Applying Biomechanical Principles to the Diabetic Foot

Preventing and healing diabetic ulcers is enhanced by understanding the forces that cause them.

Goals/Objectives

This article:

1) Describes the importance of the soft tissues in protecting the osseous elements and how diabetes changes the biomechanical function of the soft tissues.

2) Describes how sensory, motor and autonomic neuropathies combine together to markedly increase the risk of ulcerations.

3) Discusses how footgear and in-shoe orthotics can be used to equalize the inversion and eversion moments on the foot during gait.

There are countless articles detailing the prevalence of diabetic ulcerations, the number of infections, and the number of partial and full amputations of the lower extremity. The social and economic cost of these complications is overwhelming, almost epidemic, with no end in sight. The purpose of this CME is to review a few basic principles of mechanics and show how they can be utilized to create some clinical solutions for diabetic patients. Specifically, this article will review a few principles for off-loading sites that tend to ulcerate, and to point out a few ideas that will increase shoe therapy effectiveness.

The loss of a body part due to the effects of a diabetic infection is a tragic event. A major goal of diabetic programs, both public and private, is to prevent amputations. The prevention of ulcers is the major method of preventing amputations. The prevention of ulcers must be based on two major standards: prevent excessive pressure and prevent periph-

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marketed over the years, and there is not one of them that can’t point to success stories. The purpose of this article is not to look at particulars, but to review some more basic concepts of off-loading.

The simple fact is that bipedal gait requires that the full body-weight be borne by the bottom of the foot. Now it is true that patellar tendon bracing can transfer some of the weight from the bottom of the foot; however, such bracing is not practical or affordable for a great many of our patients. As a result, a person who weighs 200 lbs must either bear that full 200 lbs. under the left foot, under the right foot or share it between both feet. Gait requires that this weight be fully born by the left foot, followed by the right foot, and again the left foot, etc.

No matter what type of shoe, or what type of shoe insert one uses, you must bear this amount of weight. No shoe or insert can decrease the total body weight borne by the foot. The answer is that it can only redistribute the weight. As soon as you take the weight from under one part of the foot, it must go under another part of the foot.

Ulcerations and Peak Pressures

The correlation between development of ulcerations on the bottom of the foot and the peak pressures under the foot has been reported on numerous occasions. Peak pressure values between 7-12 kg/cm² have been used for identifying those with likelihood of developing ulcerations. As will be

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discussed later, it is often found that stresses born by normal subjects may be sufficient to create ulcerations in diabetics.7,8 Therefore, a major goal of diabetic footwear has been to reduce the pressure under those areas where peak pressures occur. The pedobarograph has become more important in our assessment of risk of ulceration.9-12

Before discussing the contact of the foot with the ground, we must take a brief pause to remember that when a round object rests on a flat surface, there is theoretically only one point of contact between the object and the surface (Figure 2). Since the theoretical point of contact is infinitely small, it means that a perfectly rigid material resting on a perfectly flat rigid surface has an infinitely high pressure. Of course this is not reality as even the most seemingly rigid materials have a little bit of give, which gives some degree of surface contact area.

If one looks at the skeleton of the foot in a weight-bearing situation, one quickly realizes that the actual bone surface in contact with the ground is very small because of the rounded surface of the calcaneal tuberle and the rounded surfaces of the five metatarsal heads (Figure 3). Round hard surfaces making contact with a flat hard surface is a very small area, and thus without any mechanism of spreading out that weight, the metatarsal heads and the plantar calcanean tuberle would very quickly be damaged and/or erode.

The Importance of Soft Tissue

The body’s own natural reducer of pressure is the fat pad under the heel and under the metatarsal heads.13,14 One may also include the fat pads under parts of the toes as well. These fat pads (Figure 4) are made up of tiny collagen fibers, most of which are vertical, interlaced together like a closed net, with fat globules in the spaces.15 Because the collagen fibers create closed cells for the fat globules, when pressure is placed on the closed cell, hydraulic pressure is created within the cell in all directions. Pressure is placed on the cell above it and also on all the cells adjoining the sides. Each of these cells then puts pressure sideways and upwards, and the process proceeds outward.

If one takes an imprint of the bottom of the foot, one quickly realizes that the foot print is much bigger than the bone surface that is closest to the ground. One notices that there is pressure being born by a big part of the heel, whereas an unpadded skeleton shows only a very small part of the heel in contact with the ground. One also notices weight being born by the areas between the metatarsal heads, and also under and between the proximal phalanges. The fat pad is a remarkable biomechanical structure. I do everything I can to protect its integrity. I avoid making incisions on the bottom of the foot, even when the “exposure is better”, because I don’t want to do anything to compromise the fat pads.

In diabetes, the fat pad under the heel and the metatarsal heads can become compromised. Some of the things that can happen are:

1. The fat pad can be displaced anteriorly by the development of claw toes16 (Figure 5). This mechanism unprotects the metatarsal heads, as the number of closed cells between the bone and the surface is decreased. It is not uncommon to see an imprint of the foot with greater points of pressure directly under the metatarsal heads than between the metatarsal heads.

2. The fat pad may degenerate. There are a number of mechanisms that contribute to this. Peripheral vascular disease will almost always be accompanied by collagen absorption, and when this happens, the number of closed cells would be expected to decrease. Therefore the pressure under the bone surfaces closer to the ground will not be dissipated outward as much. Each closed cell is called on to do more work, and as such it is more likely to be damaged.

3. Poorly-controlled diabetes can lead to increased glycosylation of the collagen fibers. The decrease in joint mobility is well documented in diabetes, and is often attributed to the glycosylation of the collagen fibers. These glycosylated fibers become more brittle and less pliable when heavy loads are placed on them, and can break easier.14,15 In other words, the septae between the closed fat cells in the pads break down and become decreased in number, thus the remaining septae have to do more work, and one quickly sees this makes for a downward spiral in the integrity of the pad.

Padding Materials

I would like to mention the importance of padding materials. To do that, I rely on the mechanical concept of the stress-strain curve. Every elastic material has a stress strain curve. The slope of the curve

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is called “Young’s modulus of elasticity.” This means that for a material to produce a force upward it has to be strained. Every material has its own stress strain curve. The more it’s strained the more it can push upward, and the more it can push upward the more it is strained. Unfortunately, the companies that provide cushioning materials don’t give clinicians much data about what the modulus of elasticity is for the various materials we use.

There are a number of different padding materials that have been developed for the shoe but it is beyond the scope of this article to discuss the various materials, which include all types of foams, rubbers, and viscoelastic polymers. When one steps into a soft insole, pressure is placed on the lowest point and that point of the insole is depressed, which brings more of the insole in contact with the foot. It is important to remember that the insole must push back. The more that the insole is compressed, the more it is able to push upward. Therefore, the portions of the insole into which the greatest indentation is made will still be pushing back against the plantar foot harder than the areas that have less indentation. This means that foam materials do indeed spread out the force under the foot, but it is very difficult to do so in an even manner. Therefore, soft and cushiony insoles are only mildly effective in alleviating pressure points on the bottom of the foot. The most prominent plantar prominences still have more pressure being placed against them than the less prominent prominences.

Because foam materials inside the shoe have their limitations in how much pressure can be alleviated, another common technique is to modify a shoe insert by cutting out an area in the insole to alleviate high pressure. This is more effective than just placing a foam material inside the shoe as the foam next to the prominence will not push up as hard as the foam directly under the prominence. The problem with cutouts is that they merely transfer pressure to a neighboring region, which may or may not be able to withstand this pressure (Figure 6) As illustrated, a cut-out under the 5th metatarsal head may have the effect of increasing weight to the 4th metatarsal head.

The lowest amount and most uniform distribution of pressure across the bottom surface of any object is achieved when there is a maximum surface contact. If you take a spherical object and build a solid, very conforming surface for it to rest upon, we will get the lowest pressure possible at every point on the bottom surface. It should be noted that if this conforming surface is soft and mushy, then the lowest points on the bottom surface will still be subjected to more pressure than the higher points.

With this concept in mind, in theory, the first and foremost role of any foot orthotic that is built for a diabetic should be to provide the lowest and most uniform pressure across the entire bottom of the foot—i.e., a rigid surface that conforms perfectly to the bottom shape of the foot. In this way all points on the top surface of the orthotic will place equal force against the bottom surface of the foot. Of course, if the patient has lost some of the fat pad or muscle padding on the bottom of the foot, the top surface of the orthotic must also function as a supplement with an additional soft material on top of the rigid contour in order to perform the function that the body’s soft tissues normally provide (Figure 7).
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Pronation and Diabetes
A lot of diabetic patients already had pronation problems before they were diabetic. But with diabetes, the glycosylation of the ligaments decreases the range of motion of the joints. This can become a problem in the pronated diabetic, because in order for the rearfoot to evert from perpendicular in stance, the forefoot has to invert against the rearfoot. As the joints of the forefoot lose their mobility, then more pressure is exerted by the ground against the medial side of the forefoot to invert it the same degree as the rearfoot is everted. This decrease in forefoot joint mobility will increase the likelihood of ulceration plantar to the medial metatarsal heads when the rearfoot is pronating.

Glycosylation
Glycosylation of the collagen tissues also has a marked effect on the function of the tendons. One of the most important is the Achilles tendon, which is responsible for creating pressure under the metatarsal heads. The amount of force in the Achilles tendon is equal to the muscle force generated by the contraction itself, plus the passive tension in the tendon. Passive tension begins to build in the tendon once the muscle starts to stretch beyond its resting length. As the tendon starts to become stiffer due to glycosylation, it begins to shift its passive length-tension curve to the left, meaning it takes less stretch to develop more tension in the tendon. The shift of the passive length tension curve to the left will have the result of increasing the pressure against the forefoot and decreasing the pressure in the Achilles, which allows forefoot ulcerations to heal, without any long-term negative effects in the concentric strength of the muscle.

Effects of Neuropathy
While entire books could be written about diabetic neuropathy, I would like to just touch briefly on a few clinical items of interest. It is well documented that decreased ability to sense a 10 g. Semmes-Weinstein monofilament is a good indicator of increased risk of ulceration under the foot. Depending, however, only on the pressure perception threshold may not be the only sensory test to predict ulceration or other adverse biomechanical effects. Loss of vibratory sensation has also been associated with development of ulcerations.

I have personally encountered many diabetics who have significant decreased vibratory sensation, yet are considered normal as judged by the Semmes-Weinstein test. Does this mean these people are not likely to develop ulcerations? It is unknown at this time; however, it has been shown that there are different patterns of diabetic neuropathy.

A simplified model of nerve size states that the large myelinated fibers (Aα) are the fastest conducting fibers and carry the vibratory and proprioception impulses. The small myelinated fibers (Aβ) are a little slower-conducting and would be thought of as carrying the pressure sensations, such as would be perceived during a Semmes-Weinstein stimulus. The unmyelinated fibers (C) are the slowest and would carry pain and temperature stimuli. If the patient, then, is undergoing a demyelinating type of...
tion velocity may be a better predictor of ulceration. Since diabetic neuropathy is considered a stocking and glove neuropathy, progressing from distal to proximal, it may be assumed that the first muscles to be affected by motor neuropathy would be those innervated most distally—specifically the lumbricales and the interossei would be considered to be among the first, followed next by the flexor digitorum brevis.

**Gait Changes**

What gait changes would be expected with loss of the intrinsic muscles of the foot? These small muscles are considered to be active during the late midstance and first part of the propulsive period of gait. The lumbricales are considered to be the major plantar-flexors of the metatarsophalangeal joints and extensors of the interphalangeal joints. Without the action of these small muscles, the contraction of the major flexor and extensor muscles will buckle the toes, creating the classic extension deformity of the metatarsophalangeal joints and the flexion deformity of the interphalangeal joints that is known as hammertoes. Indeed, then, loss of lumbricale and interossei function may already be occurring when vibratory sensation loss is detected, and may be the first stage of the hammertoe deformities, which, as we have already pointed out, shifts the plantar fat pad anteriorly and results in increased pressure under the metatarsal heads.

The next major muscles to be affected would be the quadratus plantae and the flexor digitorum brevis. The flexor digitorum brevis, due to its attachment to the plantar fascia, plays a major role in assisting in the windlass mechanism of the plantar fascia. It has been noted in many diabetics that the plantar fascia gets thicker. Is this purely a result of glycosylation of the plantar fascia or is the thickening a result of a reaction to the loss of the intrinsic muscle power of the flexor digitorum brevis?

My own opinion is that the latter is more likely the case. As the intrinsic muscle strength is lost, the center of the heel pressure is not under the center of the vertical force being exerted downward by the leg, the center of pressure under the heel produces excess rotational moment of the heel to the side that is displaced. This causes the heel to roll toward that side.
the digits lose their ability to share with the metatarsal heads the body load during the propulsive period of gait.64-66 The loss of intrinsic muscle strength and the thickening of the plantar fascia would also result in loss of the metatarsophalangeal joint dorsi-flexion motion during the gait cycle. Then we begin to lose the digital flexion stage of the gait cycle. As this is lost, it is hypothesized that we start to get digital extensor activity beginning before digital flexor activity ceases during propulsion. If this happens, then the digits will buckle.

Inversion and Eversion Moments

Abnormal pressures under the bottom of the forefoot are usually not equally distributed across the entire forefoot, but are usually located more on the medial or lateral side of the foot. Therefore, understanding the degree to which the foot is inverted or everted from the perpendicular may help a clinician alleviate abnormal pressures on the medial or lateral metatarsal heads. Certainly the use of in-shoe orthotics can be useful in neutralizing excessive inversion or eversion moments.

I would like to address a very basic concept of controlling inversion and eversion movements of the foot. Some of the adverse effects of excess pronation on the foot can include: 1) Increased strain on the medial ligaments and tendons; 2) Increased medial pressure against the forefoot; 3) Decreased stability of the superior structure; 4) Decreased digital dorsi-flexion, creating a greater anterior lean of the trunk.62,63

It is commonly considered that when the subtalar joint is in neutral position, the heel should be vertical with the ground. In fact some people have defined neutral subtalar joint position as that position where the heel is vertical.64 A mechanical analysis of moments, however, dictates that the center of the ground force pushing up on the bottom of the heel should push upward under the center of the leg (Figure 8 & 9). In this way half of the ground forces pushing up lateral to the center of the leg will provide the same amount of evertion moment on the heel as the amount of inverting moment produced by ground forces pushing up medial to the center of the leg.

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most people stand with the subtalar joint pronated, the center of the heel is usually lateral to the center of the leg. Over the years, the heel may become fixed laterally displaced to the center of the leg, due to either bony adaptation or ligamentous adaptation, or both.

Laterally Displaced Calcaneus

One common problem I have found is the laterally displaced calcaneus. This type of foot shows the center of the heel lateral to the center of the leg even when the subtalar joint is in neutral position. This type of person typically slides off of any type of neutral orthotic and often complains that an orthotic is very irritating to the arch area of their foot. Therefore it’s essential to assess how close the center of the heel is to lying directly under the center of the leg. If it is not centered, then I want to center the ground forces under the center of the leg.

The easiest way to center the upward ground force is to modify the shoe by flaring the sole outward (Figure 11). For example, if the center of the heel is 1 cm. lateral to the center of the leg, then one can quickly calculate that if the center of the sole is flared 2 cm. medially, the center of the sole of the shoe will be directly underneath the center of the leg. If the center of the heel is medial to the center of the leg, then the sole should be flared lateral, two times the amount that the center of the heel is relative to the center of the leg.

Flaring Soles

Flaring the soles of the shoes has proven to be an important adjunct in assisting to neutralize abnormal inversion or eversion moments. This technique does not change the interactions between the forefoot and the rearfoot. So if the forefoot portion of the shoe twists into an inverted state relative to the heel counter, then the foot will still pronate inside the shoe. If the forefoot is inverting to the rearfoot inside the shoe, the rearfoot will still pronate inside the shoe. If the forefoot portion of the shoe twists into an inverted state relative to the heel counter, then the foot will still pronate inside the shoe.

The Effects of Partial Foot Amputations

No matter how careful one may be in preventing ulcerations, partial foot amputations are still often the end result and may be inevitable. When removing parts of the foot, it is important to begin to plan how the foot may change its forefoot and rearfoot and superstructure after surgery. A utilization of the subtalar joint axis theory can help in that scenario. A plot of a normal subtalar joint axis

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is shown in Figure 12.56

The upward forces from the ground against the foot on the lateral side of the subtalar joint axis produce pronation moments while upward forces from the ground against the foot on the medial side of the subtalar joint axis produce supination. To prevent abnormal inversion or eversion of the foot when a person stands or walks, it is important that the pronation forces and supination forces be kept within equilibrium.57

To determine the pronation or supination moment from any vertical ground force, that force must be multiplied by its lever arm. Therefore, if the fifth metatarsal is twice the distance from the axis as the first metatarsal, it only takes half the force upward against the fifth metatarsal to neutralize the supination torque that is produced around the subtalar joint axis by the ground pushing upward against the first metatarsal.

When removing a portion of the foot, one must take into account how much weight-bearing area of the foot will be in contact with the ground and how much of that weight-bearing area will be on each side of the subtalar joint axis. Consider an amputation of the first metatarsal, which has been considered to carry about 1/6 of the body weight in a single support stance. Where does the weight go? The most likely place for it to go is under the 2nd metatarsal head. One such end result of transference of weight is a stress fracture of the 2nd metatarsal neck (Figure 13).

Because the lesser metatarsal heads are one half the diameter of the first metatarsal, they have eight times less strength to resist bending forces than the first metatarsal. Morton argued in a great many papers that the result of a shortened first metatarsal was an inverted forefoot deformity that required the rearfoot to pronate in stance.70 Another argument is that when the first metatarsal head is not present to accept weight, the remaining metatarsal heads are all lateral to the subtalar joint axis. This means that a significant supination moment is lost, and there is a tremendous overload of pronation moment acting on the rearfoot. As a result, a great many of these feet will severely pronate in stance. Such pronation may bring the first cuneiform to the ground, resulting in excess pressure against the medial side of the foot, and increasing the likelihood of ulceration under the distal first metatarsal stump, the first cuneiform, or the 2nd metatarsal head71 (Figure 14).

**Fifth Ray Amputation**

Amputation of the 5th ray is another amputation that can produce post-operative consequences that must be addressed. This is because the 5th metatarsal head has the longest lever arm relative to the subtalar joint axis, and provides the strongest pronation moment around the axis when ground force pushes upward.

Many feet before surgery have had excess pressure against the fifth metatarsal head due to either varus deformities of the rearfoot or compensated valgus deformities of the forefoot. After surgery, a significant eversion moment on the rearfoot is lost. This means that ground force upward against the metatarsus will increase the inversion moment on the rearfoot (Figure 15).

Such increase in the inversion moment will increase ground forces against the remaining base of the 5th metatarsal and/or force against the 4th metatarsal head. If the patient has adequate eversion motion in the rearfoot joints, then a foot orthosis must be designed that markedly increases the pronation effect on the subtalar joint. Flaring the sole of the shoe laterally can be a very effective way of increasing the pronatory force on the rearfoot. If there is a high degree of rearfoot varus, then the orthosis must be designed to bring the ground up to the plantar medial side of the foot, and thus al-

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**Figure 16:** After a transmetatarsal amputation, most feet will be left with the remaining forefoot inverted to the rearfoot.

**Figure 17:** Cast of a foot that has had a transmetatarsal amputation, showing how the calcaneus will want to evert to compensate for the iatrogenic inverted forefoot deformity. It is advisable that this inverted forefoot deformity be supported by a build-up under the medial side of the forefoot.

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leviate pressure against the lateral column.

Transmetatarsal Amputation

A common amputation performed is the transmetatarsal amputation and indeed most of these people maintain much better mobility than those who have higher amputations. There are, however, a number of possible gait changes that must be considered.

The most basic change is the decrease in the surface area on the plantar surface of the foot available to bear weight.

Therefore, full contact-type inlays after surgery become a very important part of the post-surgical care to maximize pressure distribution.

Due to the declination angle of the metatarsus the effect of loss of the distal metatarsus can have functional effects on the ankle and subtalar joints. Many of these depend on the preoperative configuration of the five metatarsal declinations.

An average person shows a greater declination of the first metatarsal than the 5th metatarsal. Therefore a resection of all the metatarsals at their base level leaves the forefoot in a varus condition to the rearfoot (Figure 16).

After surgery, either excess weight will be born by the 5th metatarsal base, or the rearfoot must evert to place the remaining metatarsus on the ground. This inlay must not be too soft, so that the medial side will crush downward. The shoe that this is worn in must be deep enough that it allows the inlay buildup underneath (Figure 17).

It will also be noted that with a transmetatarsal amputation, the ankle joint will have to planter-flex more in order for the forefront to reach the ground. The clinician must ask some very important questions as to whether this does or does not have any deleterious effects on the gait pattern. For example, how much does this planter-flexion take tension off the Achilles tendon? Certainly the procedure decreases the pressure against the distal part of the remaining metatarsus.

Is it possible, however, that too much tension could be taken off? Would it be possible to weaken the triceps surae too much? Can we calculate whether a person may need an elevation of the entire anterior portion of the remaining foot after surgery? These are questions that should be answered for each individual patient as there is probably a high degree of variability across the spectrum of patients who have this procedure.

While there remains a great deal of research to perform on the forces acting on the diabetic foot to create ulcers, it is hoped that this short article will inspire clinicians to seek answers for their individual patients to keep them walking.

To determine the pronation or supination moment from any vertical ground force, that force must be multiplied by its lever arm.

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Full contact-type inlays after surgery become a very important part of the post-surgical care to maximize pressure distribution.

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1) A soft cushion in a shoe:
   A) will not change the total amount of weight born by the foot
   B) will decrease the amount of weight born by the foot
   C) will shift the body weight from the heels to the ball of the foot.
   D) none of the above are true

2) Pressure is defined as:
   A) the weight born by the foot
   B) the force divided by the area over which it is spread
   C) the distance walked divided by the time it takes
   D) the weight on the forefoot divided by the weight on the rearfoot.

3) The first defense of the body to prevent pathological pressures under the foot is:
   A) plantar fat pads that are adequately thick and flexible
   B) an arch structure that is neither abnormally pronated nor supinated
   C) a normal range of motion of the subtalar and midtarsal joints
   D) normal reaction time to painful stimuli

4) Increased pressure under the metatarsal heads may be caused by all the following except:
   A) hammertoe deformities
   B) fat pad atrophy
   C) increased tension of the Achilles tendon
   D) ingrown toenails

5) Which of the following is most likely to be an indicator of motor neuropathy?
   A) increased sensitivity to the Semmes-Weinstein monofilament
   B) decreased sensitivity to touch

6) Glycosylation of collagen can result in all the following except:
   A) decreased ability of fat pads to resist pressure
   B) decreased flexibility of the midfoot joints to compensate for rearfoot pronation
   C) shift of the passive length tension curve of the Achilles to the left
   D) decreased ABIs

7) If the flexors and extensors fire simultaneously then:
   A) the subtalar joint will pronate
   B) the digits will hammer
   C) the person will become a toe walker
   D) none of the above

8) Which of the following is true about hammertoe deformities?
   A) may be associated with motor neuropathy of the intrinsic muscles
   B) pull the fat pad forward
   C) increase the tension in the plantar fascia
   D) all of the above

9) The first and foremost function of a foot orthosis in a diabetic is:
   A) to get the subtalar joint to neutral position
   B) to increase stride length
   C) to prevent hammer toe deformities
   D) to provide maximum contact surface of the plantar foot with the walking surface.

10) Loss of vibratory sensation may produce which of the following:
    A) slowed reactions or postural perturbations
    B) inability to detect a foreign object in the shoe
    C) acceleration of the glycosylation process
    D) atrophy of the metatarsal fat pad

11) When standing, as the subtalar joint pronates and the rearfoot everts from perpendicular:
    A) the forefoot inverts to the rearfoot
    B) the forefoot abducts to the rearfoot
    C) the tension in the flexor digitorum brevis increases
    D) all of the above

12) A stress-strain curve helps us understand:
    A) how materials push upward as they deform under body weight
    B) how the muscles react to changes in the walking surface
    C) how the subtalar and midtarsal joints move
    D) how atherosclerosis develops

13) Excessive pronation of the feet may cause:
    A) increased likelihood of posterior tibial tendon strain
    B) decreased digital dorsiflexion during propulsion
    C) increased postural instability
    D) all of the above

14) For a foot that shows the heel 2 cm medial to the center of the leg, one would want to change the shoe by:
    A) flaring the sole posteriorly 4 cm.
    B) flaring the sole medially 2 cm.
    C) flaring the sole laterally 4 cm.
    D) flaring the sole medially and laterally 2 cm.

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15) The axis of the subtalar joint should normally be:
   A) under the navicular tuberosity
   B) medial to the first metatarsal base
   C) lateral to the first metatarsal head
   D) lateral to the 4th metatarsal head

16) Pressure under which metatarsal head will produce the greatest amount of pronation torque on the subtalar joint?
   A) the 2nd metatarsal head
   B) the 3rd metatarsal head
   C) the 4th metatarsal head
   D) the 5th metatarsal head

17) Amputation of the first metatarsal will create:
   A) a higher risk of fracture of the 2nd metatarsal
   B) greater pronation moment around the subtalar joint axis
   C) increased risk of ulceration under the first cuneiform
   D) all of the above

18) Amputation of the fifth metatarsal will increase the risk of:
   A) ulceration under the 4th metatarsal head
   B) ulceration under the styloid process of the 5th metatarsal
   C) lateral ankle instability
   D) all of the above

19) Transmetatarsal amputations may cause all of the following except:
   A) decreased tension in the Achilles tendon
   B) increased pressure on the lateral side of the foot
   C) increased pressure on the plantar foot even with a full contact orthosis.
   D) all of the above

20) Podiatry can have the greatest preventative effect on the ill-effects of diabetes by:
   A) preventing excessive pressure
   B) preventing neuropathy
   C) preventing vascular disease
   D) preventing falls

See answer sheet on page 185.
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.

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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 $20.00 per exam, or $129 to cover all 10 exams (thus saving $71 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 $20 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 $20 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 $20.00 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 $129.00 (thus saving me $71 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
EXAM #5/06
Applying Biomechanical Principles to the Diabetic Foot (Phillips)

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

LESSON EVALUATION

Please indicate the date you completed this exam
___________________________________________

How much time did it take you to complete the lesson?
______ hours ______ minutes

How well did this lesson achieve its educational objectives?

______ Very well ________ Well

______ Somewhat ________ Not at all

What overall grade would you assign this lesson?
A   B   C   D

Degree_____________________________________

Additional comments and suggestions for future exams:
__________________________________________________
__________________________________________________
__________________________________________________
__________________________________________________
__________________________________________________
__________________________________________________
__________________________________________________