

The forces on the tibia in skiing are an example of cantilever bending. The forward bending resistance of the tibia is about three times the twisting resistance. The forward bending elastic threshold and plastic limit are directly proportional to the cross section of the tibia shaft. The backward bending fracture limit is 15% less and the elastic threshold 10% less than in forward bending. This is probably related to the fact that the anterior aspect of the tibia is narrower than the posterior surface, and also there is a slight forward bend normally in the tibia.

In real structures, loading conditions are usually combinations of the three primary types of loads.

Combined Loads

In real structures, loading conditions are usually combinations of the three primary types of loads. Bending and torque both produce maximal stresses at surface fibers. In fact, much larger surface stresses are produced by combined bending and torque than any other combination of two loads.

This is usually the result of athletic injuries, especially skiing. Ultimate strengths and elasticity of bone are decreased about 12-15 % when there is combined bending and twisting. **PM**

References

Frost, H.M., An Introduction To Biomechanics, Charles Thomas, Springfield, 1967

Biomechanical Studies of the Musculo-Sketal System,Ed. F. Gaynor Evans, Charles Thomas, Springfield, 1961

Dr. Skliar was Associate Professor in Biomechanics at N.Y. College of Podiatry and Barry University. He is the author of the textbook "Biomechanics and Podiatric Orthopedics" and is past president of the American College of Foot Orthopedists.

SEE ANSWER SHEET ON PAGE 181.

1) Body weight on the foot bones is considered to be a:
A) Load
B) Stress
C) Strain
D) none of the above

2) Forces generated in a substance without deforming it are termed:
A) loads
B) stresses
C) strains
D) unit forces

3) Friction is equated with:
A) Tension stress
B) Shear stress
C) Compression stress
D) Compression strain

4) Delamination of an object is the result of:
A) Tension stress
B) Compression strain
C) Shear strain
D) Shear stress

5) Perfect elasticity is exhibited if, after removal of the load, the object returns to its original shape:
A) instantaneously
B) in a delayed manner
C) viscoelastically
D) all of the above.

6) Elastic Modulus refers to a material's:
A) Stiffness
B) Toughness
C) Elastic limit
D) Rupture strength

7) Young's modulus is determined on a stress-strain relation from zero stress to its:
A) proportional limit
B) elastic limit
C) yield point
D) rupture point

8) The larger the modulus of elasticity:
A) the stiffer the material
B) the greater its tensile strength
C) the higher is its rupture point
D) none of the above

9) Rupture strength of a biological material is:
A) weakest in tensile stress
B) intermediate in shear stress
C) greatest in compressive stress
D) not related to type of applied stress

10) A hole placed into a bone will not effectively lead to bone failure if the hole is no more than __% of the diameter of the bone.
A) 75%
B) 50%
C) 40%
D) 20%

11) All are correct except:
A) Viscosity is a measure of resistance of fluid to flow.
B) Flow is a form of tension stress.
C) Low viscosity fluids flow quickly.
D) High viscosity fluids are better lubricants.

12) The purpose of a pin or screw in bone is to:
A) Keep the parts together
B) Reduce stress at the fracture site
C) Stimulate new bone growth
D) none of the above

13) Stress risers in biologic materials can be caused by:
A) Surface scratches
B) sharp angles
C) grooves
D) all of the above

14) Stress gradients can be minimized when placing multiple screws into a bone:
A) by placing the screw holes a minimum of 1X the diameter of the hole from each other.
B) by placing the screw holes a minimum of 2X the diameter of the hole from each other.
C) and not staggering the holes.
D) None of the above.

15) Which factors usually cause increased bone fractures:
A) Large bone diameter.
B) Being an adult male.
C) Age under 17 years.
D) None of the above.

16) The rupture strength of typical wet bone is:
A) 2,000 psi in tensile strength
B) 4,000 psi in tensile strength
C) 12,000 psi in tensile strength
D) 24,000 psi in tensile strength

Continued on page 180

17) The rupture strength of typical wet bone is:
  A) 5,000 psi in compressive strength
  B) 15,000 psi in compressive strength
  C) 25,000 psi in compressive strength
  D) 35,000 psi in compressive strength

18) Regarding Torque (torsion), which of the following is correct?
  A) Tension and compression are zero when the forces are parallel, opposite, and at right angles to a bone.
  B) Tension and compression are maximized when the forces are parallel with the long axis of the bone.
  C) Because of torque effect on long bones, bars are ineffectual in correcting a femoral or tibial torsion.
  D) All of the above.

19) Cantilever bending results from a force placed on an erect beam at a distance from the beam:
  A) which causes only a tension stress on the beam.
  B) which causes only a compression stress on the beam.
  C) which causes a compression stress and a bending force causing tension stress on the external side.
  D) which makes the convex side more prone to fracture.

20) Regarding bone fracture:
  A) Most bone fractures are the result of the three primary types of loads.
  B) Bending and torque produce maximal stresses at surface fibers.
  C) Combined bending and torque are usually the result of athletic injuries, especially skiing.
  D) All of the above.

SEE ANSWER SHEET ON PAGE 181.

PM's CPME Program

Welcome to the innovative Continuing Education Program brought to you by *Podiatry Management Magazine*. Our journal has been approved as a sponsor of Continuing Medical Education by the Council on Podiatric Medical Education.

Now it's even easier and more convenient to enroll in PM's CE program!

You can now enroll at any time during the year and submit eligible exams at any time during your enrollment period.

PM enrollees are entitled to submit ten exams published during their consecutive, twelve–month enrollment period. Your enrollment period begins with the month payment is received. For example, if your payment is received on September 1, 2006, your enrollment is valid through August 31, 2007.

If you're not enrolled, you may also submit any exam(s) published in PM magazine within the past twelve months. **CME articles and examination questions from past issues of *Podiatry Management* can be found on the Internet at http://www.podiatrym.com/cme.** Each lesson is approved for 1.5 hours continuing education contact hours. Please read the testing, grading and payment instructions to decide which method of participation is best for you.

Please call (631) 563-1604 if you have any questions. A personal operator will be happy to assist you.

Each of the 10 lessons will count as 1.5 credits; thus a maximum of 15 CME credits may be earned during any 12-month period. You may select any 10 in a 24-month period.

The Podiatry Management Magazine CME program is approved by the Council on Podiatric Education in all states where credits in instructional media are accepted. This article is approved for 1.5 Continuing Education Contact Hours (or 0.15 CEU's) for each examination successfully completed.

Home Study CME credits now accepted in Pennsylvania

Enrollment/Testing Information and Answer Sheet

Note: If you are mailing your answer sheet, you must complete all info. on the front and back of this page and mail with your credit card information to: ***Podiatry Management*, P.O. Box 490, East Islip, NY 11730.**

TESTING, GRADING AND PAYMENT INSTRUCTIONS

(1) Each participant achieving a passing grade of 70% or higher on any examination will receive an official computer form stating the number of CE credits earned. This form should be safeguarded and may be used as documentation of credits earned.

(2) Participants receiving a failing grade on any exam will be notified and permitted to take one re-examination at no extra cost.

(3) All answers should be recorded on the answer form below. For each question, decide which choice is the best answer, and circle the letter representing your choice.

(4) Complete all other information on the front and back of this page.

(5) Choose one out of the 3 options for testgrading: mail-in, fax, or phone. To select the type of service that best suits your needs, please read the following section, "Test Grading Options".

TEST GRADING OPTIONS

Mail-In Grading

To receive your CME certificate, complete all information and mail with your credit card information to:

Podiatry Management
P.O. Box 490, East Islip, NY 11730

PLEASE DO NOT SEND WITH SIGNATURE REQUIRED, AS THESE WILL NOT BE ACCEPTED.

There is **no charge** for the mail-in service if you have already enrolled in the annual exam CPME program, and we receive this exam during your current enrollment period. If you are not enrolled, please send $23.00 per exam, or $179 to cover all 10 exams (thus saving $51 over the cost of 10 individual exam fees).

Facsimile Grading

To receive your CPME certificate, complete all information and fax 24 hours a day to 1-631-563-1907. Your CPME certificate will be dated and mailed within 48 hours. This service is available for $2.50 per exam if you are currently enrolled in the annual 10-exam CPME program (and this exam falls within your enrollment period), and can be charged to your Visa, MasterCard, or American Express.

If you are *not* enrolled in the annual 10-exam CPME program, the fee is $23 per exam.

Phone-In Grading

You may also complete your exam by using the toll-free service. Call 1-800-232-4422 from 10 a.m. to 5 p.m. EST, Monday through Friday. Your CPME certificate will be dated the same day you call and mailed within 48 hours. There is a $2.50 charge for this service if you are currently enrolled in the annual 10-exam CPME program (and this exam falls within your enrollment period), and this fee can be charged to your Visa, Mastercard, American Express, or Discover. If you are not currently enrolled, the fee is $23 per exam. When you call, please have ready:

1. Program number (Month and Year)
2. The answers to the test
3. Your social security number
4. Credit card information

In the event you require additional CPME information, please contact PMS, Inc., at **1-631-563-1604**.

ENROLLMENT FORM & ANSWER SHEET

Please print clearly...Certificate will be issued from information below.

Name ____ Soc. Sec. # ____________________
Please Print: FIRST MI LAST

Address ____

City ______________________________ State ______________ Zip ____________________

Charge to: _____Visa _____ MasterCard _____ American Express

Card # ______________________________ Exp. Date ____________

Note: Credit card is the only method of payment. Checks are no longer accepted.

Signature ____________________ Soc. Sec.# ______________ Daytime Phone ________________

State License(s) ________________ Is this a new address? Yes_______ No_______

Check one: ______ I am currently enrolled. (If faxing or phoning in your answer form please note that $2.50 will be charged to your credit card.)

______ I am not enrolled. Enclosed is my credit card information. Please charge my credit card $23.00 for each exam submitted. (plus $2.50 for each exam if submitting by fax or phone).

______ I am not enrolled and I wish to enroll for 10 courses at $179.00 (thus saving me $51 over the cost of 10 individual exam fees). I understand there will be an additional fee of $2.50 for any exam I wish to submit via fax or phone.

Over, please

ENROLLMENT FORM & ANSWER SHEET *(continued)*

EXAM #3/14
Understanding Biomechanical Forces (Skliar)

Circle:

1.	A	B	C	D	11.	A	B	C	D
2.	A	B	C	D	12.	A	B	C	D
3.	A	B	C	D	13.	A	B	C	D
4.	A	B	C	D	14.	A	B	C	D
5.	A	B	C	D	15.	A	B	C	D
6.	A	B	C	D	16.	A	B	C	D
7.	A	B	C	D	17.	A	B	C	D
8.	A	B	C	D	18.	A	B	C	D
9.	A	B	C	D	19.	A	B	C	D
10.	A	B	C	D	20.	A	B	C	D

Medical Education Lesson Evaluation

Strongly agree [5]	Agree [4]	Neutral [3]	Disagree [2]	Strongly disagree [1]

1) This CME lesson was helpful to my practice ____

2) The educational objectives were accomplished ____

3) I will apply the knowledge I learned from this lesson ____

4) I will makes changes in my practice behavior based on this lesson ____

5) This lesson presented quality information with adequate current references ____

6) What overall grade would you assign this lesson?

A B C D

How long did it take you to complete this lesson?

______hour ______minutes

What topics would you like to see in future CME lessons ?

Please list :

____

____

____

____

____