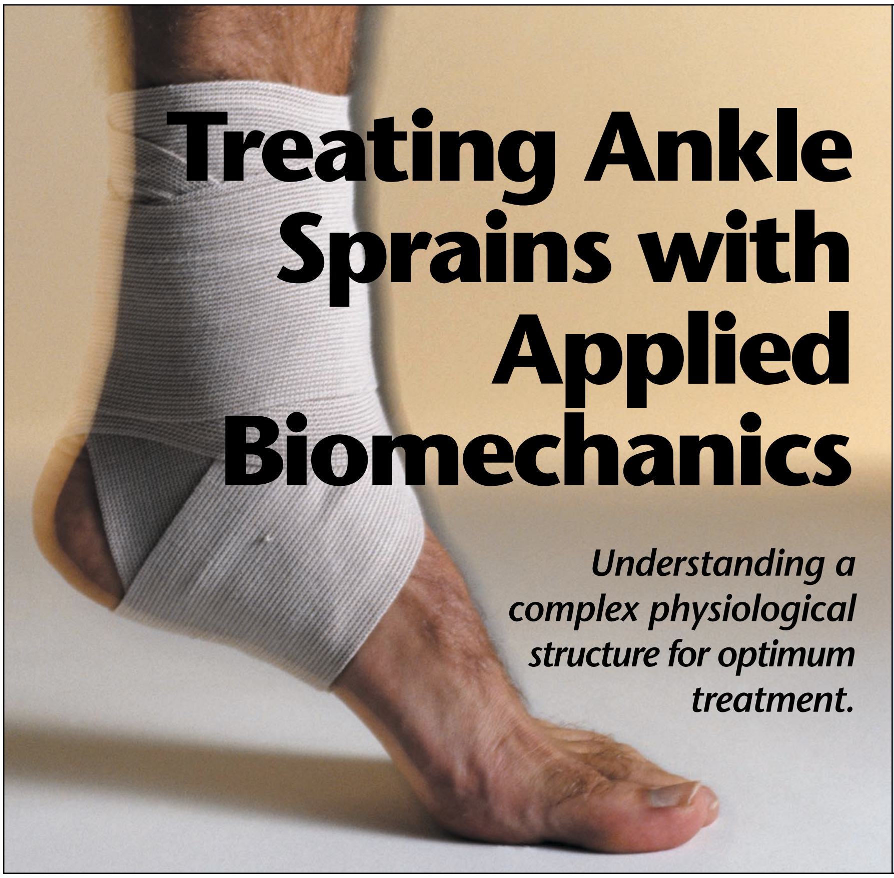

Treating Ankle Sprains with Applied Biomechanics

Understanding a complex physiological structure for optimum treatment.

Objectives

After reading this continuing education article, the podiatric physician should be able to:

1) Identify the key anatomic structures involved in passive and dynamic stabilization of the ankle joint complex.

2) Understand movement transfer between the joints of the foot and the ankle.

3) Identify the essential components of neuromuscular control over the ankle joint.

4) Understand the role of passive supportive devices in treating and preventing lateral ankle instability.

5) Understand the essential steps in the four-week treatment of a Grade II or Grade III lateral ankle sprain.

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*Following this article, an answer sheet and full set of instructions are provided (p. 146).—**Editor***

By Douglas H. Richie, Jr., D.P.M.

Introduction

Approximately 23,000 people experience a lateral ankle sprain in this country each day. Lateral ankle sprains are also the most common injury in sports and account for up to 25 percent of all time lost from participation.

Despite the emergence of newer technologies for the rehabilitation of a lateral ankle sprain, it is estimated that at least 30 percent of patients suffering this injury will develop chronic residual symptoms of instability and other functional impairments.(5, 9, 11, 126-128) This may be the result of a lack of understanding and agreement on effective protocols for the management of lateral ankle sprains among the various groups of practitioners who commonly treat this injury.

During the past 20 years, considerable insight has been gained in

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the understanding of the biomechanics of the ankle-rearfoot complex. Experimental and clinical research has provided significant insight into the role of passive and dynamic supporting structures of the talocrural joint. Today, clinicians can utilize biomechanical principles to formulate effective treatment plans in the management of acute lateral ankle sprains and chronic lateral ankle stability. This paper will review essential biomechanical principles of the talocrural joint and the rearfoot complex. Effective treatment guidelines will then be proposed based upon these principles.

Functional Anatomy

Several key features of the anatomic structures of the ankle joint will be discussed. Knowledge of the anatomy and functionality of these structures will enable the treating practitioner to select better treatment interventions when these structures become injured.

The lateral collateral ligaments include the anterior and posterior talofibular ligaments as well as the calcaneal fibular ligament. Two of these structures are considered to be the most important stabilizers of the lateral aspect of the ankle joint: the anterior talofibular ligament and the calcaneal fibular ligament.(2)

The calcaneal fibular ligament is an extracapsular structure, approximately 30 mm in length and 6 mm in width. It runs from the anterior edge of the distal fibula and extends posteriorly and inferiorly to attach to the mid-lateral surface of the calcaneus. It is interesting to note that the orientation of the calcaneal fibular ligament is almost parallel to the subtalar joint axis. Surgical procedures utilizing tendon grafts to replace the calcaneal fibular ligament may seriously compromise subtalar joint motion if the surgeon is not careful to orient the graft parallel to the individual patient's subtalar joint axis. Such a clinical determination can, indeed, be difficult.

The anterior talofibular ligament is approximately 25 mm long and 7 mm wide. It is situated within the anterolateral joint capsule of the ankle. The anterior talofibular ligament originates from the anterior edge of the lateral malleolus, extends slightly superiorly, anteriorly, and medially to attach to the lateral aspect of the neck of the talus.

The anterior talofibular ligament is considered the most important passive stabilizer of the ankle joint. It is most frequently injured in inversion ankle sprains. Contrary to previous reports, the anterior talofibular ligament is the primary restraint to inversion and anterior talar translation in all positions of flexion.(114)

Most authors agree that talar tilt is restrained in plantarflexion and neutral ankle position by the anterior talofibular ligament. In dorsiflexion, the calcaneal fibular ligament as well as the posterior talofibular ligament limit talar tilt. With plantarflexion of the ankle, the anterior talofibular ligament has been observed to tighten while the calcaneal fibular ligament tightens in dorsiflexion.(10)

> *It is possible for patients with excessive rotational instability to have normal frontal plane talar tilt findings with stress radiography.*

The osseous configuration of the ankle includes the articulating surface of the distal aspect of the tibia forming a roof over the superior articular surface of the talus. Inman described the trochlea of the talus as being a section of a cone with its base lateral and apex directed medially. The width of the anterior margin of the talar trochlear joint surface is approximately 2.4 mm wider than the posterior surface.(1) Therefore, the ankle mortise widens during dorsiflexion due to the increased width of the anterior section of the talar trochlea moving into the mortise. Measurements of lateral displacement of the fibula during ankle dorsiflexion suggests 1 to 2 mm of movement. External rotation of the lateral malleolus also occurs during dorsiflexion, estimated to be approximately 4 degrees.(2)

Controversy exists about the nature and orientation of the ankle joint axis of rotation. Early investigators, including Inman, proposed a single-fixed axis of rotation running approximately through the tips of the medial and lateral malleoli. The axis is, therefore, inclined posteriorly and inferiorly from the sagittal and transverse planes respectively.(17) However, numerous investigators in the past decade have conducted experimental studies, demonstrating that the axis of ankle joint rotation is not fixed but, rather, demonstrates continuous change of orientation throughout its entire range of motion. In addition, two distinct patterns of motion about two different axes have been proposed by several investigators, one axis occurring in the region of plantarflexion while the other in the range of dorsiflexion.(25-28)

Experimental techniques have varied widely in most of these investigations of ankle joint axis orientation. Indeed, numerous errors have occurred in failing to recognize the contribution of subtalar joint motion and the effect of constraining movement of the tibia in cadaver models. An elegant study by Singh and coworkers attempted to eliminate many of these errors and, indeed, reaffirm the original single-hinge axis model proposed by Inman.(153)

Stability of the Ankle

Controversy exists regarding the relative importance of the osseous versus the ligamentous structures in providing overall stability to the ankle joint. From a clinical standpoint, ankle joint stability has traditionally been assessed via anterior-push pull stressing as well as frontal plane inversion talar tilt. However, there is increasing evidence that rotational stability may be equally important yet almost impossible to measure clinically.

It is important to note that axial load, or weightbearing, significantly increases ankle stability. This has been demonstrated in numerous studies including McCullough and Burge as well as Stormont, et al.(12, 13) In Stormont's study, the authors incorrectly concluded that the articu-

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lar surface of the ankle joint provides 100 percent of stability in frontal plane inversion. However, Cass and Settles noted that Stormont's work did not allow complete freedom of tibial rotation and subtalar joint inversion-eversion during loading. When these movements are allowed to occur in cadaver models, truly depicting a real life situation of coupled pedal movements, it is clear that the osseous configuration of the ankle is unable to provide significant stability without intact ligaments. In Cass and Settles' study, significant talar tilt did not occur in axial loaded cadaver specimens until both the anterior talofibular ligament and calcaneal fibular ligaments were released.(144) The amount of talar tilt occurring after both ligaments were sectioned averaged 20.6 degrees. The rotational instability of the ankle joint was also measured after sectioning of the anterior talofibular ligament, demonstrating 4.9 degrees increased external rotation of the tibia after ATF sectioning, and 12.8 degrees extra rotation after sectioning of both the ATF and CF ligaments.

Therefore, a newer type of ankle instability has been discovered involving excessive axial rotation of the tibia upon the talus in an external direction that occurs after loss of integrity of the anterior talofibular ligaments and/or calcaneal fibular ligaments. It is possible for patients with excessive rotational instability to have normal frontal plane talar tilt findings with stress radiography.

Pathomechanics of an Ankle Sprain

The role of the foot in transmitting abnormal rotational force to the talocrural joint is often overlooked in the medical literature. Understanding movement transfer within the pedal joints enables a clinician to implement effective preventive treatment regimens to treat lateral instability of the ankle.

The talus has no muscle attachments. Movement of the talus, therefore, is determined by the bones attached to it via ligamentous connection. Kelikian describes the talus as connecting two unequal levers: the leg and the foot. In its dorsiflexed position, the talus moves with the leg. In a plantarflexed position, the talus moves with the foot.(2)

Most authorities agree that the most vulnerable position of the ankle to undergo an inversion sprain is when the talus is a plantarflexed position. Situations where ankle sprains commonly occur include landing on the forefoot from a fall, stepping off a curb, stepping down stairs, or landing from a jump on an opponent's shoe during sport activity. When such a landing occurs on the forefoot, a rapid supination movement is generated throughout the pedal joints, ultimately transmitting rotational force to the talocrural joint. This movement transfer from the forefoot to the rearfoot and ankle remains poorly understood from a kinematic standpoint. However, a crude, oversimplified description will be provided to allow better understanding of effective treatment interventions.

The two primary joints transferring movement or force from the forefoot to the ankle include the mid-

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tarsal joint and the subtalar joints. Once thought to be simplified hinge joints, these two major pedal joints have also demonstrated complicated changing axes of rotation. However, both joints have their axes oriented obliquely to the three cardinal body planes, thus allowing the movements described as pronation and supination.

Therefore, if an inversion moment develops in the forefoot, the pedal joints rotate about their joint axes to result in not only inversion of the foot but plantarflexion and adduction. When an ankle sprain occurs, the subtalar joint moves simultaneously in three directions. These movements can occur on both sides of the subtalar joint with the calcaneus inverting while the talus dorsiflexes and abducts. The leg moves with the talus and thus external rotation of the leg is a strong component of the rotational force causing lateral collateral ligamentous ankle injury. Understanding the pathomechanics of a lateral ankle sprain allows an appreciation of a critical factor in evaluating patients who have suffered such an injury. The pedal joints transfer supination moment to the ankle joint and, therefore, undergo abnormal rotational movement themselves when the ankle is sprained. Therefore, the clinician must appreciate the fact that ligamentous injury within the foot commonly coexists with lateral collateral ankle injury.


Balance

It has been well-documented in the literature that many patients with a history of recurrent ankle sprains demonstrate mechanical instability of both the ankle joint and the subtalar joint.(95, 99) In their study of 12 subjects with a history of unilateral ankle sprains, compared to eight healthy controls, Hertel and coworkers demonstrated that 78 percent of patients with excessive talar tilt, documented with fluoroscopy, also demonstrated laxity of the subtalar joint with manual testing.(142) Objective measurement of subtalar instability is difficult to perform clinically. Controversy exists about the validity of the Broden view radiographically. There is evidence that subtalar joint stress fluoroscopy can validate instability. The important point to remember here is the fact that a subtalar sprain commonly coexists with a lateral ankle sprain and that long-term protection of the subtalar joint from abnormal rotational force is an important part of the treatment regimen for patients with chronic lateral ankle instability.

Peroneal reaction time has been shown to be significantly delayed in patients with chronic lateral ankle instability.

Movement transfer from the forefoot to the rearfoot commonly occurs as part of a compensation mechanism when there are inverted or everted forefoot deformities. Some frontal plane deformities can induce supination moment through the midtarsal and subtalar joints. The presence of such supination moment can predispose to a lateral ankle sprain.(18, 24)

Specifically, a forefoot valgus deformity (everted forefoot) or a plantarflexed first ray are compensated by inversion of the forefoot on the rearfoot about the longitudinal axis of the midtarsal joint. Further supination may be necessary at the subtalar joint to achieve a balanced weightbearing foot at midstance. When the subtalar joint is in a compensated, supinated position, the delivery of an insignificant inversion force on the foot such as occurs when walking on unstable terrain can be enough to push the patient over the edge and induce an inversion sprain to the lateral collateral ligaments. Therefore, a knowledge and ability to balance forefoot to rearfoot deformities with functional foot orthoses and prevent supination compensation within the pedal joints is an important powerful tool for the practitioner in treating chronic lateral ankle instability.

Neuromuscular Control

The four essential components of neuromuscular stabilization of the ankle joint are proprioception, muscle strength, muscle reaction time, and postural control.(36, 41) After an ankle sprain, one or more of these components of dynamic stabilization of the ankle joint are compromised or lost.(30, 35) An effective treatment program for an acute ankle sprain must address restoration of this essential dynamic defense mechanism.

Proprioceptive receptors in the lower extremity are located in muscles, tendons, joints, and cutaneous tissue. The monosynaptic stretch reflex involves muscle spindle receptors connecting Ia nerve fibers as well as Golgi tendon organs connecting to Ib fibers. In gait, when a rapid perturbation occurs such as tripping or falling, monosynaptic reflexes are absent and compensation occurs via transmission of impulses along group II and III afferent fibers from secondary muscle spindles. These fibers connect through a polysynaptic reflex system to generate an appropriate response. A central program, as well as supraspinal influences, interact in a complex manner which is poorly understood. The contribution of vestibular and visual input to these reflexes is minimal. Gravity and pressure on the joints of the lower extremity as well as pressure on the plantar skin surface of the feet appears to provide significant proprioceptive input for protective muscular activation.

Several studies have indicated that proprioceptive input is compromised after significant ankle injury. Glencross and Thornton found significant differences between sprain and non-sprained ankles in an active

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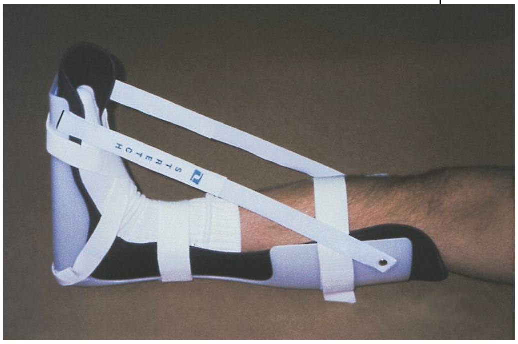
positioning task. Konradsen studied 44 patients with clinical Grade II and Grade III first-time ankle inversion sprains.(41) Twelve weeks after injury, a significant loss in ankle joint position sense persisted in the sprained ankles of the subjects.

It has been previously speculated that an ankle sprain, leading to ligamentous injury, disrupts sensory input from joint mechanoreceptors, leading to proprioception loss. However, ankle joint proprioception may not depend on ligament or capsule mechanoreceptors. DiCarlo and Talbot performed anesthetic injection into the anterior talofibular ligament and tested subjects for proprioception and balance.(148) Anesthetic block into the ankle ligaments actually improved balancing ability in these subjects. Feuerbach examined 12 non-injured subjects before and after anesthesia applied to the anterior talofibular and calcaneofibular ligaments. Joint positioning tasks were not compromised by anesthesia applied to these ligaments.(125)

Therefore, critical sensory input for ankle and foot position sense appears to be provided by receptors located in the tendons around the foot and ankle as well as cutaneous receptors in the lower leg, ankle, and foot. Passive supportive devices such as tape or ankle braces as well as functional foot orthoses that contact these cutaneous receptors appear to enhance proprioceptive input to improve balance and stability.

The peroneal musculature is primarily responsible for resisting inversion (supination) torque about the ankle-subtalar joint complex. The peroneal reflex, stimulated by sudden inversion perturbation, resulting in protective muscular activation, has been extensively studied in the medical literature. Konradsen tested ten subjects with mechanically stable ankles while walking and standing on a trap door. The trap door mechanism is capable of suddenly inverting the foot up to 30 degrees in the frontal plane whereby peroneal latency (time for initial peroneal EMG activity) can be measured. Konradsen found that the reflex latency for the peroneal musculature is approximately 54 milliseconds.(30)

Peroneal reaction time has been shown to be significantly delayed in patients with chronic lateral ankle instability. Konradsen and Raven found a significant mean



Night Splint

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delay of 17 milliseconds in peroneal reaction time in patients with unstable ankles compared to patients with stable ankles.(30) Brunt and coworkers found a 13 millisecond difference in patients with previous Grade II ankle sprains compared to healthy subjects.(36) Karlsson also found significantly delayed peroneal reaction time in patients with unstable ankles.(29) However, when these unstable ankles were taped, peroneal reaction time improved significantly.

Experimental research indicates that a delay of at least 150 milliseconds occurs between peroneal reaction time and the development of sufficient muscular force to actively resist a sudden inversion moment in the ankle joint. This same research has demonstrated that it takes only 80 milliseconds for a weight bearing subject to fall beyond 30 degrees of inversion on a tilting platform.(30) Therefore, the peroneal muscles, at rest, do not appear capable of protecting the ankle from a sudden, unexpected inversion force.

Studies on lower extremity compensation during tripping and falling allow insight into the dynamic defense mechanism.(79) Melvill, Jones and Watt demonstrated that human subjects deprived of visual input, when dropped from a height, required a minimum of 74 milliseconds to activate lower leg muscles and prepare for impact. Effective build-up of muscle tension did not occur until at least 102 milliseconds. Therefore, falls from heights under 5cm occurring in less than 100 milliseconds, resulted in insufficient activation of lower leg musculature to protect the skeleton. Falls above a height of 18cm will allow enough time (over 190 milliseconds), to activate a protective shock absorbing reaction. During gait, Winter has demonstrated that the foot passes as close to the ground as 5mm. Therefore, during normal gait, simply "stepping on a crack in the sidewalk" is a more precarious position for the human ankle than the situation of an athlete landing from a height of over 18cm.

In normal running, stretch-shortening determines some muscle stiffness that accounts for the spring-like elastic properties of muscle in landing, push-off, and acceleration of the body.

Research on peroneal reaction time has been conducted on subjects standing at rest. Considerably different results could be anticipated if such studies were conducted on subjects during gait when the peroneal musculature is pre-activated prior to touch-down. Pre-activated peroneal muscles, with fully activated cross-bridges of contractile units prior to foot touch-down, could provide significantly greater eversion muscle force without significant time delay. A higher rate of tension rise would occur during peroneal stretching as the foot suddenly inverts during an ankle sprain scenario. Inversion of the foot with activated peroneal muscle tension leads to eccentric lengthening contractions within these muscles. The force per active fiber ratio is greater during eccentric muscular contractions than during concentric contractions. The peroneal muscles would then undergo a pliometric contraction involving a stretch-shortening sequence which combines eccentric and concentric contractions. The force developed from stretch-shortening is greater than any other type of contraction. In normal running, stretch-shortening determines some muscle stiffness that accounts for the spring-like elastic properties of muscle in landing, push-off, and acceleration of the body.

From their data on muscle eversion power in an isometric condition, Ashton-Miller and coworkers calculated the potential effect of pre-contracted muscle action prior to ground contact on a 15 inverted surface. The resulting eccentric contraction would increase muscle force from 35.8 Newton-meters to 68.0 Newton-meters. The total equivalent muscle force based on the lever arm of the peroneus longus and brevis was calculated to be 2533 Newtons. This force is easily great enough to avulse the styloid process of the fifth metatarsal base during inversion ankle sprains.

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FIGURE 5

3 sets / 30 sec:		Balance	Ant-Post	Clockwise	Counter Clockwise	Week
On floor	One foot	1				1
Wobble	Two feet	2	2	2	2	2
Wobble	One foot	3	3	3	3	3
Wobble	Eyes closed one foot	4	4	4	4	4

4 week disc training

Fig. 1

Use of Passive External Support

The dynamic defense mechanism can be augmented by the use of passive external supportive devices such as ankle braces, functional foot orthoses, and foot wear. These supportive devices can restrict excessive ranges of motion, balance forefoot to rearfoot deformities, enhance proprioceptive input, and increase muscular torque on the ankle and rearfoot joints.

Several studies have demonstrated that both athletic tape and ankle braces can increase isometric ankle eversion moment developed by the peroneal musculature.(61) However, the protective benefit of athletic taping has also been shown to be lost after 10-40 minutes of exercise.(48, 49)

Athletic taping does not appear to mechanically stabilize the ankle joint. In a study conducted on 20 patients with mechanically unstable ankles, Karlsson utilized stress radiography to demonstrate that taping of the ankle provided no reduction of talar jolt.(29) However, these same subjects showed significant improvement of peroneal reaction time with standard athletic ankle taping. This study suggests that taping facilitates proprioceptive input by stimulating receptors located in the cutaneous areas about the ankle joint.

Several studies have shown that a semirigid plastic ankle brace is more effective than tape in limiting ankle inversion, both before, during, and after exercise.(57, 58, 59, 66) Overall, bracing and taping can provide up to two times improvement of resistance to ankle inversion.

Ankle taping or bracing become less effective when the ankle is placed in a plantarflexed position. Ashton-Miller and Manfroy measured isometric ankle eversion strength in human subjects under full weightbearing conditions in a neutral position and at 32 degrees of plantarflexion.(104) Ankle taping, ankle bracing, and a three-quarter high-top athletic shoe all significantly improved isometric eversion moment around the ankle joint although no significant differences were found between any of the passive supportive devices. However, differences did occur depending on ankle position: passive supportive devices improved inversion resistance by 7.8 percent at 0 degrees plantarflexion and by 4.6 percent at 32 degrees of plantarflexion.

In this same study, Ashton-Miller calculated that at 15 degrees of inversion, the ankle everter muscles isometrically developed an eversion moment up to six times larger than that developed by a high-top athletic shoe.(104) Active tension in the peroneal musculature is more than 63 percent greater in an inverted ankle compared to a neutral ankle. When the ankle is plantarflexed 32 degrees, the peroneal muscles generate 73 percent more power. These findings indicate that, as the ankle plantarflexes, the effectiveness of passive supportive ankle

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braces decreases while the natural dynamic defense mechanism effectiveness actually increases.

Treatment of Lateral Ankle Ligamentous Injury

Clinicians can implement treatment of lateral ankle sprains utilizing knowledge of the biomechanics of the foot and ankle complex presented in this paper. Specifically, maintaining optimal osseous configuration of the talocrural joint for stability, employing movement coupling of the pedal joints for reciprocal ankle stabilization, enhancing the dynamic muscular defense mechanism, and selecting appropriate passive supportive devices can provide a successful treatment regimen of even the most severe ankle sprains.

O'Donohue proposed a classification of lateral collateral ankle ligament sprains that continues to be widely accepted. A Grade I sprain involves strain of the lateral ligaments with partial tear of the capsule, no hemorrhage and no functional loss. A Grade II ankle sprain involves incomplete (partial) ligament tear with moderate functional impairment. A Grade III ankle sprain involves complete rupture of any ligament with mechanical instability of the ankle and loss of function (inability to bear weight).


Camwalker

Evaluation of the ligamentous integrity can be performed with manual stress testing of the ankle (anterior drawer and talar tilt tests) as well as stress radiography. While these diagnostic tests can be important baseline measures, they provide no significant direction for the treating clinician in terms of selecting appropriate treatment measures. Specifically, initial treatment of a Grade II or Grade III ankle sprain should be identical. There is little evidence in the literature that surgical treatment of a first time Grade III ankle sprain has better outcome than non-surgical treatment. Whether there is partial or complete disruption of the lateral ligamentous structures of the ankle, the non-surgical treatment principles remain the same to optimize ligament healing. Notwithstanding, controversies still exist about the various treatment approaches possible.

The first area of controversy involves immobilization. Opinions vary among experts advocating everything from long-term rigid cast immobilization to simple Ace-wrap immobilization after ankle ligamentous injury. Studies on patients suffering lateral ankle ligamentous injury have clearly demonstrated that excessive joint motion, when allowed to occur during the first month post-injury, can lead to long-term joint instability. At the same time, total cast immobilization has been demonstrated to decrease ligament repair by slowing down the

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rate and strength of collagen synthesis. Therefore, the ideal treatment of Grade II and Grade III ankle ligamentous injuries utilizes "protected immobilization" measures. Specifically, the ankle must be protected from abnormal rotation both in the transverse and the frontal planes that would exert damaging torque and separation on the injured collateral ligaments and joint capsule. The most effective device to achieve this treatment goal is the removable cast-boot or camwalker. Internal and external rotation of the leg upon the foot is minimized with these devices while frontal plane inversion and eversion of the foot upon the leg is also prohibited.

O'Donohue proposed a classification of lateral collateral ankle ligament sprains that continues to be widely accepted.

Exercise and joint motion stimulate healing and influence the strength of ligaments after injury. Studies published in the orthopedic literature evaluating ligamentous healing suggest that, the sooner the injured joint begins passive and active physiologic range of motion, the sooner ligamentous healing occurs.(108, 111) Therefore, the immobilization devices must be easily removed by the patient for the implementation of exercise programs.

The most overlooked aspect of ankle joint immobilization post-ligamentous injury is the benefit of loading the ankle to enhance healing.(110, 111) There still appears to be a preference, among all disciplines, for recommending crutches and non-weightbearing on the injured limb during the first week or two post-ankle ligamentous injury. There is an erroneous assumption that torn ankle ligaments are further disrupted by early weightbearing. However, experimental and clinical research have demonstrated the opposite findings.

Smith and Reischl, in a series of cadaver studies, demonstrated that, after lateral collateral ankle ligamentous disruption, the optimal position of the foot for reapposition of torn ligamentous ends is in end-range dorsiflexion.(11) This position of the ankle joint not only brings the torn ligament ends closely together, it positions the ankle into its anatomically stable close-packed position. At the same time, passive dorsiflexion of the ankle creates tension on the tendo-Achilles which further re-apposes the torn ligaments.

Crutches

When the foot is maintained in a non-weightbearing position, it passively plantarflexes at the ankle joint without proper support. When sitting or sleeping supine, the injured patient cannot control the ankle from passively dropping into plantar flexion. The unloaded plantarflexed ankle is in its most unstable position with greatest strain and separation upon the lateral ligamentous structures. Indeed, the unprotected injured ankle is most painful after sleeping in this precarious position.

The best advice for a patient suffering a Grade II or Grade III ankle sprain is to begin immediate protected weightbearing in a camwalker.(112, 114, 124) If full weightbearing cannot be tolerated due to pain, at least partial touch-down weightbearing should be encouraged to compress the ankle joint and stimulate muscle action. As described earlier, axial loading of the ankle increases stability. Loading can occur either through weight-bearing or by muscle action or elastic tension created through the heel cord. Radiographic studies have shown that, during the stance phase of gait, contraction of the flexors of the foot and ankle pulls the fibula distally and tightens the interosseous membrane. This activity resists movement at the distal tibiofibular joint and tendons to increase the rotary stability of the ankle during walking.

During the first week after lateral collateral ligamentous injury, the patient should be encouraged to bear weight but in a relatively pain-free fashion. The choice

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of immobilization device and degree of weightbearing should be based upon this subjective evaluation of pain. During the first week, active range of motion exercises should begin. This involves removal of the cast boot three times daily and the performance of toe flexion exercises with tissue pick-ups. (See Fig. 2) Immediately after, the heel cord should be passively stretched at least five times. Passive plantarflexion-dorsiflexion as well as inversion and eversion range of motion exercise should also be conducted for two minutes during each exercise session. Ice should be applied 12-15 minutes after each session with immediate return to the immobilizer boot.

> *The best advice for a patient suffering a Grade II or Grade III ankle sprain is to begin immediate protected weightbearing in a camwalker.*

Sagittal plane motion should not be allowed until the second week post-injury. (See Fig. 2) The patient can be progressed from a cast boot to a properly designed removable ankle brace that supports the foot, allows sagittal plane motion, but limits foot inversion/eversion, internal and external rotation.

Active resistance range of motion exercises should begin at week 2. Isotonic (Theraband) or isometric (hands on) techniques have unique benefits and are best implemented and supervised by a therapist. Heel cord stretching should be emphasized during the entire rehabilitation program to allow maximal ankle joint dorsiflexion to maintain osseous stability.

As described earlier in this paper, the dynamic muscular defense mechanism is the most important powerful protection of the ankle after ligamentous injury. This mechanism requires proprioception, balance, postural control, and muscular strength to be fully effective. Research has shown that all four components of this neuromuscular control over the ankle are significantly compromised after Grade II or Grade III ligamentous injury.

The single most important rehabilitation technique to restore neuromuscular control over an injured ankle is the use of a wobble board.(89, 92, 93) Because these exercises are performed in a weightbearing fashion, wobble board training is the most effective way to re-educate peripheral proprioception and centrally mediated balance and postural control mechanisms. Numerous studies have demonstrated that ankle disc training with a wobble board restores reaction time and overall strength while enhancing overall balance to greater than normal levels. Also, ankle disc training has demonstrated a long-term protective effect for athletes involved in contact sports where preseason balance training has led to a decreased rate of ankle sprains. A four week ankle disk training is proposed in Fig. 3.

Up to 75 percent of patients with mechanical instability of the ankle have co-existing subtalar joint instability.(106) Many ankle immobilization techniques fail to properly support the subtalar joint to allow proper ligamentous healing. Several studies have demonstrated the effectiveness of traditional balanced functional foot orthoses in the treatment of patients suffering a lateral ankle sprain.(107, 98) Gusklewicz and Perin demonstrated that the use of functional foot orthoses reduced postural sway, reduced pain and improved single leg balance after a lateral ankle sprain.(98) In addition to stabilizing the subtalar joint, functional foot orthoses provide contact to the cutaneous receptors on the plantar surface of the foot. This can provide a powerful enhancement of position sense of the foot and ankle complex during weightbearing.

Another benefit of utilizing functional foot orthoses post-ankle sprain is the neutralization of compensation mechanisms that lead to supination moment about the pedal joints. Specifically, forefoot valgus deformities and rearfoot varus deformities can be balanced or stabilized through appropriate intrinsic and extrinsic posting. Orthotic modifications for patients with lateral ankle instability include forefoot valgus sulcus wedging, deep heel cups, and lateral flanges added to a rearfoot post.

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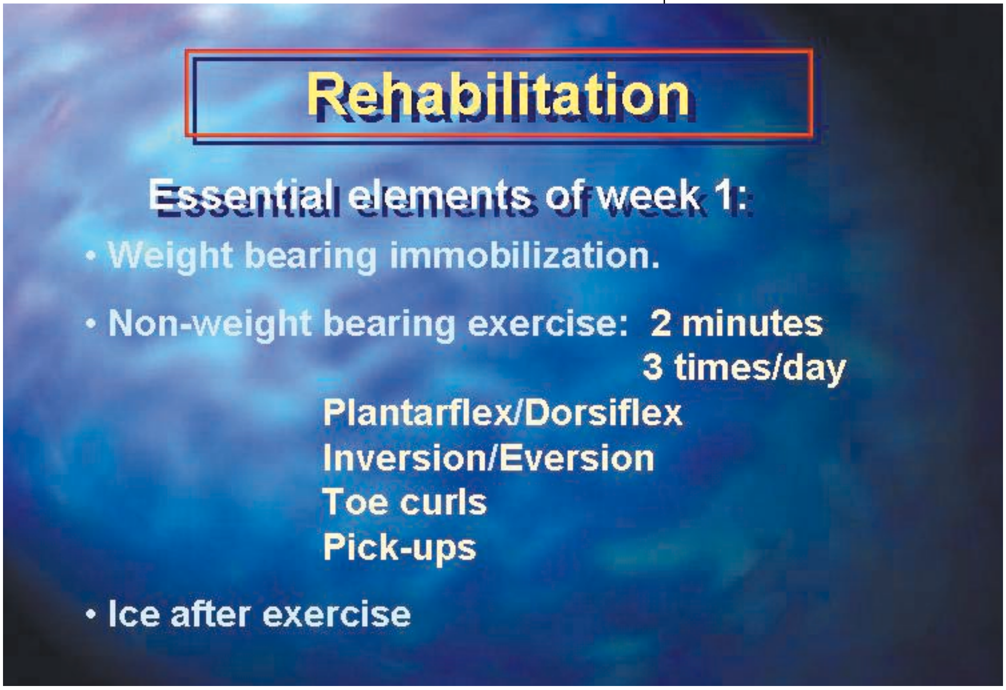


Rehabilitation

Essential elements of week 1:

- Weight bearing immobilization.
- Non-weight bearing exercise: 2 minutes 3 times/day
  - Plantarflex/Dorsiflex
  - Inversion/Eversion
  - Toe curls
  - Pick-ups
- Ice after exercise

Fig. 2

Circle #96

Biomechanics...

Summary

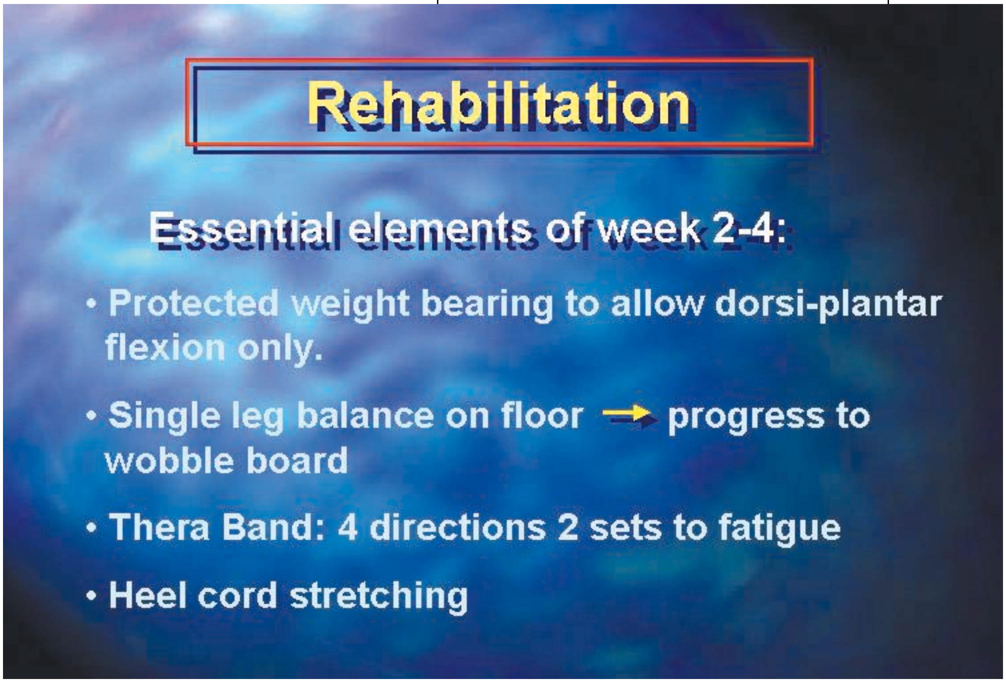
The foot and the ankle are interdependent in both normal and abnormal function. An ankle sprain cannot occur without supination torque delivered through a gearing mechanism from the pedal joints. Understanding and neutralizing abnormal movements of the foot can, therefore, be a powerful tool for the practitioner treating lateral ankle instability.

The talocrural joint has a natural position of stability in its dorsiflexed position. However, the primary restraints for both rotation and inversion of the talocrural joint are the anterior talofibular ligament and the calcaneal fibular ligaments. Significant loss of stability of the ankle joint occurs only after disruption of both of these ligaments.

Stability of the ankle joint is significantly enhanced by neuromuscular control. The components of neuromuscular control include proprioception, coordination, balance and muscular strength. All four components are significantly compromised after a first-time Grade II or Grade III ankle ligamentous injury.

Restoration of neuromuscular control and optimal biomechanical stability of the ankle joint is the primary goal of non-operative treatment of lateral collateral ankle ligamentous injuries. Early weightbearing with protected mobilization assures the proper combination of maximum stability with activation of neuromuscular recovery. Range of motion exercises accelerate collagen synthesis and ligamentous repair. The proper use of passive supportive devices during the various phases of ankle sprain rehabilitation are critical in providing the optimal conditions for repair and recovery. These passive supportive devices include removable camwalkers, functional ankle braces, and functional foot orthoses. ■

Orthotic modifications for patients with lateral ankle instability include forefoot valgus sulcus wedging, deep heel cups, and lateral flanges added to a rearfoot post.



Rehabilitation

Essential elements of week 2-4:

- Protected weight bearing to allow dorsi-plantar flexion only.
- Single leg balance on floor → progress to wobble board
- Thera Band: 4 directions 2 sets to fatigue
- Heel cord stretching

Fig. 3

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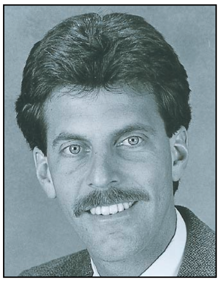

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EXAMINATION

See answer sheet on page 147.

1) Functional foot orthotic modifications recommended for the management of patients with lateral ankle instability include:
A) Valgus sulcus wedging
B) Deep heel cups
C) Lateral flange on rearfoot post
D) All of the above

2) The ankle joint is most stable in its position of:
A) Dorsiflexion
B) Plantarflexion
C) Neutral
D) External rotation

3) Wobble board training, post-ankle sprain, can provide the following therapeutic effect:
A) Improved strength
B) Improved proprioception
C) Improved balance
D) All of the above

4) As the ankle plantarflexes, the dynamic support mechanism strength of the peroneal musculature:
A) Increases
B) Decreases
C) Remains the same
D) Is variable

5) The following neuromuscular functions may be lost after a lateral ankle sprain:
A) Muscle strength
B) Muscle reaction time
C) Proprioception
D) All of the above

6) Axial loading of the ankle joint has the following effect on stability:
A) Increases
B) Decreases
C) No effect
D) Variable

7) The recommended time, post-injury, to begin weightbearing after a Grade II lateral ankle sprain is:
A) Immediately
B) Week one
C) Ten days
D) Three weeks

8) The primary ligamentous restraint to ankle inversion is:
A) Anterior talofibular ligament
B) Calcaneal fibular ligament
C) Spring ligament
D) Posterior talofibular ligament

9) The following muscles attach to the talus:
A) Tibialis anterior
B) Tibialis posterior
C) Extensor digitorum longus
D) None

10) With rotational instability of the ankle after lateral collateral ligamentous rupture, the tibia _______ rotates on the talus:
A) Internally
B) Externally
C) Forward
D) Backward

11) Which pedal joint movement immediately precedes talocrural inversion during an ankle sprain?
A) Lisfranc's joint
B) Midtarsal joint
C) Metatarsal phalangeal joint
D) Subtalar joint

12) It is estimated that up to ___ percent of patients with lateral ankle instability also have co-existing subtalar joint instability:
A) 10
B) 20
C) 50
D) 75

13) The vital proprioceptive receptors of the ankle are located in:
A) Ligaments
B) Tendons
C) Cutaneous receptors
D) B & C

14) Which of the following is <u>not</u> a component of neuromuscular control of the ankle?
A) Muscle strength
B) Proprioception
C) Subtalar alignment
D) Peroneal reaction time

15) The dynamic defense mechanism can be enhanced by:
A) High top shoes
B) Ankle braces
C) Athletic tape
D) All of the above

Continued on page 146

EXAMINATION

(cont'd)

16) In O'Donohue's classification, which Grade describes a complete ankle ligamentous rupture?
A) Grade I
B) Grade II
C) Grade III
D) Grade IV

17) Bracing the ankle after a lateral collateral ligament sprain may provide the following physiologic effects:
A) Increased isometric strength of the peroneal muscles
B) Enhanced proprioception
C) Reduced frontal plane movement
D) All of the above

18) After a Grade II or Grade III ankle sprain, plantarflexion of the ankle at rest causes:
A) Osseous instability
B) Separation of the torn ligaments
C) Enhanced proprioception
D) A & B

19) Re-apposition of torn lateral collateral ankle ligaments is best achieved by maintaining the ankle in a position of:
A) Dorsiflexion
B) Plantarflexion
C) Internal rotation
D) External rotation

20) Preactivation of the peroneal muscles can protect the ankle because:
A) Reaction time is shortened
B) Strength is increased
C) Proprioception improves
D) A & B

See answer sheet on page 147.

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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.

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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 check to: ***Podiatry Management*, P.O. Box 490, East Islip, NY 11730.** Credit cards may be used only if you are faxing or phoning in your test answers.

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 check to:

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

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 $15.00 per exam, or $99 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 $17.50 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, or American Express. If you are not currently enrolled, the fee is $17.50 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 payment may be used for fax or phone-in grading only.

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 a $15.00 check payable to Podiatry Management Magazine 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 $99.00 (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

EXAM #3/2001

Treating Ankle Sprains with Applied Biomechanics

(Richie)

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**

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:

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