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SPORTS THERAPY

Lateral and Syndesmotic
Ankle Sprain Injuries:
A Literature Review

Abstract

Ankle sprains are one of the most common sport related injuries. These types of injuries typically involve the supporting soft tissue structures on the outer aspect of the ankle, in particular the anterior talofibular ligament (ATFL). This paper is a literature review that discusses normal anatomy and biomechanics of the foot and ankle, mechanisms that may result in a lateral ankle sprain or syndesmotic "high ankle" sprain, assessment and diagnostic procedures, and presents a treatment algorithm based on normal ligament healing principles. An accurate diagnosis and prompt treatment can minimize an athlete's time lost from sport and prevent future re-injury. The majority of ankle sprains can be successfully managed using an aggressive non-surgical approach.

Introduction

Ankle sprains are the most frequent injuries sustained by athletes[1,2,3,4,5,6]. Literature reveals that ankle sprains may account for approximately 20%-40% of all athletic injuries[7,8,9]. Eighty-five percent of ankle sprains are caused by excessive inversion[10,24]. When the ankle rolls inward at a high velocity it may lead to stretching or tearing of the lateral ligament complex[5,11,12,13]. Ankle sprains are common among athletes who participate in sports that involve running on changing terrains, repetitive jumping, or frequent changes in direction, such as basketball, volleyball, soccer, football, and cross-country[14,15,16]. In basketball, the ankle may roll inward when a player awkwardly lands on an opponent's foot (Figure 1). The injured basketball player may have heard a popping noise. Symptoms may include pain, swelling, and joint stiffness. Depending on the severity of the injury, the athlete may be able to ambulate cautiously with little or no pain, or may be unable or only partially able to bear weight on the injured ankle[2,10,17,18].

Most ankle sprains can be treated successfully with an aggressive non-surgical care program that is tailored to the individual athlete[18,19,20,21,22,23,24,25,38]. The treating physician should have an understanding of the following: the anatomy and biomechanics of the foot and ankle; diagnostic skills to differentiate the type and grade of ankle sprain; knowledge of the different phases and approximate time frames of ligament healing; and the ability to recognize and rule out red flags that may necessitate a time period of complete immobilization, or surgery. Progression through treatment should be based on the science of ligament healing, the patient's symptoms, and the physician's clinical assessment[26].

Fig. 1 *Basketball Player Sustaining a Lateral Ankle Sprain*

Anatomy and Biomechanics of the Foot and Ankle

The ankle joint connects the lower leg to the foot and consists of two separate joints: the talocrural joint (ankle mortise) and the subtalar joint. The talocrural joint (TCJ) consists of the articulation of the distal aspect of the tibia and fibula with the talus (Figure 2)[38]. The distal aspect of the fibula is contained within a vertically oriented groove, the fibula notch, located on the lateral aspect of the tibia and situated between the anterior and posterior tibial tubercles[27]. The distal aspect of the tibia and fibula form a protective housing that surrounds and articulates with the superior aspect of the body of the talus, the trochlea. The medial border of the housing consists of the medial malleolus, the distal portion of the tibia; the superior border consists of the pilon, a horizontal expansion of the tibia; and the lateral border consists of the lateral malleolus, the distal portion of the fibula[10]. During gait, range of motion of the TCJ consists of ground reactive dorsiflexion when the tibia moves forward over the foot, and plantar flexion when the heel lifts off of the ground as the foot prepares for toe-off (Figure 3). Although variability exists, normal range of motion of the TCJ is 50° of plantar flexion and 20° of dorsiflexion[2,28,39].

Fig. 2 *Talocrural Joint (indicated by red demarcation)*

Fibula — Tibia
Anterior Tibial Tubercle
Lateral Malleolus
Medial Malleolus
Talus
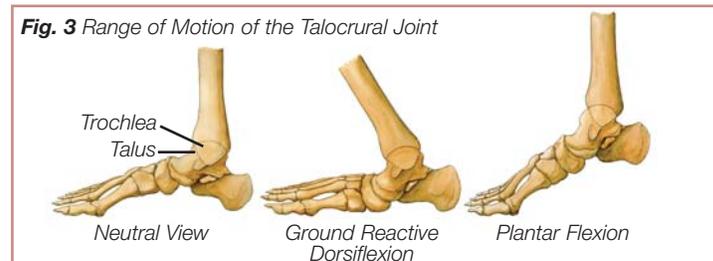
Fig. 3 *Range of Motion of the Talocrural Joint*

Trochlea
Talus

Neutral View　　*Ground Reactive Dorsiflexion*　　*Plantar Flexion*

Fig. 4 *Subtalar Joint (indicated by red demarcation)*
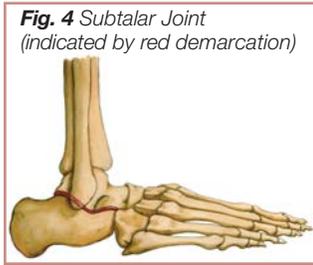
The subtalar joint (STJ) consists of the articulation between the undersurface of the talus and the calcaneus (heel bone) (Figure 4). Motion of the STJ consists of eversion (the heel pivots outward) and abduction (the foot turns away from the midline), or inversion (the heel pivots inward) and adduction (the foot turns towards the midline) (Figure 5). Although variation exists, average range of motion of the STJ is 25-30° of inversion and 5-10° of eversion. These ranges of motion are rarely exceeded during a normal walking or running gait[28,29]. Normally, "during the stance phase of gait on even ground the heel strikes with minimal inversion at the STJ followed by eversion ranging from 5-10° at 10% of the walking cycle. From there, inversion occurs at the STJ reaching a maximum of 5° at 62% of the walking cycle"[29].

Fig. 5 *Range of Motion of the Subtalar Joint (right foot)*

Talus

Calcaneus

Inversion   Neutral View   Eversion
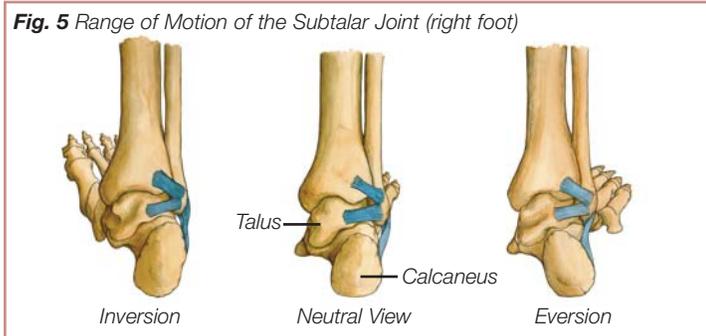
The talus is the centerpiece of the lower extremity that connects the lower leg to the foot through its articulations with the TCJ and STJ. Shortly after the foot strikes the ground, the foot and ankle go through a series of motions termed pronation[30,31]. Pronation of the foot and ankle consists of the following movement patterns: dorsiflexion of the TCJ, positioning the wider anterior aspect of the trochlea within the ankle mortise; eversion of the calcaneus at the STJ; and the distal aspect of the talus, the talar head, drops downward and inward. These adaptations maximize the surface contact area of the talus within the ankle mortise and the underlying calcaneus, temporarily transforming the ankle joint into a solid mass that connects the foot to the leg. Other motions occur during pronation that allow for increased mobility at the knee and midfoot articulations. The tibia rotates internally allowing the knee joint to flex, and the navicular bone, a tarsal bone anterior to the talus, advances forward thereby unlocking the midfoot articulations[28,29,30,31]. Under normal circumstances pronation of the foot and ankle permit the lower extremity to effectively absorb vertical and rotational forces associated with running, cutting, or landing from a jump without incurring injury.

Ligaments are soft tissue structures that connect one bone to another bone. The ligaments surrounding the ankle joint aid in providing passive support to the STJ and/or TCJ as these joints approach or exceed the end ranges of motion[2]. Ligaments are mainly constituted of dense parallel bundles of collagen fibers that are arranged in an undulating pattern (crimp). The crimp of the ligament has been equated to the action of a spring. When the ligament is placed under tension, the crimp of the ligament straightens, and collagen fibers are recruited to dissipate internal forces and resist excessive motion. If these forces do not exceed the mechanical strength of the ligament, pathological motion of the ankle is prevented and the crimp of the ligament recoils. However, if the load surpasses the mechanical strength of the ligament and is applied at a fast velocity that exceeds the speed of a corrective muscle reflex, it may lead to microscopic failure of the collagen fibers, or a complete rupture of the ligament[10,32].

Fig. 6A *Lateral Oblique View of the Ankle Joint*

Anterior Inferior Tibiofibular Ligament
Anterior Tibiofibular Ligament
Calcaneofibular Ligament

Fig. 6B *Posterior View of the Ankle Joint*

Syndesmotic Space
Posterior Inferior Tibiofibular Ligament
Posterior Tibiofibular Ligament
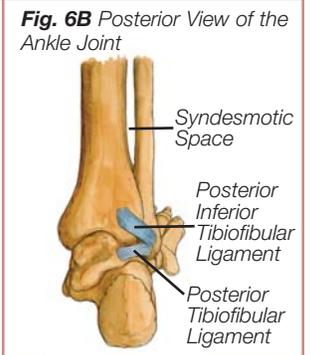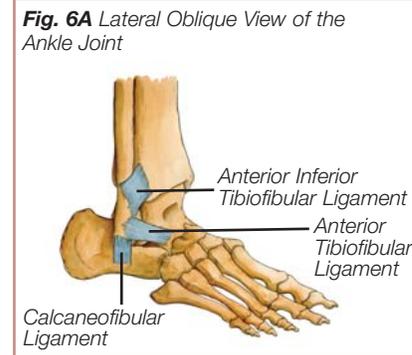
The ligaments that surround the ankle joint consist of the lateral collateral ligaments, syndesmotic ligaments, and the medial collateral ligaments. The lateral collateral ligaments consist of the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL) and the posterior talofibular ligament[1,33,34,38] (Figures 6A and 6B). The ATFL and CFL originate from the lateral malleolus; the former inserts onto the neck of the talus and the latter onto the calcaneus. The ATFL resists pathological inversion and plantar flexion of the ankle joint. The CFL resists excessive inversion of the ankle joint, and is further stressed at the end ranges of dorsiflexion[35].

The syndesmotic ligaments consist of the anterior inferior tibiofibular ligament (AITFL), interosseous ligament, posterior inferior tibiofibular ligament (PITFL), and the transverse ligament. The AITFL originates from the lateral malleolus of the fibula and travels medially, obliquely and proximally and inserts onto the anterior lateral tibial tubercle (see Figure 6A). The interosseous ligament lies underneath the AITFL and originates from the anterior inferior aspect of the lateral malleolus and inserts onto the anterior inferior aspect of the tibia. The PITFL originates on the lateral malleolus and inserts onto the posterior lateral tibia process (see Figure 6B), and the transverse ligament lies deep to the PITFL[2,10,26,27,38 41]. The function of the syndesmotic ligaments is to hold the fibula tight to the tibia, thereby preventing abnormal widening of the ankle mortise. During ground reactive dorsiflexion the posterior aspect of the talus rotates 5° externally within the ankle mortise, the fibula rotates 3-5° externally, and the ankle mortise widens 1-2mm[36]. Ogilvie-Harris et al conducted a study on cadaveric ankle models to evaluate the contribution of each syndesmotic ligament in maintaining an intact ankle mortise. The results indicated the following: AITFL 35%, PITFL 33%, interosseous ligament 22%, and the transverse ligament 9%[37].

The medial collateral ligaments consist of three superficial ligaments, the tibionavicular, tibiocalcaneal, and tibiotalar ligaments; and two deep ligaments, the anterior and posterior tibiotalar ligaments. These ligaments resist excessive eversion and external rotation of the ankle joint[10,35,38].

Dynamic Support Structures of the Ankle Joint

"Preservation of joint stability is dependent on synergistic function of bones, joint capsules, ligaments, muscles, tendons and sensory receptors and their spinal and cortical neural projections and connections in the brain"[32]. The dynamic support structures of the ankle consist of the muscles of the leg, associated tendons, and the proprioceptive fibers contained within the surrounding soft tissue structures. Proprioceptive fibers supply sensory afferent input in regards to joint position, and stimulate muscle reflexes to position the foot and ankle for proper joint function[10,32,40].

Tendons are non-elastic structures that attach muscles to bone and transfer forces generated by the attaching muscle across a joint. Muscles generate force through three types of contractions: concentric, eccentric, and isometric. A concentric contraction involves shortening of muscle fibers to generate a particular motion. An eccentric contraction is a controlled lengthening of muscle fibers to decelerate a particular motion. And an isometric contraction involves neither elongation nor shortening of muscles, and is useful in the initial stages of a rehabilitation program[42].

The peroneus longus and peroneus brevis muscles are located on the outside of the leg, and their tendons pass behind the lateral malleolus. The peroneus longus tendon travels diagonally underneath the foot, inserting onto the plantar surface of the medial cuneiform bone and the base of the first metatarsal, while the peroneus brevis tendon inserts onto the dorsal surface of the tuberosity of the fifth metatarsal bone (Figure 7). The tibialis anterior muscle is located on the front of the shin and attaches to the medial and inferior aspect of the medial cuneiform and the base of the first metatarsal bone (Figure 8)[43]. A concentric contraction of the peroneii musculature promotes ankle eversion. An eccentric contraction of the tibialis anterior musculature and adjacent extensor musculature of the anterior leg decelerate plantar flexion.
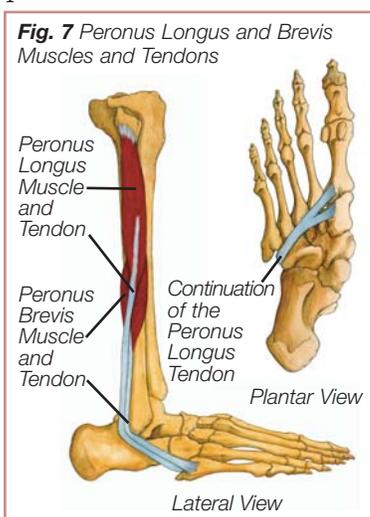
Fig. 7 *Peronus Longus and Brevis Muscles and Tendons*

Peronus Longus Muscle and Tendon

Peronus Brevis Muscle and Tendon

Continuation of the Peronus Longus Tendon

Plantar View

Lateral View

A normal stride depends on an accurate sense of joint position[44]. As the non-weightbearing leg prepares for initial ground contact (terminal swing) the lateral edge of the foot passes only 5 mm above the ground[45]. The optimal position of the foot and ankle during terminal swing would be in a slightly dorsiflexed and minimally inverted position. A lateral ankle sprain may occur if the lateral edge of the foot strikes the ground in an

Fig. 8 Tibialis Anterior Muscle
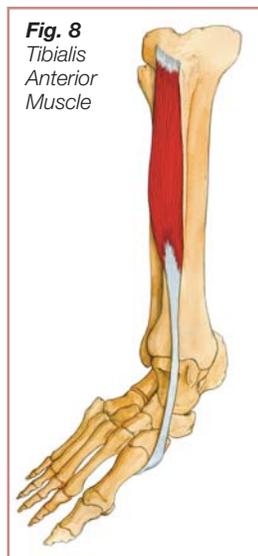
excessively inverted position. Results of previous studies have suggested that a proprioceptive muscle reflex response of the peroneal muscles would not be fast enough to prevent a sudden forceful inversion sprain mechanism. However, proprioceptive input can stimulate peroneal and tibialis anterior muscle reflexes correcting faulty foot biomechanics before initial ground contact[46].

Faulty movement patterns, trauma, or awkward landings may predispose to an ankle injury. Depending on the mechanism, an appropriate diagnosis of ligamentous injury can usually be ascertained[10].

Mechanisms of Ankle Sprains

Injury to the lateral collateral ligaments usually occurs when the athlete's center of gravity is shifted over the lateral border of the weightbearing leg, causing the ankle to roll inward at a high velocity[47]. The ATFL is the weakest of the lateral collateral ligaments and therefore the first to be injured[2]. Injury to the CFL may also occur in more severe sprains[48]. Mechanisms of injury may include landing awkwardly on an opponent's foot, catching the outer aspect of the foot on the ground terrain, or a slide tackle that contacts the inside of the opponent's weightbearing leg[11] (Figure 9). A study utilizing cadaver foot and ankle models revealed tearing of the lateral

Fig. 9 *Mechanism of a Lateral Ankle Sprain*

Injury of Anterior Talofibular Ligament
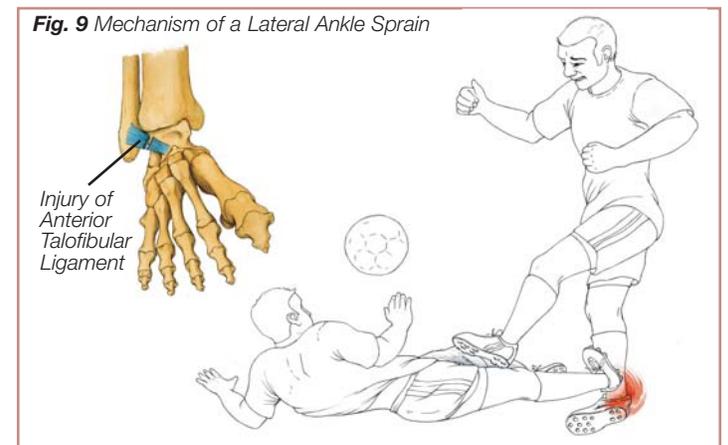
collateral ligaments when the talus inverts approximately 30-45° within the ankle mortise[10]. Other structures that may be injured during a lateral ankle sprain may include the peroneal tendons, lateral joint capsule, and the proprioceptive nerve endings found within these soft tissue structures[33,44]. Literature indicates that injury to joint mechanoreceptors may occur during an ankle sprain, resulting in proprioceptive deficits and poor ankle/foot biomechanics[49]. Reduced mechanical strength of the ligaments and proprioceptive deficits lead to joint laxity, and impaired dynamic support of the surrounding musculature[10,50].

Syndesmotic "high ankle" sprains constitute approximately 10% of all ankle sprains[10,38]. These sprains are more prevalent in high-energy contact sports or in sports that involve wearing a stiff boot or skate, such as hockey or skiing[41]. Examples of injury may include a skier that catches the inside edge of the uphill ski while attempting to avoid a gate, or a football player that pivots suddenly to the inside with the outside foot fixed on the playing surface (Figure 10). Both of

Fig. 10 *Mechanism of a Syndesmotic Sprain*

Injury of Anterior Talofibular Ligament
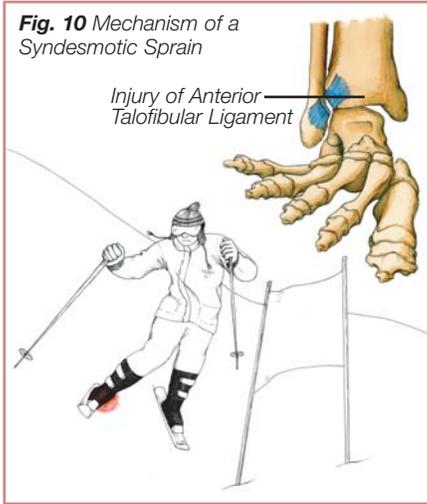
these mechanisms of injury may result in an excessive external rotation force on the fibula with respect to the tibia that may lead to disruption of the syndesmotic ligaments, in particular the AITFL[26,51]. Severity of injury usually depends on the magnitude of the force and how long it was applied to the ankle mortise. The rehabilitation time period for syndesmotic injuries tends to be longer than lateral ankle injuries. A recent study indicated that a syndesmotic sprain may require a treatment time period almost twice as long as a Grade 3 lateral ankle sprain[36,52].

Diagnosis

The examining doctor can usually determine the type and severity of ankle sprain based on the history and physical examination. The history should include the following:

- date of injury;
- mechanism of injury;
- presence of a popping sound at time of injury;
- ability to bear weight through the injured leg;
- past history of ankle injury, including treatment received;
- sport specific goals.

It is important to ascertain sport specific goals that may necessitate prompt diagnosis and more aggressive treatment procedures[2]. A detailed physical exam should follow the history.

The physical exam should begin with observation for gross abnormalities, edema, ecchymosis, neurovascular assessment, and palpation for areas of tenderness. Check the dorsal pedal pulse, capillary refill, and sensation to light touch. Edema may be quantified using a tape measure to make a figure eight measurement that encompasses the medial malleolus, lateral malleolus, navicular, and base of the fifth metatarsal[39]. Palpate for regions of tenderness over the lateral collateral ligaments, syndesmotic ligaments, deltoid ligaments, the osseous landmarks used in the figure of eight measurement, and the soft tissue structures of the leg.

The following Ottawa guidelines should be utilized to determine if radiographs are necessary: palpation that reveals tenderness over the medial malleolus, lateral malleolus, navicular, and/or base of the fifth metatarsal; an inability to bear weight immediately following injury or during the clinical evaluation; or tenderness that extends 6cm superiorly from the tip of either malleolus, not over the ATFL[1,38,41]. Radiographs should be performed immediately if gross abnormalities are visualized. Standard radiographic views include anterior to posterior, lateral, and ankle mortise. Even if radiographs are inconclusive, a Salter Harris Type 1 fracture should be considered in a skeletally immature patient if palpation elicits tenderness over the distal tibia or fibula growth-plates[2,53].

Goniometer measurements should be taken of active and passive ranges of motion of the injured and non-injured ankles. Active range of motion measurements assess the musculo-tendinous integrity of the gastocnemius/soleus complex, peroneus longus and brevis, tibialis anterior and extensor digitorum longus, and tibialis posterior by having the patient plantarflex, evert, dorsiflex, and invert the ankle respectively. Passive range of motion measurements of the injured ankle assesses joint integrity and is compared to clinical norms and measurements of the non-injured ankle.

The following orthopedic tests may prove useful in aiding diagnosis:[1,2,10,22,41,52,54,55,56]

- Anterior Drawer Test – Stabilizing the tibia and fibula, the foot is held in 20° of plantar flexion while the talus is drawn forward in the ankle mortise. This tests the integrity of the ATFL and anterior joint capsule. A positive test would be greater then 5 mm of anterior motion of the STJ as compared to the non-injured ankle, and an audible clunk may be elicited. If the ankle is inverted while conducting the anterior drawer test it also evaluates the integrity of the CFL.
- Talar Tilt Test – The ankle is held in anatomic position and the talus is tilted into adduction and abduction. This primarily tests the integrity of the CFL when the foot is in a neutral position; when the test is performed with plantar flexion it also evaluates the integrity of the ATFL. A positive test would be 5-10° of increased inversion as compared to the non-injured ankle and would be indicative of a tear of the CFL.
- External Rotation Test – Manual passive external rotation of the foot and ankle in a neutral or slightly dorsiflexed position would widen the ankle mortise. Pain over the distal syndesmosis is positive for a syndesmotic injury.
- Tibia/Fibula Squeeze Test— This test is positive for a syndesmotic sprain if compression of the tibia and fibula in the mid-calf region produces pain over the distal syndesmosis.
- Stabilization Test – Tape is applied around the distal syndesmotic region for support. A positive test for syndesmotic injury would be reduced pain over the distal syndesmosis during ambulation or when performing a heel raise.

These orthopedic tests should be conducted bilaterally. During the initial stages of injury the findings of these examination tools may be limited because of pain, swelling, and spasm. The anterior drawer and the talar tilt test are found to have a markedly increased sensitivity when performed 4-5 days after injury[38].

Examination findings of a lateral ankle sprain may include:

- Swelling observed distal to the lateral malleolus of the ankle that may extend to the foot if the lateral capsule is torn.
- Tenderness palpated over the ATFL, and in more severe cases the CFL.
- The Anterior Drawer and the Talar Tilt test may reveal joint laxity due to tearing of the ATFL and/or the CFL ligament.
- Stress radiographs may reveal excessive anterior translation of the talus, or inversion of the talus.

Lateral ankle sprains are based on a Grade 1-3 classification. A Grade 1 ankle sprain usually entails microscopic tearing of the ATFL. Symptoms may include minimal swelling and point tenderness directly over the ATFL; however, there is no instability and the athlete can ambulate with little or no pain. A Grade 2 ankle sprain involves microscopic tearing of a larger cross sectional portion of the ATFL. Symptoms may include a broader region of point tenderness over the lateral aspect of the ankle, a painful limp if able to ambulate, and bruising and localized swelling due to tearing of the anterior joint capsule, ATFL, and surrounding soft tissue structures. A Grade 3 ankle sprain entails a complete rupture of the ATFL and may also involve microscopic or complete failure of the CFL. The posterior talofibular ligament is rarely injured during inversion ankle sprains. Symptoms may include diffuse swelling that obliterates the margins of the Achilles tendon, inability to ambulate, and tenderness on the lateral and medial aspects of the ankle joint[2,38,57].

Examination findings of a syndesmotic sprain may include:

- Edema observed proximally to the ankle mortise.
- Tenderness palpated over the AITFL that may extend up the leg. The length of tenderness measured from the distal tip of the fibula proximally up the interosseous space has been called the "tenderness length". The "tenderness length" has been reported to correlate with the severity of a syndesmotic sprain[56].
- The external rotation test, squeeze test, and stabilization test may be positive.
- Standard or stress radiographs may reveal abnormal widening of the ankle mortise.

Syndesmotic sprains have been separated into 3 categories: (1) sprain without diastasis (pathological separation) of the ankle mortise; (2) latent diastasis, or diastasis that is only apparent after stress radiographs; and (3) frank diastasis that is usually accompanied by a fracture[26,27].

Dynamic ultrasound examination may prove useful in the early diagnosis and grading of syndesmotic sprains. In a preliminary study conducted by Mei-Dan et al., dynamic ultrasound examination was accurate in visualizing a tear of the AITFL and abnormal widening of the ankle mortise[36].

If symptoms persist after 6 weeks of therapy a CAT Scan (CT) or a magnetic resonance imaging test (MRI) may be considered[24,51]. These advanced imaging tools may aid in ruling out osteochondral lesions, tumors, or in re-evaluating the grade of injury[58,59,60,61].

Stages of Ligament Healing
Chronology of ligament healing has been separated into 3 distinct phases: inflammatory, reparative, and remodeling. The following healing chronology is based on a completely ruptured ligament.

The initial response to injury would be the acute inflammatory phase, lasting 24-72 hours. Damage to the blood vessels within the ruptured ligament and surrounding tissues result in a hematoma that fills the gap between the two retracted ligament ends. The capillaries surrounding the injured ligament increase in permeability resulting in swelling, and the migration of plasma proteins and leukocytes (white blood cells). The white blood cells engulf and eliminate the damaged cells and dead debris, a process termed phagocytosis. Chemical mediators are released during phagocytosis and promote new blood vessel formation, neovascularization. Oxygen and nutrients are now available for the process of tissue repair[10,18,32,62].

The reparative phase of healing begins 3-5 days post-injury. Dead or damaged tissue is repaired or replaced with healthy cells and connective tissue. At approximately 5 days post-injury the gap between the two retracted ligament ends is filled with granulation connective tissue, consisting of macrophages, new blood vessels, and fibroblasts. The fibroblasts produce proteoglycan and collagen, the subunits necessary for ligament repair. Collagen production intensifies, and by 10-14 days disorganized collagen now connects the two ligament ends. The ligament may now be able to resist low-level tensile forces.

The remodeling phase of healing begins 15-28 days post-injury. The newly formed collagen fibers align themselves longitudinally and cross linkages form. By 3 weeks, as collagen maturation continues, the ligament may regain approximately 60% of its tensile strength. By 3 months the ligament may regain its pre-injury strength.

The ligament healing process can be expedited by immediately instituting an aggressive non-surgical treatment protocol that initially minimizes pain, inflammation and swelling and incorporates early controlled motion. The treatment approach should be individualized and under the careful observation of the treatment staff. Studies indicate that early progressive rehabilitation has a favorable outcome in restoration of ligament tensile strength, encourages lymphatic drainage, restores proprioception, decreases muscle atrophy, and minimizes excessive arthrofibrosis or scarring[10,56].

Treatment
The goals of therapy are to accentuate the normal healing process and protect the ligament from further injury. The acronym PRICESMMS stands for proprioception training, modified activity, ice, compression, elevation, stabilizion, medications (Non-Steroidal Anti-Inflammatory Drugs, NSAIDs), mobilization, and strength training[19]. These rehabilitation techniques should be applied appropriately during each phase of treatment. Progression of the treatment plan depends on the severity of injury, the patient's response to therapy, and the achievement of goals during each treatment phase[37,38].

Acute inflammatory phase (24-72 hours): The initial goals of therapy are to limit inflammation, reduce pain, and protect from further injury[2,25,26].

- Ice therapy should be applied 20 minutes on/1 hour off throughout the day, with a compression bandage and the leg elevated above the heart. Cryotherapy reduces pain, edema, and secondary hypoxic damage to injured tissues[2,55,63,64].
- NSAIDs, electric muscle stimulation, pulsed ultrasound, anti-edema massage, and low-level laser therapy may help in reducing inflammation[2,26,32].
- Ankle pumps, 10-20 pumps/hour, should be conducted in a pain-free range to decrease edema and increase circulation[26].

- Ambulate-weightbearing as tolerated-with axillary crutches if necessary. A semi-rigid orthosis, lace-up style brace, or tape provides mechanical joint stability in the frontal plane[65,66].
- Depending on the severity of injury, pain-free modified activity can be utilized to maintain cardiovascular fitness. Examples of modified activity may include deep-water pool running, swimming with a pool bouy between the legs, or stationary cycling[21, 26,39].

A more cautious approach to treatment may be necessary if there is suspicion of a Grade 3 lateral ankle sprain[38]. In one of the author's opinion, if the initial examination reveals severe swelling, pain, and inability to bear weight, the athlete should be placed in a functional walking orthosis and instructed to ambulate with crutches in a non-weightbearing gait. NSAIDs, ice, compression and elevation should be utilized to attempt to reduce swelling and pain. A re-examination should be conducted 3 days later. If there is no observable improvement, an MRI study should be utilized to assess the severity of injury. If the MRI indicates a completely torn ligament the athlete should continue to follow the above regimen for approximately 4 more days, thereby allowing the retracted ligament ends to heal appropriately before progressing to the next stage of treatment.

A brief period of non-weightbearing (1-4 days) may be necessary in the initial treatment of a syndesmotic sprain where frank diastasis of the ankle mortise is not visualized on radiographs[56]. Early weightbearing may lead to undue stress on the injured syndesmotic ligaments, possibly predisposing to heterotrophic ossification in the interosseous space between the tibia and fibula[41]. In the case of a syndesmotic sprain that reveals diastasis of the ankle mortise > 6mm, surgical fixation with screws would be necessary to stabilize the ankle mortise and allow for proper ligament healing[26,37,51]. An intact ankle mortise is necessary when attempting to push off the ground to propel forward or for cutting activities of most sports[37].

Reparative phase (3-5 days, collagen production intensifies 10-14 days): Goals include reduce inflammation, facilitate the ligament healing process, restore active and passive ranges of motion, minimize loss of strength, maintain cardiovascular fitness, and start proprioceptive rehabilitation[21,25,26].

- Active or passive soft tissue techniques such as, Active Release Technique®, Graston Technique®, and transverse friction massage can be applied directly to the ligament and surrounding soft tissue structures to facilitate early ligament healing.

Numerous clinical studies support the use of transverse friction massage in the treatment of ligament sprains[67]. Recently Loghmani and Warden conducted a study on instrument-assisted cross-fiber massage (IACFM) and its effect on ligament healing. Bilateral medial collateral ligament (MCL) injuries were induced on the knees of 51 rodents. IACFM was commenced with a Graston® hand held tool on one of the rodent's MCLs 1 week post-injury, at a frequency of 3 sessions per week and for a minute duration. The contralateral MCL was utilized as the non-treated control. Histological sections were obtained 4 weeks post-injury. The scar region of the IACFM treated ligaments, as compared to the contralateral non-treated ligaments, appeared to have greater cellularity and the collagen fibers appeared to be aligned more longitudinally. This study suggests that IACFM may accelerate early tissue-level healing[68].

- Joint mobilization of the TCJ and the STJ to free up joint restrictions and aid in improving range of motion[2,26].
- Passive stretch of the gastrocnemius and soleus musculature with a towel, 3 sets of 30 second holds. Stretching on a slant board or with a pro-stretch can be incorporated when the patient can at least partially bear weight with minimal pain.
- Isometric exercise should be conducted as soon as the patient can tolerate them to prevent muscle atrophy[32]. Active and passive range of motion can be conducted with minimal pain in dorsiflexion, plantar flexion, eversion, and in the pain-free range of inversion. The therapist may conduct 3 sets of 10 with a 3-5 second hold at the passive end range. The patient can conduct isometric exercises at home.
- Strengthen the peroneii, tibialis anterior and extensors, and the triceps surae with Thera-Band, 3 sets of 10-15 reps for each muscle group26. Also strengthen the gluteus medius musculature to prevent lateral sway[47]. Once the patient can fully weightbear without pain he can add resistance greater than body weight as tolerated. This may include standing and seated calf raises. If no weights are available teach the patient to go up on the toes on both feet and then shift all the weight to the injured side and lower down on that leg.
- Standing proprioception training can be conducted on the floor, a wobble board, or an air filled cushion. Start with single leg standing (SLS) on a flat surface, 3 times with 30 second holds, use upper extremity support from a counter if necessary. Progress to eyes closed. Progress to exercises on an air filled cushion. Have patient balance on a wobble board for 30-60 seconds conducting various drills[3,18,39]. Proprioception training has been shown to reduce the occurrence and re-occurrence of ankle sprains[69,70].
- Proprioception training in the seated position with the Biomechanical Ankle Platform System (BAPS) board. BAPS board exercises activate the peroneus longus, tibialis anterior and gastrocnemius musculature[71]. Have the patient tap the BAPS board to the floor at 12 o'clock, 3 o'clock, 6 o'clock, 9 o'clock, and then add 1:30, 4:30, 7:30, and 10:30. Conduct 3 sets for 2 minutes each set. The patient may also alternate counterclockwise. When the patient can fully weight bear without pain, and has demonstrated proficiency in the seated position, the BAPS exercises can be conducted standing with upper extremity support as needed.
- Shoe gear modification depending on the athlete's foot structure and the playing surface[10].
- Modified activity can be progressed appropriately. A program to incorporate restoration of cardiovascular fitness with running may include a 5 minute warm up with walking, followed by a 3 minute run at a very easy intensity, followed by a 2 minute walk, repeat run/walk repetitions for 20-30 minutes. When the athlete can conduct a 20-30 minute run session without rest periods, and there is no noticeable pain or post-swelling, the weekly mileage can be increased by 10%. The

intensity of the training runs should only progress when the athlete regains the pre-injury duration[78,79].

- At the end of each treatment session apply ice therapy and other modalities to control inflammation[2].

The above exercises should be conducted relatively pain-free and progressed based on the patient's response to therapy and based on the principles of ligament healing. After demonstrating proficiency in conducting the exercises under the supervision of a therapist the patient can be given a home exercise routine. If there is an excessive increase in swelling or pain, temporarily reduce the intensity or duration of the exercises followed by inflammation control.

Remodeling phase

(15-28 days, 3 weeks regain ≅ 60% strength, 3 months regain ≅ 100% strength) Goals include restoration of tensile strength, proprioception, and return to sport[25,26].

- Modified training may progress and include activities such as jumping rope, higher intensity training runs or sprints.
- Incorporation of multi-directional agility drills can begin at this stage. Start with controlled exercises that are on both legs, then progress to single leg. Progress to jumping over a height, such as a low cone. Progress to increasing in speed. It is important to vary the speed and intensity of sport-specific exercises in order to continually challenge the proprioceptive system[80]. All progressions should be performed only as pain, comfort and stability allow.
  – Begin jumping forward and backward over a line.
  – Progress to jumping laterally over a line.
  – Progress to box drills: Draw a box on the floor with tape and number the boxes starting in the upper-left corner and progressing clockwise. Jump from box 1-4, landing as close to the exact middle of the box as possible. Variations include reversing order from box 4-1 and adding diagonal patterns such as 1,3,4,2.

1	2
4	3

- Incorporate multi-directional sport-specific proprioceptive exercises once the athlete is able to perform the proprioceptive exercises described in the reparative phase.
  – On level ground, begin single-leg standing exercises incorporating sport-specific exercises such kicking a ball, catching and throwing a ball, or swinging a bat. Progress to standing on an air-filled or foam cushion.
  – Begin by keeping the exercise, such as catching a ball, close to the body. Progress to throwing the ball farther from the body to force the athlete to shift his center of gravity. (Figures 11A and 11B)
- Ladder drills can be incorporated with the athlete's program. This stage is used to create exercises and movement patterns that will increasingly challenge the neuromuscular coordination of the injured athlete. Example A: Side-Shuffle: The athlete begins with both feet at position 1 where the L and R are located. Moving the left foot first to outside of the box in front, then the right into the box next to it. Proceed as depicted.

Example B: Carioca: Step over with the left leg first, then behind with the right leg.
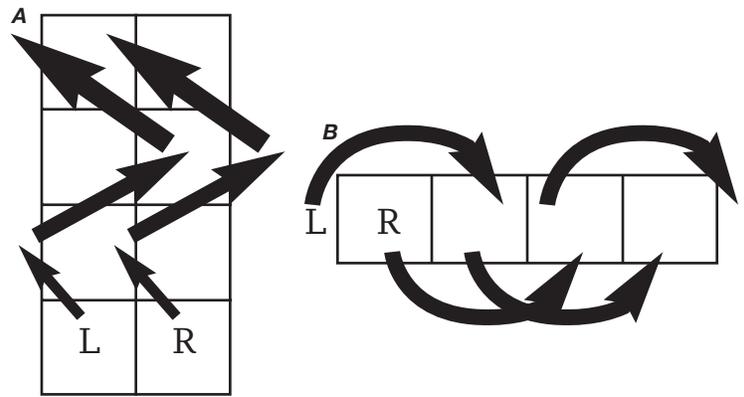
The above exercises prepare the athlete to begin sport-specific drills. The athlete must be able to demonstrate proficiency in stopping, changing direction, jumping, and landing as pertaining to the specific sport before returning to practice or competition. A supportive ankle brace or taping has been shown to be an effective aid in preventing re-injury without impeding performance[72,73,74,75]. Technical training (on jumping and landing), proprioceptive training and orthosis have all been shown to decrease risk of re-injury, with technical training and proprioceptive training being more effective in those with a history of four or more sprains[81].

Poor compliance with therapy may predispose to functional instability of the ankle. The athlete may complain of impeded sport performance due to the feeling that the ankle is unstable and fear of re-injury. Although the injured ligament may have regained pre-injury tensile strength, complete proprioception rehabilitation may take longer. Upon initial return to sport the athlete should continue to support the ankle with tape or a brace[76]. To prevent re-injury proprioception rehabilitation should continue until the athlete demonstrates improved functional skills particular to the individual sport.

After being discharged from care the athlete should be encouraged to continue a home exercise program to ensure full restoration of impairments and to prevent re-injury. McHugh et.al. had football players with a history of ankle sprains perform single-leg stance on a foam stability pad for five minutes each leg. This was done five days a week for four weeks of preseason, and two days a week for nine weeks during the season. This

Fig. 11A Proprioception Training Close to the Center of Gravity

Fig. 11B Proprioception Training with Center of Gravity Shift

was the only preventative exercise used, and was done on their own. The study showed a 77% decrease in injury incidence[82]. A study by Hupperets et.al. showed a similar decrease in injury risk with unsupervised exercises, demonstrating that a home program can be an effective tool in rehabilitation[83].

Conclusion:

Ankle sprains are one of the most common lower extremity injuries. The majority of these injuries respond favorably to an aggressive non-surgical treatment approach[2]. A comprehensive history and examination aid the therapist in diagnosing the severity and type of ankle sprain. Based on the diagnosis and an understanding of ligament healing properties a progressive treatment regimen can be developed utilizing PRICESMMS. During the acute inflammatory phase the goal of care is to reduce inflammation and pain, and to protect the ligament from further injury. During the reparative and remodeling phase the goal is to progress the rehabilitation appropriately to facilitate healing, and restore the mechanical strength and proprioception.

Radiographic imaging techniques may need to be utilized to rule out fractures, complete ligament tears, or instability of the ankle mortise. A period of immobilization and ambulating with crutches in a non-weightbearing gait may be necessary to allow for proper ligament healing before commencing a more active treatment approach. Surgery should be considered in the case of Grade 3 syndesmotic sprain injuries or those ankle sprains that are recalcitrant to conservative care[77].

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