1 Acute Ankle Ligament Injuries

Kenneth J. Hunt and Peter Lawson

1.1 Introduction

Acute lateral ligament sprains of the ankle are a common injury for patients and athletes and a burdensome healthcare issue for hospitals. While in general a relatively well-understood and treatable injury, lateral ankle sprains and recurrent injuries are very common and predictive and prognostic factors are still not entirely understood. In the treatment of these injuries, it is important for providers to have a clear understanding of injury mechanisms and identify patients at risk for recurrent injury and chronic instability. In order to select appropriate treatment strategies, the provider must understand not only the severity of the injury but also the mechanisms and contributing factors that lead to lateral ankle ligament injuries and chronic instability. As new surgical and rehabilitation techniques evolve, understanding of both natural and injury mechanics is critical.

1.2 Epidemiology

Ankle sprains continue to be a prevalent and costly healthcare issue with estimates suggesting that ankle sprains account for 7–10% of emergency department admissions [1]. By other estimates, injury to the lateral ligaments of the ankle joint can account for about 1 in 10,000 people a day [2]. Generally, lateral ankle sprains are much more common than syndesmotic and medial ankle sprains [3].

Rates of incidence vary across gender, race, and age—black and white adolescent females are recognized as the populations most at risk for ankle sprains. Racially, black patients and white patients have shown incidence rates three times greater than Hispanic patients [4]. Generally, females have shown to be at a higher risk for ankle sprain injury than males, reporting 13.6 vs. 6.94 ankle sprain injuries per 1000 exposures [3]. However, there is some evidence that suggests that among patients 15–24 years, males present with higher rates of ankle sprains than females, but among patients older than 30 years, females have higher incidence rates than males [4]. It is important to take into consideration that while lateral ankle sprains are more common among female patients, medial and high ankle sprains generally show lesser or no gender differences [5]. Among youth, children are at higher risk than adolescents, and adolescents at higher risk than adults, reporting 2.85, 1.94, and 0.72 ankle sprain injuries per 1000 exposures, respectively [3].

Sports activities are widely recognized as the environment where participants are most prone to ankle injuries. This is particularly true of sports that involve jumping and changes in direction.

K. J. Hunt (✉) · P. Lawson
Department of Orthopaedic Surgery, University of Colorado School of Medicine, Aurora, CO, USA
e-mail: kenneth.j.hunt@ucdenver.edu

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Among youth sports, injury to the lateral ligaments of the ankle joint accounts for approximately one-fourth of all sports-related injuries [2]. Half (49.3%) of ankle sprains occur during athletic activity, 41.1% of which are associated specifically with basketball [4]. Analysis of injury risk by gender and sport has shown that female basketball athletes are considered most prone to first-time inversion ankle ligament injury [6]. Male basketball athletes and female lacrosse athletes are also considered high risk to injury [6]. Football and soccer also have high associations with ankle sprains [4].

Collegiate sports are a more unique domain of interest as it includes large athlete populations commonly recognized for the higher stakes of competition, levels of training, greater athlete size, strength and speed, and demand to return to play. It is estimated that among the 25 most common NCAA sports in the United States, there are over 16,000 lateral ligament complex (LLC) ankle sprains each year—accounting for approximately 7.3% of all collegiate sport injuries [7]. LLC sprains are regarded as the most common injury in college sports in the United States, occurring at a frequent rate of 1/2020 (4.95/10,000) athlete exposures—more specifically, the most frequent LLC sprain rates are in men's and women's basketball, which report at 1/836 (11.96/10,000) and 1/1052 (9.5/10,000), respectively [7]. Recurrence of LLC sprains is well recognized as an area of importance when monitoring and treating athletes. Studies have shown that among collegiate athletes 11.9% of LLC sprains are attributed to recurrence. Recurrent injuries are most frequent in women's sports—specifically basketball (21.1%), outdoor track (21.1%), field hockey (20.0%), and tennis (18.2%) [7]. The sports with the most frequent recurrence rate among males include basketball (19.1%), tennis (14.3%), outdoor track (14.3%), and soccer (14.0%) [7]. Rapid identification and treatment of the competitive athlete is paramount. Reassuringly, 44.4% of athletes who suffer an LLC sprain are able to return to play within 24 hours [7]. Alternatively, 3.6% of athletes have higher grade injuries and require more than 21 days before returning to play, with some unable to return [7]. Thus, it is very important to reduce the incidence, severity, and recurrence of LLC sprains [7].

1.3 Anatomy

The ankle joint complex is multiplanar and is made up of the subtalar (talocalcaneal) joint, the tibiotalar joint, and the transverse-tarsal joint [8]. Each of these joints has a particular plane of motion and a specific function associated with it. The subtalar joint allows for ankle inversion and eversion, and the joint is primarily linked via the interosseous talocalcaneal ligament which connects the inferior articular facet of the talus to the articulating facet on the superior surface of the calcaneus [8]. The tibiotalar joint primarily functions is a hinge joint, in the plantarflexion and dorsiflexion movements of the foot [8]. The motion of this joint is limited by three groups of ligaments—the tibiofibular syndesmosis, the medial collateral ligaments, and the lateral collateral ligaments [8]. The transverse-tarsal joint is a combination of articulations between the talus, the calcaneus, and the navicular, and shares an inversion-eversion axis of motion in the foot [8].

Ligaments are an essential structural feature in the ankle joints, providing stability and controlled range of motion across each specific joint. The lateral ligament complex of the ankle is made up of the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and the posterior talofibular ligament (PTFL) [1]. The medial (deltoid) ligament complex of the ankle is made up of the deep components—the anterior tibiotalar ligament (ATTL) and the posterior tibiotalar ligament (PTTL)—and the superficial components—the tibionavicular ligament (TNL), the tibiospring ligament (TSL), and the tibiocalcaneal ligament (TCL) [9] (Fig. 1.1).

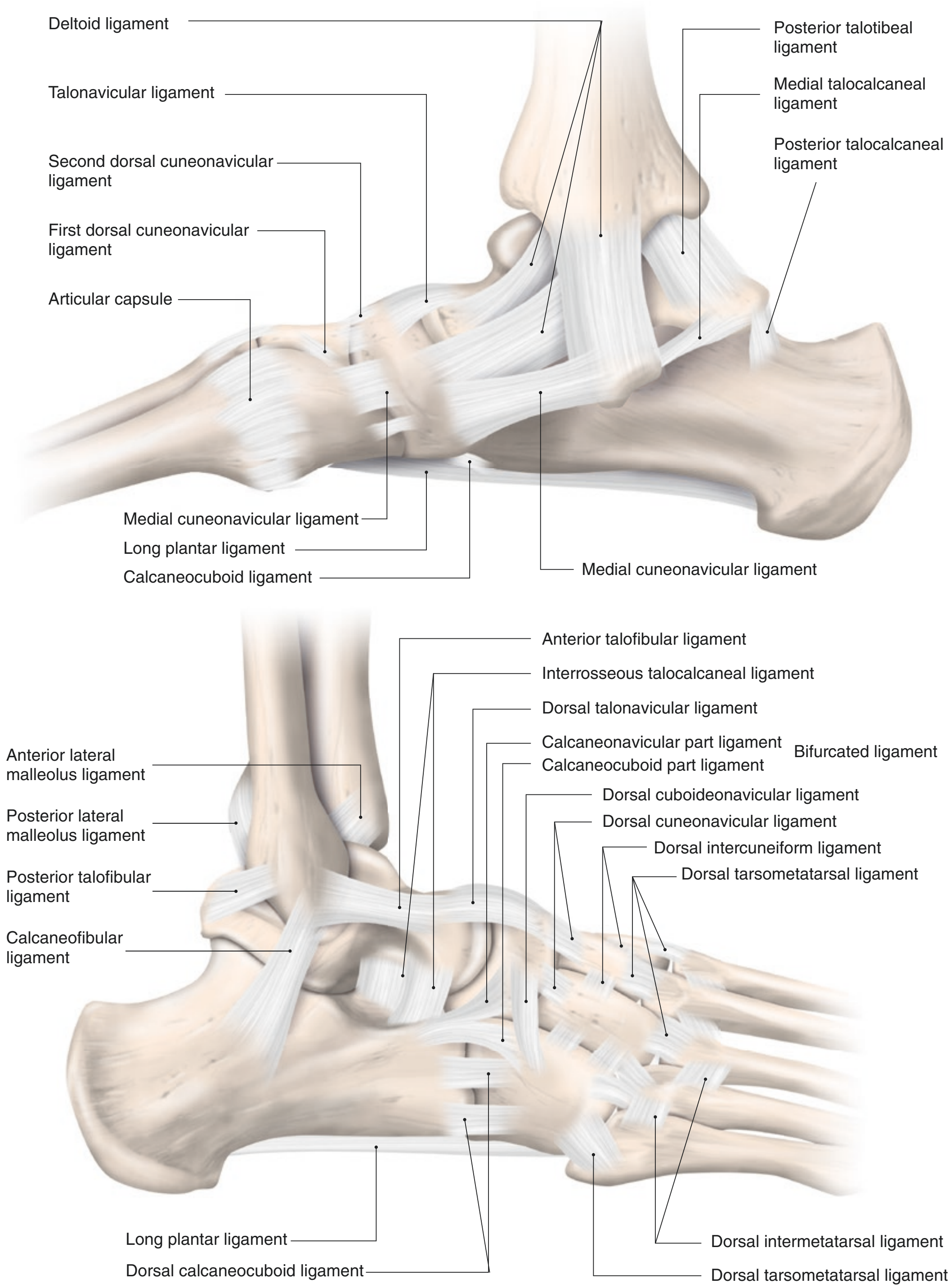

Fig. 1.1 Drawing depicting the ligaments on the medial (**a**) and lateral (**b**) side of the ankle joint

The stability of the ankle joint is multifactorial—many intrinsic elements (articular geometry) and extrinsic elements (ligaments) contribute to supporting the ankle joint [10]. These primary contributing elements also depend upon other factors such as ground condition, loading level, and the direction and magnitude of applied forces when loading and unloading [10]. When considering the articular geometry of the ankle, it is important to recognize that the talus has the bone morphology of a truncated cone, where the medial radius of curvature is lesser to the lateral radius of curvature, but there is variance in the medial-lateral distribution [11]. These structural variances explain the occurrence of high-risk ankles via their alteration in joint mechanics within the ankle [11]. A relatively high bone congruency across the tibiotalar joint distributes the applied loads across the large load-bearing surface area to mitigate impact stress on the ankle—some theorize even more effectively than the hip or knee [8]. Regarding stability of the ankle joint, the value of the high bone congruency has shown that when loaded (1 BW), articular geometry contributes 100% to translational stability and 60% to rotational stability [10]. Ligamentous stability is recognized as the other primary element contributing to ankle joint stability. The anterior stability of the ankle is approximately 70–80% dependent upon the lateral ligaments, when unloaded [10]. The posterior stability of the ankle is approximately 50–80% dependent upon the deltoid ligaments, when unloaded [10]. The rotational stability is 50–80% dependent upon both the lateral and deltoid ligaments, but medial-lateral stability is not primarily dependent upon these ligaments [10]. Due to the unique geometry of the tibiotalar joint, it is recognized that the ankle is more stable in dorsiflexion and less stable in plantarflexion [10, 12].

1.4 Ankle Joint Complex Biomechanics

Direction and ranges of motion of the ankle joint are complex. The ankle joint primarily moves in plantarflexion-dorsiflexion, with the addition of variable amounts of inversion-eversion (and abduction-adduction), allowing for more complex motions like supination and pronation [8]. The degree of multi-axial motion throughout the tibiotalar, subtalar, and transverse-tarsal joints varies depending primarily on the variance in talar anatomy and tissue stiffness [8]. However, typical range of motion for these joints from a neutral stance has been shown to be as much as 20° of dorsiflexion, 55° of plantarflexion, 23° of inversion, and 12° of eversion [8].

When assessing athletes with acute or chronic ligament injuries, it is important to understand the fundamentals of a gait mechanics to appreciate the impact, distribution of force, and flexion of muscles throughout the gait phases. A normal gait is comprised of a stance phase—which is further subdivided into heel rocker, ankle rocker, and forefoot rocker subphases—and a swing phase [8]. The heel rocker phase begins when the heel strikes the ground and ends when the foot is flat—during which the ankle is in a slight plantarflexed position, and the dorsiflexor muscles exhibit eccentric contraction [8]. The ankle rocker phase is transitional phase from plantarflexion to dorsiflexion about the tibiotalar joint [8]. The forefoot rocker phase begins when the heel of the calcaneus lifts off of the ground and ends when there is toe-off from the ground—this is marked at 50% of the gait cycle during which active plantarflexion generates the maximal joint power that propels the walker forward [8]. The swing phase activates slight dorsiflexion to better ensure foot clearance of the ground, before returning to plantarflexion in the heel rocker phase [8]. Inversion complements the plantarflexion at heel strike, and eversion compliments the plantarflexion throughout the forefoot rocker phase, as both biplanar motions are enabled by the subtalar joint [8].

The load and applied forces are skillfully distributed about the ankle joint throughout ones walking gait. The amplitude of the vertical component of the ground reaction force peaks at approximately 1.0–1.5 body weight, with slight proportional increase depending on walking speed [13]. On the superior surface of the talus, the tibiotalar joint bears 83% of the load and the fibulotalar joint bears 17% of the load [14]. Seventy-seven to ninety percent of the load on the tibiotalar joint is applied on the surface of the talar dome with an appreciable loss across the medial and lateral gutter surfaces [15]. The relatively high bone congruency across the tibiotalar joint is credited for guiding the distribution of loading forces primarily through the tibiotalar joint to mitigate irregular location and magnitude of impact stress on the ankle [8].

1.5 Mechanism of Injury

The most common mechanism of injury to the lateral ligament complex is inversion of the ankle with the foot in plantarflexion [1, 11]. Of the lateral ligaments, a tear of the anterior tibiofibular ligament (ATFL) is most common, particularly in athletes, followed by the calcaneofibular Ligament (CFL) [16]. Other common ligaments injured include PTFL, the cervical ligament and the talocalcaneal ligament—which is more commonly injured when in dorsal-varusflexion [11]. Common symptoms associated with the acute ankle sprains include pain, range of motion deficit, postural control deficit, and muscle weakness [17].

Ankle sprains are graded, and treated, based on their severity, and the treatment protocol is guided by grading. Severity of ankle sprains is graded I—mild, II—moderate, III—severe [16]. Grade I and II injuries are typically successfully treated by nonoperative management and functional treatments—this includes the use of RICE (rest, ice, compression, elevation), brief immobilization and protection, early range of motion, neuromuscular training, proprioceptive training, balance, and weight-bearing exercise [16]. Treatment of grade III injuries can be more complicated [16]. Grade III "sprains" involve complete tearing of the ATFL and CFL ligaments and much or all of the PTFL. Since the ligamentous complex is completely ruptured, these injuries must necessarily be managed differently. Immobilization, swelling reduction, and functional rehabilitation are initiated to help the ankle recover more quickly while avoiding risks of other complications and sequelae [16]. However the use of surgical repair techniques for primary treatment is growing in popularity given the effectiveness of modern rehabilitation techniques, and the lost time and recurrent injury rates associated with high-grade ligament tears [16, 18].

1.6 Concomitant Injury Considerations

Further complications stemming from injury to the lateral ligaments of the ankle joint often include acute pain local to the site of injury, residual complications such as joint instability, stiffness, swelling, peroneal tendon injury, avulsion fractures, cartilage damage, and recurrent injury that increases the risk of long-term joint degeneration [2]. Common sequelae that occur in 10–30% of patients with chronic lateral ligament injuries include synovitis, tendinitis, ankle stiffness, swelling, pain, nerve stretch injury, and muscle weakness [16]. Pain in the limb, sprain of the foot, and abrasion of the hip/leg are complications that have been found to be more common in lateral ankle sprain events than medial joint injury [5].

1.7 Chronic Ankle Instability

Chronic ankle instability (CAI) is classified by the persistence of lateral ankle sprain symptoms—including pain, range of motion deficit, postural control deficit, and muscle weakness—however the true cause remains controversial [17]. Chronic mechanical instability is characterized by general laxity which is associated with ligament lesions and other complications including impingement, osteochondral lesions, and fibular tendon pathology [11]. Postural factors and proprioceptive deficiencies also favor functional instability and should be evaluated and considered during treatment of chronic ankle instability [11].

There remains debate and uncertainty regarding the factors and mechanisms that contribute to chronic ankle instability. Some challenge the theory that kinematic variations are a significant mechanism contributing to CAI—as a study showed lower limb kinematics during forward and side jump landing tasks were not different when comparing CAI to healthy subjects [19]. Other studies suggest that while proprioceptive deficits, neuromuscular changes, muscle strength, postural changes, and central adaptations have been shown to contribute towards CAI, the direct mechanism by which these factors lead to CAI remains poorly understood [19–21].

1.8 Risk Factors

Given the ubiquitous nature of ankle ligament injury, and differences in study populations, there are an array of risk factors for recurrent injury and CAI. These include, but are not likely limited to, sex, weight, height, limb dominance, ankle joint laxity, anatomical alignment, strength, reaction time, and postural sway [22]. Factors that have been shown to correlate with an increased risk of lateral ankle sprain include increased body mass index, muscle strength (slow eccentric inversion strength, and fast concentric plantarflexion), proprioception (passive inversion joint position sense), and muscle reaction time (earlier reaction time of the peroneus brevis) [23]. There is inconclusive evidence regarding the associations between decreased ankle eversion strength and delayed ankle evertor reaction time, and lateral ankle ligamentous sprains [23].

Generalized ligamentous laxity is considered a risk factor for instability recurrence following modified Broström procedure for chronic ankle instability [24]. Other metrics that have been shown to be associated with clinical failure following use of the modified Broström procedure for chronic ankle instability include syndesmosis widening, osteochondral lesion of the talus, high preoperative talar tilt angle (>15°), and high preoperative anterior displacement of the talus (>10 mm) [24]. Further research suggests determining additional predictive factors and grading chronic ankle instability to improve patient outcomes, and to better evaluate better treatment options to prevent early failure, including anatomic ligament reconstructions, nonanatomic ligament reconstructions, additional augmentations, tendon grafts, and suture tape [24].

1.9 Evaluations and Diagnosis

Prompt and thorough examination of the ankle is of great importance when assessing ankle sprain injuries. Physical examination within 4–5 days of traumatic injury provides the highest quality diagnosis [1]. Diagnostic features often include swelling, hematoma, local pain on palpation, and a positive anterior door test [1]. When assessing a patient with an ankle sprain, it is important to test for ligamentous disruption and ligament function [16]. There are two main clinical stability tests used—these include the anterior drawer test, which tests ATFL function, and the inversion tilt test, which tests ATFL and CFL function [16]. Further assessment may include radiographic imaging to assess ligament injuries [16]. It is important to be cognizant of the situational needs of your patient. While the Ottawa rules may be applied, weight-bearing ankle radiographs are very helpful to obtain in athletes with higher grade injuries since assessing alignment and identifying fracture, articular or other bony injury can be very useful for treatment. While less common in the lay person, ultrasound and MRI are more commonly used to diagnose associated injury and are routine evaluations in athletes [1]. As always, it is important to consider and balance both the timeliness and accuracy of these evaluations as patients' risks, benefits, costs, and desires vary by injury and by individual [1].

1.10 Treatment

Beneficial treatment methods for acute lateral ligament injuries in the ankle joint include functional treatment, immobilization, NSAIDs, and sometimes surgery [2, 25]. The majority of acute lateral ankle ligament injuries can be managed without surgery, most commonly protected by a semi-rigid ankle brace [26]. Braces have been shown to reduce risk of reinjury following an ankle sprain [22].

Initially, nonsurgical treatment is used to treat mild, moderate, and severe ankle sprains. RICE (rest, ice, compression, and elevation) therapy is commonly used as it is beneficial in reducing pain and swelling in the first 4–5 days following injury [1]. Beyond immediate treatment, immobilization (below knee cast or removable boot) provides treatment of pain for 5–10 days [1]. It is important to note that while immobilization is a common and effective treatment in reducing pain in swelling in the first 7–10 days, it can worsen symptoms if used for more than 4 weeks [2, 25]. RICE, ankle braces, and immobilization remain the most common and effective nonsurgical treatments; however questions still remain concerning which nonsurgical treatments are associated with the lowest re-sprain rates [26].

Surgical treatment is recommended for severe ankle sprain injuries that do not resolve with the initially conservative nonsurgical treatment methods, chronic ankle instability, and injureis with certain associated injuries or pathology. The details of these procedures are explored in later chapters. The goal of ankle ligament repair or reconstruction is to restore soft tissues to the anatomic condition prior to their instability, trauma, or arthritis [10]. Modifications of the Broström procedure are the primary technique used for surgical treatment of lateral ankle instability, specifically ATFL repair; however surgical techniques continue to warrant need for improvement [27]. Surgery may provide increased joint stability, but it is important to consider potential risks of each surgical approach [2, 25]. Surgical repair should be considered on an individual basis, particularly for patients with chronic instability and grade III injuries [26].

Beyond surgical reconstruction and traditional nonsurgical treatment, a few alternative treatment methods are used but effectiveness in improving symptoms remains poorly understood—these treatments include cold treatment, diathermy, homeopathic ointment, physical therapy, and ultrasound [2, 25]. Additionally, neuromuscular balance training has shown to be an effective preventative treatment for patients with previous sprains [26].

When treating athletes, there is a trend toward more aggressive treatments such as surgery for professional athletes with acute grade II or III injuries, as this may provide better long-term stability and mitigate risk of recurrent injury and asociated injur, or prolonged missed time from sports participation [1].

1.11 Prognosis

The vast majority of patients do well following lateral ligament injury and following lateral ligament repair. Barring major concomitant injury (e.g., osteochondral injury), most are able to return to their previous level of function. Prognostic factors for acute lateral ankle sprains remain somewhat elusive in aggregate [28]. Age has demonstrated prognostic value in some studies, but not all [28]. Independent predictors of poor recovery may include but are not limited to female gender, swelling, pain, limited range of motion and ability, injury severity rating, and MRI determined sprained ligaments [28]. Recent work suggests that generalized ligamentous laxity may be an independent predictor of clinical failures and poor radiological outcomes following modified Broström procedure for chronic ankle instability [24].

1.12 Ankle Arthritis and Salvage Strategies

Post-traumatic osteoarthritis, and other degenerative processes, can negatively impact the biomechanical functions of the foot and ankle [29, 30]. Furthermore, a decrease in muscular strength associated with increasing age demonstrates a reduction in the range of motion in the ankle joint across both genders [12]. However, while younger age females (20–39 years) have a higher range of motion than males, elderly women (70–79 years) demonstrate less dorsiflexion and greater plantarflexion comparatively to elder men [12]. These changes in bone strength, muscle strength, and range of motion are important considerations to take particularly when treating more elderly patients.

More complex surgical treatment methods arise for patients whose lateral ankle sprain or chronic ankle instability may be complicated by other factors such as age and arthritis. Total ankle joint replacement is a common surgical intervention considered for end-stage ankle osteoarthritis, as total ankle replacements have shown improvements in walking speed, spatio-temporal function, and range of motion, in exchange for reductions in ankle joint moments and power [29, 30]. Ankle arthrodesis via fusion of the tibiotalar joint into a fixed position is another surgical consideration—this treatment option has been shown to improve walking speed and spatio-temporal function, but a reduction in the range of motion of the joint may result in adjacent joint osteoarthritis and other complications including malalignment, non-union, dysfunction, and pain [31, 32].

1.13 Economics

Ankle sprain emergency department admissions can be costly for both the patient and the hospital [1]. A very high recurrence rate of lateral ankle sprains contributes to significant medical expenses—mainly attributed to care, prevention, and secondary disability [17]. There are nuances that differentiate the costs and related care between various ankle sprain injuries and their treatments. Emergency room treatment of lateral ankle sprains (US $1025) are relatively more costly than medial ankle sprains (US $912), but are comparable in costs for high ankle sprains (US $1034) [5]. These numbers do not include subsequent visits to a specialist, physiotherapy, and related treatments, let alone the costs of those that become chronic and/or require surgical repair. Among sources of expenses, medial ankle sprains are more likely to include diagnostic radiology, lateral ankle sprains are more likely to include medications, and high ankle sprains are more likely to include hospitalizations [5].

When treating patients with an ankle sprain, it is important to consider cost-effective treatment options. One study suggests using the Ottawa ankle rules diagnostic decision aid to exclude fractures of the ankle and mid-foot, rather than using radiographs, as a means of reducing radiograph expenses [33]. Furthermore, semi-rigid ankle braces worn during sports activities have shown to be a more cost-effective secondary intervention for preventing recurrence of ankle sprains than neuromuscular exercise training [34]. Additionally, proprioceptive balance board training programs targeted at players with previous ankle sprains that are prone to recurrence may prove to be a cost-effective long-term intervention [35]. It has been suggested that preventative intervention via use of proprioceptive balance training programs targeted at athletes with previous ankle sprains may reduce costs per player up to $56 USD [7, 35]. More general estimates suggest that the cost of preventing one ankle sprain has been estimated at $483 USD [7]. Overall, preventative and cost-effective treatments for ankle sprain injuries particularly among patients at risk for recurrence can prove to be effective in reducing the financial burden of ankle sprain injuries.

1.14 Summary

Lateral ankle sprains are a very common and often troublesome injuries in athletes and nonathletes alike. There is substantial existing evidence of anatomic, biomechanical, and ligamentous tissue qualities that provide an explanation for lateral ankle sprain injuries; however predictive and prognostic factors remain incompletely understood. Conservative treatment, such as RICE and semi-rigid ankle braces, are common and effective initial treatments for ankle sprain injuries. Surgical treatment considerations are reserved for more severe injuries that do not resolve and athletes that demand more stable treatment but should be used cautiously among elderly patients that present risks of other ankle complications. Risk for recurrence is important to consider as recurrent injuries can be damaging and costly for the patient and can be indicative of greater chronic instability issues at hand. Ultimately, it is important to treat these patients, but also to identify patients at risk for injury recurrence to mitigate the patient's potential losses and to ultimately improve their outcome, performance, and quality of life.

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