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Ankle sprain, conservative versus operational treatment: A literature review

Master Thesis

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Abstract

Title

Ankle sprain, conservative versus operational treatment: A literature review

Aim

The main purpose of this thesis is to assess and review the efficacy of main types of conservative and surgical interventions applied on ankle sprain injuries, as also the factors that influence the clinical outcomes in patients undergoing the selected treatment procedures.

Method

This thesis is a literary research, reviewing articles from relevant journals and books. Information and data sources were retrieved from English, released between 1980 and 2016, using electronic databases and reference lists of articles. The following databases were searched for the highest possible amount of relevant articles, with an attempt to reduce publication and/or selection bias: PubMed, EMBASE, CINAHL, The Cochrane Library (Cochrane Database of Systematic Reviews), Web of science and Medline. Preliminary searches began at the inception of the project, and the full search was concluded in October 10th, 2016. A restriction for the type of publication (meta-analysis, systematic review, clinical trials, comparative trials, practice guidelines and case studies) was applied when allowed by the databases research tools.

Results

The analysis of the reviewed studies resulted that conservative treatment approaches is the main treatment of choice regarding ankle sprain injuries. Patients undergoing conservative care and surgical intervention improve in long term, however conservatively treated patients present faster recovery times, with less complications when compared to surgical approaches.

Conclusions

Conservative treatment is preferable to surgery for most types of ankle sprains. However for patients with persistent symptoms that doesn't respond to conservative treatment, surgery must be taken into consideration.

Key words: Ankle sprain, acute sprain, lateral ankle sprain, ankle sprain treatment, ankle instability, sports injury, athletic injury, treatment, therapy.

Abstrakt

Název

Distorze hlezna – porovnání konzervativní a operační léčby: literární přehled

Cíl

Hlavním cílem práce bylo vyhodnotit a podat přehled o účinnosti hlavních způsobů konzervativní a chirurgické intervence v případech distorze hlezna a rovněž faktorů, které mají vliv na klinický výsledek u pacientů, u nichž jsou vybrané léčebné postupy uplatňovány.

Metoda

Práce je literární rešerší zahrnující články publikované v relevantních časopisech a monografiích. Informace a údaje byly získány z anglicky psaných pramenů zveřejněných v období let 1980 až 2016, a to za využití elektronických databází a seznamů literatury uvedených u jednotlivých časopiseckých článků. Největší počet relevantních článků byl vyhledáván v následujících databázích ve snaze dosáhnout maximální vyváženosti a minimální chybovosti publikací resp. výběru: PubMed, EMBASE, CINAHL, The Cochrane Library (Cochrane Database of Systematic Reviews), Web of Science a Medline. Rešerše byla zahájena předběžným stadiem na počátku projektu a v plném rozsahu byla uzavřena ke dni 10. 10. 2016. Tam, kde to rešeršní nástroje příslušné databáze umožňovaly, byla aplikována omezení typů publikací (metaanalýza, systematický přehled, klinické studie, porovnávací studie, praktické pokyny a kazuistiky).

Výsledky

Z analýzy studií, které byly předmětem rešerše, vyplynulo, že při distorzi hlezna se jako hlavní uplatňuje konzervativní léčba. U pacientů se v dlouhodobém horizontu dosahuje zlepšení jak při uplatnění konzervativní péče, tak při použití chirurgické intervence, ovšem u pacientů s konzervativní léčbou je oproti chirurgickému zákroku doba rekonvalescence kratší a četnost a závažnost komplikací nižší.

Závěry

U většiny typů distorze hlezna je konzervativní léčba vhodnější než chirurgický zákrok; ovšem tam, kde u pacienta symptomy i přes konzervativní léčbu přetrvávají, je třeba chirurgický zákrok zvážit.

Klíčová slova: distorze hlezna, akutní distorze hlezna, laterální podvrtnutí kotníku, léčba podvrtnutého kotníku, nestabilita kotníku, sportovní úraz, úraz u sportovce, léčba, terapie.

Declarations

I declare that this master's thesis is an original work that was handled and fulfilled by myself, under the supervision and instructions of Doc. Paed Dr. Dagmar Pavlů, CSc. When other sources were used, credits have been given to the author(s) and owner(s) of the information through in-text citation and bibliographic reference.

Prague, March 2017 Bc. Dimitrios Millas

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I would like to express my gratitude to my teachers for their guidance and sharing their secrets on how to become efficient, productive and scholastic during my study years, as also their contribution to my transformation into an autonomous medical expert today.

Special thanks to my supervisor Dr. Dagmar Pavlů for being an exceptional academic, always available to guide me meticulously during my thesis and all those years as a student.

Dedications

To my mother, a true symbol of love, kindness and hope, my backbone in this exhausting journey abroad.

To my father, who kept reminding me the virtues of fortitude, prudence and temperance all those years, contributing to the man I am today.

To my sister, who stood beside me, giving me the courage to overtake my inner demons.

To all those, whose love and passion met no limits.

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List of Abbreviations

BMI	Body mass index
ROM	Range of motion
CAI	Chronic ankle instability
FAI	Functional ankle instability
LAS	Lateral ankle sprain
LASER	Light amplification by stimulated emission of radiation
ATFL	Anterior talofibular ligament
CFL	Calcaneofibular ligament
LCL	Lateral collateral ligaments
MCL	Medial collateral ligament
PTFL	Posterior talofibular ligament
OAR	Ottawa ankle rules
MRI	Magnetic resonance imaging
SEBT	Star excursion balance test
QAS	Quality assessment scale
RCT	Randomized control trial
PNF	Proprioceptive neuromuscular facilitation
COX	Cyclooxygenase
NSAID	Non-steroid anti-inflammatory drug
RICE	Rest, ice, compression, elevation
PRISMA	Preferred reporting items for systematic reviews and meta-analyses
RAMESES	Realist and meta-narrative evidence synthesis evolving standards

1. Introduction

In the past many researchers performed studies in search for the most common inflicted sports injuries. Ankle is definitely one of the most frequently injured body parts after the knee and among all ankle injuries, ankle sprains are the most common. [16] After the initial ankle sprain, mechanical restraints (injured ligaments, joint capsule), muscle strength, and neuromuscular control (proprioception deficits) may be compromised at the ankle joint. [22] More than 55% of patients after ankle sprain injury, experiencing residual symptoms at 6 weeks to 18 months. The frequency of complications and the breadth of longstanding symptoms has led to the conclusion that ankle sprain is a complicated musculoskeletal syndrome. Estimations have shown that more than 50% of individuals suffering from ankle sprain injuries don't seek for professional medical treatment and are often mistreated. [20] The severity of ankle sprains is often underestimated by the patients resulting into an incomplete recovery that could be typically followed by a re-sprain or by a series of complications with most commonly seen, chronic ankle instability. There are several possible approaches on how to diagnose, manage and treat a sprained ankle which will be discussed analytically in the following chapters.

2. Background

2.1. Epidemiology and prevalence

Ankle sprains are one of the most prevalent injuries of the musculoskeletal system with an estimation of 1 ankle sprain per 10.000 people daily. [3, 33, 52] Ankle sprains account for approximately 80%, of which 77% are lateral sprains. 73% of those are due to rupture or tear of the ATFL. [2] Studies have shown that both court games and contact sports, such as rugby, soccer, volleyball, handball and basketball have a higher incidence for ankle injuries, where 80% of those were ankle sprains. [4, 7, 10, 16, 40, 61]

Ankle sprain incidence rates range from to 5.3-7.0 sprained ankles per 1000 person-years in Europe. In the United States alone, there is 1 inversion injury of the ankle per 10 000 persons per day, resulting in an estimated 23.000 sprains per day. It has been estimated that ankle sprains compose approximately one quarter of all musculoskeletal injuries [2, 3] It has been also estimated that in the US the annual cost of acute ankle sprains and their rehabilitation reaches $2 billion. [10] Evaluation of the injury risk factors must be performed especially when female athletes are included because women have shown higher rates of injury when compared to male populations. [20, 29]

Once an ankle sprain occurs, up to 80% will suffer recurrent sprains, and up to 72% develop recurrent symptoms or chronic instability. Basketball athletes have present one the highest overall injury rates among participants in non-collision sports [29] with a recurrence rate that strongly correlates with premature return to sport and a prior ankle injury. [7]

Several factors have been identified by the researchers that may cause injury, including the age of the player, injury conditions, physical characteristics (height, weight and BMI), musculoskeletal characteristics (balance, proprioception, strength, ROM), history of previous injury, the mechanism of injury, the use of external ankle support, and player position. These factors can influence either individually or in different combinations, the occurrence of injury. [29, 37, 39, 40]

2.2. Review of relevant anatomy

An in-depth knowledge of ankle anatomy is crucial for both diagnosis and treatment. Anatomically, the ankle is the connection between the segments of the foot and the leg. The tibio-talar or talocrural joint, the subtalar joint, and the distal tibiofibular syndesmosis make up the ankle complex. [20] These articulations work harmonically together, coordinating the foot movement, which occurs in the sagittal plane, the frontal plane and the transverse plane. [2, 17]

2.2.1. The ankle joint

Tibio-talar joint

The tibio-talar joint is formed by the articulation of the dome of the talus, the medial malleolus, the tibial plafond, and the lateral malleolus. [2] The shape of the tibio-talar joint allows the torque forces to be transmitted from the lower leg (internal and external rotation) to the foot (pronation and supination) during weight bearing. The axis of rotation of the tibio-talar joint passes through the centre of the medial and lateral malleoli. The tibio-talar joint isolated movement takes place mainly in the sagittal plane but minimal transverse and frontal plane motions are also possible. [17] The articular surfaces function as the main stabilisers against extra-talar rotation when full load is taken on the ankle complex. At this point, the three lateral collateral ligaments provide the joint support. [20]

Subtalar joint

The articulations between the calcaneus and the talus make up the subtalar joint, which transmits torque between the lower leg (rotation) and the foot (pronation and supination). The subtalar joint consists of the anterior subtalar joint and the posterior subtalar joint. The anterior subtalar joint is made up from the concave proximal surface of the tarsal navicular, the sustentaculum tali of the calcaneus, the anterior-superior facets and the talar head, whilst the posterior subtalar joint is made up between the superior posterior facet of the calcaneus and the inferior-posterior facet of the talus. As such, the anterior subtalar joint and the posterior subtalar joint along with ligaments form an articulation like a ball-and-socket joint. The anterior and posterior subtalar joints

have a common rotation axis, but the are separated from each other by the sinus tarsi and tarsal canal. Thus there are four important subtalar joint ligaments. The lateral talocalcaneal ligament is short and descends obliquely from the lateral talar process to the lateral calcaneal surface. The medial talocalcaneal ligament, that connects the medial talar tubercle with the back of the sustentaculum tali and the medial surface of the calcaneus. The interosseous talocalcaneal ligament which is a wide and relatively flat band into the sinus tarsi. The fourth that is called the cervical ligament which is located lateral to the sinus tarsi and attached to the superior calcaneal surface. [2, 17, 20]

Distal tibiofibular syndesmosis

The distal tibiofibular joint, which is located within the tibia and fibula, allows a limited movement between the tibia and the fibula with supportive glide that is of core mechanically importance for the ankle complex. The stable roof of the tibio-talar joint mortise is formed by the structure of the distal tibiofibular joint, which is supported by the tibiofibular ligaments and a thick interosseous membrane. [2, 17, 20]

2.2.2. Ankle ligaments

The ankle ligaments fall into three groups: the lateral collateral ligaments (LCLs), medial collateral ligament (MCL), and the ligaments of the tibiofibular syndesmosis. The anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and the posterior talofibular ligament (PTFL) form the LCL (lateral collateral) complex, while the medial collateral ligament is divided into superficial and deep fibres. [2, 17, 20, 36, 37]

Lateral collateral ligaments

Three ligaments – the ATFL, CFL, and PTFL at the lateral aspect – support the tibio-talar joint, which is a hinge joint that allows dorsiflexion and plantarflexion (Fig. 1). This complex is the static stabilizer of the lateral ankle and these ligaments are commonly implicated in ankle sprains. [48]

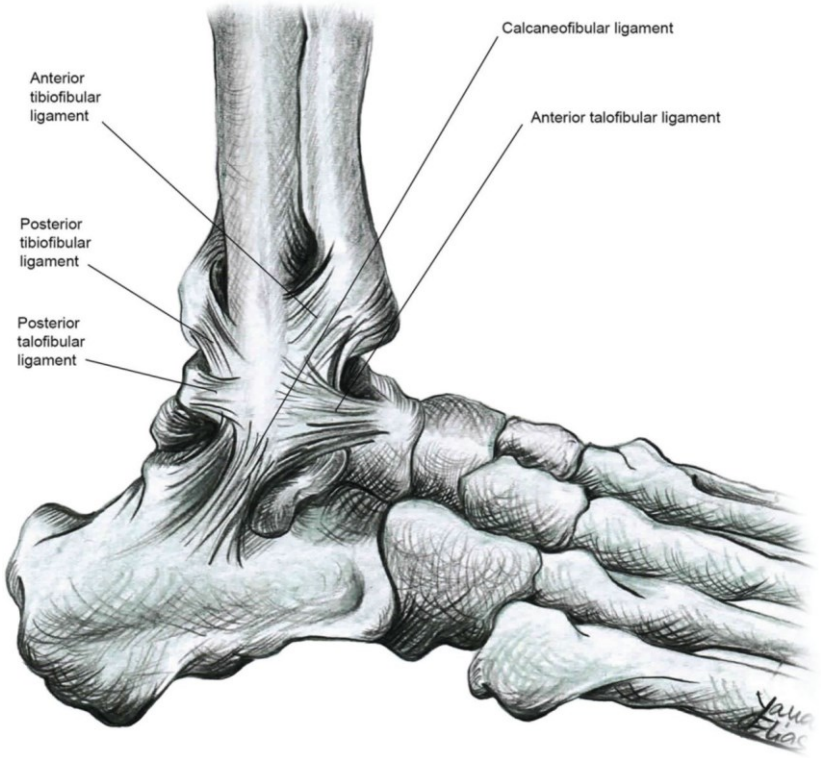

Figure 1. The lateral collateral ligaments of the ankle joint. [2]

Anterior talofibular ligament (ATFL)

The anterior talofibular ligament is the one that controls the anterior displacement and the plantar flexion of the talus. The ATFL originates at the anterior aspect of the lateral malleolus and is directly inserted to the joint capsule of the ankle. The ATFL is horizontal in a neutral position to the ankle and passes to the intersection on the talar body anterior to the joint surface. In dorsiflexion, the ATFL runs upwards, whilst it inclines downwards in plantar flexion where it is likely to be injured. The anatomy of the ATFL reveals that it is 10 mm in length, 2 mm in thickness and between 6 and 10 mm in width. The ATFL is 1 cm proximal to the distal tip of the fibula and contiguous with the ankle joint capsule. Since the ATFL is the weakest of the 3 ligaments, with the lowest ultimate load along with anatomical positions and insertions, it is most commonly injured in a lateral ankle sprain. [2, 17, 20]

Calcaneofibular ligament (CFL)

The CFL originates from the anterior aspect of the lateral malleolus resting below the lower band of the ATFL. When the ankle is positioned neutrally, the CFL is directed downwards and backwards obliquely. The peroneal tendons and sheaths cross the CFL superficially. The CFL is rounded in shape, has a 6-8 mm diameter and is about 20 mm in length. The CFL is also connected with the posteromedial section of the peroneal tendon sheath and separated from the joint capsule of the ankle. CFL is a particular ligament as it is the only one that connects the subtalar joint and the tibio-talar joint. [2, 17]

Posterior talofibular ligament (PTFL)

The PTFL originates from the malleolar fossa and runs horizontally to enter into posterolateral aspect of the talus. The ligament is relaxed in the neutral position of the ankle and in plantar flexion, while it is under tension when ankle is dorsiflexing. The PTFL is thick and strong and is very rarely injured. PTFL is a ligament of trapezoid shape and lies in a horizontal plane. The ligament is just 10 mm proximal to the distal tip of the fibula. [2, 17]

Medial collateral ligament (MCL)

The medial collateral ligament (MCL), which is also known as the deltoid ligament (Fig. 2), consists of two layers: deep and superficial. The MCL, is a multifascicular ligament which runs from the medial malleolus passing next to the talus, calcaneus and finally to the navicular bone. Most of the MCL is covered by tendons and extends to the skeletal foot insertions. [2, 17]

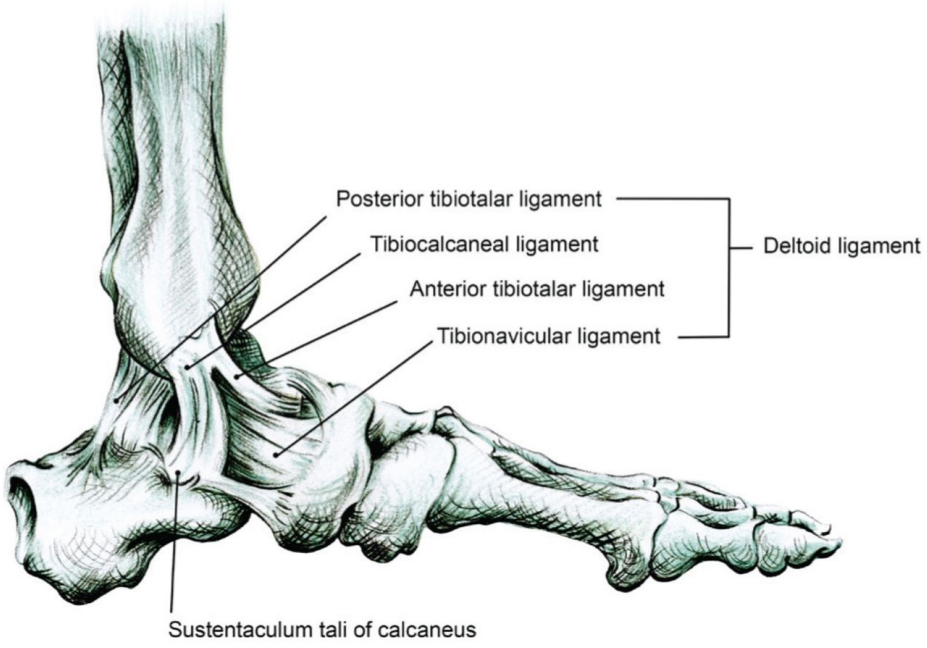

Figure 2. The deltoid ligament (medial aspect) [2]

2.2.3. Muscles and tendons

The joints are supported by groups of muscles and tendons. The peroneus brevis and longus play very important role in the protection against lateral ankle sprain and in hind-foot supination control. The lateral ankle complex is also supported and stabilised by the peroneus tertius, extensor digitorum brevis, extensor digitorum longus and tibialis anterior. In addition, they can prevent lateral ligament injury by slowing the plantar-flexion supination. The tunnel for the flexor hallucis longus tendon is formed partially by some fibres, and the middle and posterior parts of the MCL are covered by the tendon sheath of the tibialis posterior muscle. [2, 20]

2.2.4. Innervation

The sacral and lumbar plexuses provide the sensory and motor support to the ankle complex. The sensory supply to the muscles is provided by the superficial peroneal, deep peroneal, sural, saphenous and tibial nerves, while the motor supply to the muscles is provided by the superficial peroneal, deep peroneal and tibial nerves. The lateral ligaments and joint capsule of the talocrural and subtalar joints have been shown to be extensively innervated by mechanoreceptors that contribute to proprioception. The muscle spindles, especially those in peroneal muscles are of high significance for proprioception of the ankle complex. [2, 20]

2.3. Signs and symptoms

Common signs and symptoms of acute ankle sprains include the following:

- Pain
- Difficulty with weight bearing
- Tenderness
- Significant swelling
- Ecchymosis

Assessment of an acute ankle sprain begins with a complete history and physical. A thorough history anamnesis should begin by clarifying the mechanism of injury, as this will direct the rest of the examination toward the ligaments at greatest risk for injury and the extent of injury. Patients who suffer with a complete ligament rupture often describe immediate swelling, inability to continue physical activity, and inability to bear weight. Ligament sprains are often presenting a delayed onset of swelling in the ankle region and the ability to bear weight while continuing physical activity. [10]

2.4. Mechanism of injury

Understanding the mechanism of ankle sprains is critical to diagnosis, management and prevention.

Ankle injuries can be defined as either acute or chronic, with ligamentous injury the most common acute diagnosis. Approximately 85% of all ankle injuries are ankle sprains which involve the lateral ankle ligaments. [47] Chronic injuries are often related to, or are the result of acute sprains, or overuse syndromes of the surrounding soft tissues. Allegedly, ankle sprains are most common in contact sports, indoor sports, and sports with high frequency of jumping.

The most common mechanism of injury to the ankle results from supination and inversion of the foot with external rotation of the tibia on the fixed foot. The foot twists medially in relation to the lower leg, resulting in a progression of tears in a predictable sequence. [48] Inversion injuries commonly damaging the lateral ligamentous complex of the ankle, which consists of the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and the posterior talofibular ligament (PTFL). Many ankle sprains occur

when the foot is in systematic loading and unloading. Discretely, sprain is characterized by inversion and adduction (internal twisting) whilst the tibiotalar joint is in plantar flexion. (Fig. 3)

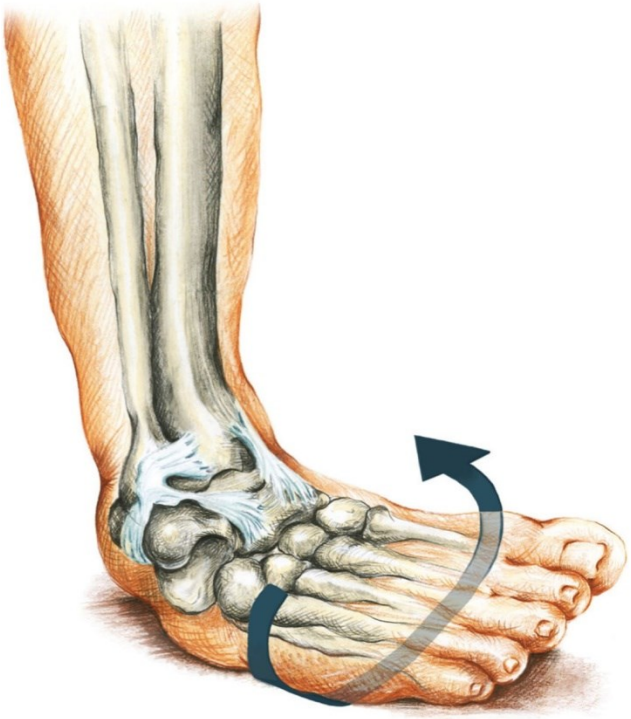

Figure 3. Inversion of the ankle is the main mechanism in lateral sprains. [2]

The weakest of the ligaments is the ATFL, and when the mechanism of injury occurs around the lateral aspect of the ankle and CFL damage occurs followed by the PTFL in sequence. A combination rupture of the ATFL and CFL is rather uncommon (approximately 20%), and the PTFL injury does not occur unless the ankle joint dislocates. On the other hand eversion ankle sprains occur much less frequently than those on the lateral side. This can be explained by the fact that we are mechanically more prone to inversion injuries but also because of the strength of the medial-sided ligaments. The deltoid ligament is a broad shaped ligament composed by 4 superficial and 2 deep components, making it the strongest of the ankle ligaments. A hyper-dorsiflexion injury might cause damage to the syndesmosis and an eversion trauma will cause injury to the deltoid ligaments. [1, 10, 17]

Ankle sprain can be referring to several morphological and pathological conditions that can extend from ligamentous overstretching to complete rupture with joint instability. Depending on the nature of severity, ankle sprains are classified into three grades. Classification aids into the identification the injury levels and correct treatment selection. Ankle sprains are classified from grades I to III (mild, moderate or severe). Grade I and II injuries are typically recover quickly with non-operative management. [35] Figure 4 present analytically the three grades of acute ankle sprain. Practically, acute ankle sprain can be classified as stable or unstable according to the findings on physical examination.

Grade	Severity	Pathophysiology	Clinical findings
Grade 1	Mild	Stretch of the ATFL, causing tear of the ligament fibres.	Mild swelling, no laxity, little ecchymosis, and difficulty in full weight bearing.
Grade 2	Moderate	Moderate injury to the lateral ligamentous complex with a complete tear of the ATFL ± Partial tear of the CFL.	Localised swelling, hemorrhage ecchymosis, and anterolateral tenderness. Abnormal laxity may be mild or absent.
Grade 3	Severe	Complete disruption of the ATFL along with CFL and PTFL.	Tenderness, swelling and ecchymosis on the lateral ankle and heel side with marked laxity.

Figure 4. Classification of acute ankle sprain according to: grade, severity, pathophysiology and clinical findings. [2]

2.5. Diagnosis of the sprained ankle

2.5.1. History

Detailed history and careful physical examination [24] are both crucial for diagnosis and management of ankle sprains, as they reveal the severity of the ankle sprain the patient has experienced. The ligament trauma can be evaluated by observing swelling and weight-bearing ability. Therefore, a thorough history is essential to evaluate the ankle injury. [48] It can help identify a whole set of important diagnostic clues, such as:

- The patient's ability to walk after the injury, which helps to identify and grade the level of injury.
- Clarify the patient's mechanism of injury which will eventually lead into a more targeted and specific examination procedure.
- To analyze possible risk factors, discover previous related injuries that could subsequently affect re-sprains.

2.5.2. Imaging

Tenderness to palpation of specific areas about the ankle joint and an inability to bear weight indicate the need for radiographic studies. [10] Plain radiographs should include anteroposterior, lateral weight-bearing and mortise views. X-rays can be used to diagnose ankle sprains and associated injuries, including distal fibular fractures, malleolar fractures, syndesmosis separation, and talar fractures. Stress radiography is a tool that can aid into the evaluation of the laxity. The Ottawa Ankle Rules (OAR) were initially developed in order to reduce the excess radiographs and decide whether radiographic studies are indicated in patients who undergo ankle trauma. [24] Whilst ultrasound can be a valuable technique, it is user-dependent. Magnetic Resonance Imaging (MRI) can be also helpful to rule out associated lesions and degenerative changes and assess ligamentous injuries. However, MRI is equivalent to plain radiographs in acute injury and is more useful in assessing painful ankle sprains after a 6-8 week period of therapy. [1] MRI is offering a high sensitivity rate for diagnosing ligament injuries of the ankle but due to the high incidence rates of ankle injuries, the poor availability and high price it should be limited only to CAI cases or when there are suspicions for osteochondral lesions, occult fractures or injuries of the tibiofibular syndesmosis. [48]

2.5.3. Ottawa ankle rules

In LAI, ADL, the existence of a fracture is the main red flag. The ability to walk again within 48 h after trauma is an auspicious sign and indicates a good prognosis. The Ottawa Ankle Rules have been developed to rule out ankle fracture or other osseous trauma after acute ankle injury. [36, 39] The OAR were first tested on adult patients with ankle sprains from acute injuries, revealing very sensitive results for adult and young populations. As such the OAR reduced unnecessary radiographs by 30-40%. Ottawa Rules are summarized in the matrix below (Fig 5).

Ottawa Ankle Rules	Ottawa Foot Rules
An ankle radiograph is required only if pain is indicated in the malleolar part and any of these is present:	A foot radiograph is required only if pain is indicated in the mid-foot and any of these is present:
• Bone tenderness at lateral malleolus or posterior edge • Bone tenderness at medial malleolus or posterior edge • Unable to bear weight	• Bone tenderness at the 5th metatarsal base • Navicular bone tenderness • Unable to bear weight

Figure 5. Ottawa ankle and foot rules [2]

Most patients who visit the emergency room are examined using radiographs to rule out fractures despite the fact that the prevalence of ankle fractures is less than 15%. [27] Patients who may have undergone ankle sprains should be physically examined by various methods such as evaluation of the patient's weight bearing ability, visual and hands-on inspection, injury-specific physical diagnostic tests, and palpation. The physician should also assess the swelling and ecchymosis and should palpate the fibula to exclude any possible fractures. In addition, if a tissue deficit or tenderness can be found, then the Thompson Test should be carried out to exclude an Achilles tendon injury. Tenderness should be also checked using the sites of Ottawa Ankle Rules (Fig.6) since distal tibial or fibular tenderness may reveal a fracture accompanying an eversion or inversion strain. An osteochondral talar dome fracture may be inferred by pain and tenderness on tibio-talar joint line palpation.

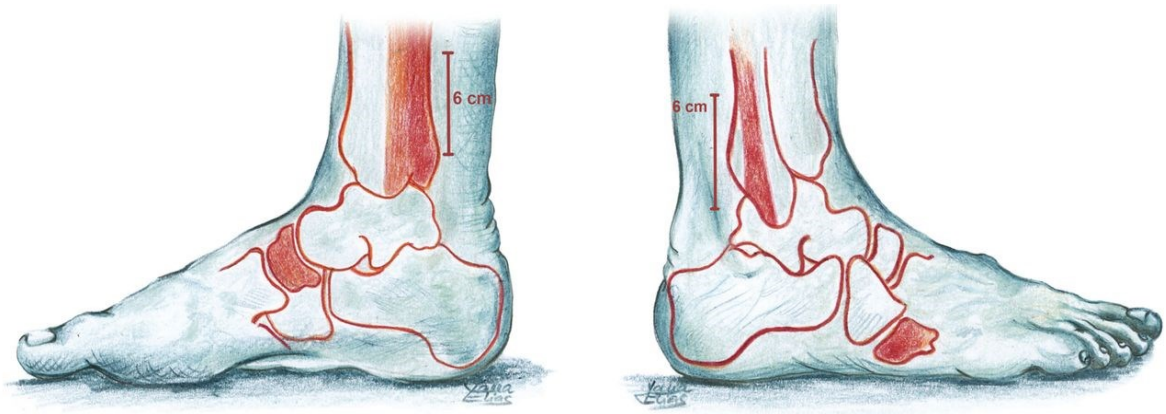

Figure 6. Medial and lateral views of the ankle specifying the bone tenderness regions of Ottawa ankle rules. [2]

The Ottawa Ankle Rules consists of a questionnaire and research protocol for examination of ankle and foot. X-ray diagnostics is only indicated in case of pain in the malleoli or middle foot, combined with one of the following findings: palpation pain on the dorsal side of one or both of the malleoli, palpation pain at the bases of the metatarsal bone V, palpation pain of the navicular bone and finally if the patient is unable to walk at least four steps. The use of the Ottawa Ankle Rules is strongly recommended in the emergency room of hospitals and in general practice in order to exclude fractures. In the training of healthcare professionals, sufficient attention should be paid to proper application of the Ottawa Ankle Rules. [23, 28, 36]

2.6. Physical examination tests

Specific examinations should be carried out to and identify the nature of the ankle sprain through certain tests, [24] such as:

Eversion stress test

The eversion stress test is performed with the patient's leg hanging from the examination table. The leg is then stabilized with one hand while the other hand grasps the calcaneus applying an eversion stress by rolling the calcaneus laterally; pain indicates a deltoid ligament injury. [10]

External rotation test

The external rotation test is performed with the knee flexed at 90 and the ankle in neutral position. The examiner stabilizes the leg proximal to the ankle joint with one hand while the other hand grasps the plantar aspect of the foot and externally rotates the foot; pain indicates a syndesmotic ankle sprain. [10]

Squeeze test

In the squeeze test, the leg is gently compressed from the medial and lateral sides at mid-calf level; pain indicates a syndesmotic injury. [10]

Anterior drawer test

The anterior drawer stress test should be performed to estimate the stability of the ATFL. (Fig. 7) The anterior drawer test is performed with a lateral view of the ankle in neutral position attempting to manually translate the foot anteriorly with respect to the leg. Instability may be assessed by comparing to the uninjured side; anterior subluxation of more than 3 mm indicates rupture of the ATFL. [10, 36, 37, 48]

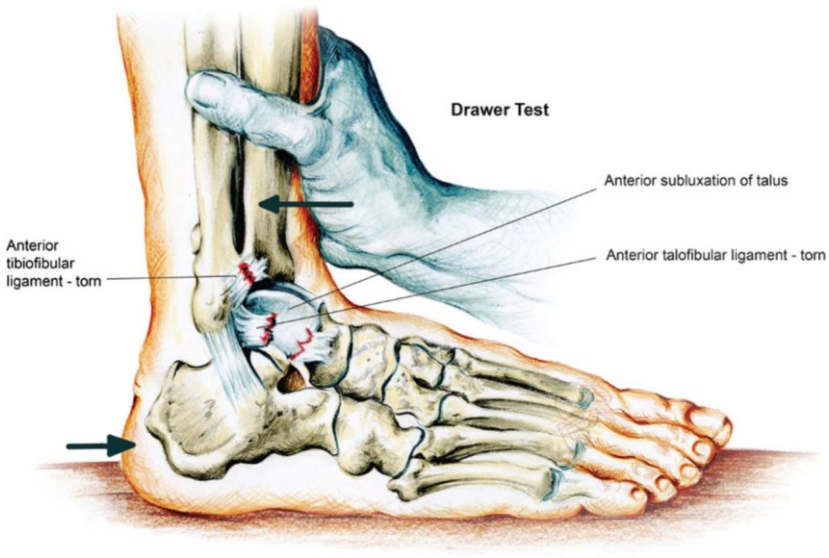

Figure 7. The anterior drawer test [2]

Talar tilt test

The talar tilt test (Fig. 8) is used to evaluate the excessive ankle inversion and is commonly used because of its reliability. [48] With the ankle resting in neutral position, a gentle inversion force is applied to the ankle and the degree of inversion is evaluated and compared with the uninjured side; a positive test indicates CFL tear [10, 36, 37]

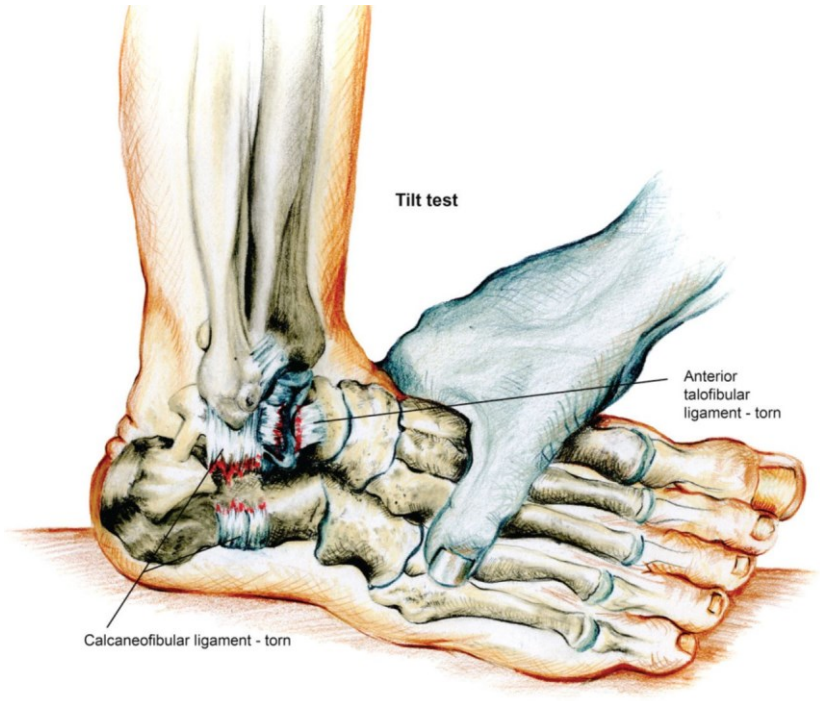

Figure 8. The talar-tilt test. [2]

2.7. Functional performance tests – Return to sport

Patient with FAI have usually deficits of functions of their foot. For that reason functional performance tests are an important tool for the assessment of joint stability, muscle flexibility, muscle strength and power, proprioception, dynamic balance, and agility. [24]

Dorsiflexion lunge test

The dorsiflexion lunge test is a weight bearing test performed by placing the foot perpendicular to a wall and lunging the knee toward the wall. The foot is sequentially moved farther away from the wall until the maximum range of dorsiflexion is achieved. The heel must not be lifted from the floor, and the subtalar joint must remain locked. The distance from the foot to the wall is measured; Measurement less than 10 cm is considered restricted. The angle of the tibial shaft in reference to the wall is also evaluated; a measurement of less than 35° is considered restricted. [7]

The star excursion balance test

The star excursion balance test (SEBT) determines unilateral balance and dynamic neuromuscular control as it requires strength, flexibility, and proprioception. Testing individual must set his base of support on 1 leg while reaching maximally in defined directions with the contralateral leg, forming an 8-point star shape. [7, 37]

Agility T- test

The agility T-test is a drill that measures movement in multiple directions. The athlete must sprint a T-shaped course from the base of the longitudinal arm to the center of the horizontal arm (9.14 m). Then, facing forward, he or she sidesteps to one end of the horizontal arm without crossing feet and continues to the other end. To finish, they sidestep back to the center of the horizontal arm and run backward down the longitudinal limb to the starting point. Typical times for athletic adults are between 8.9 to 13.5 seconds. [7]

Vertical jump test

Athletes that demonstrate deficits in strength and flexibility are at a higher risk for ankle sprain injury. The vertical jump test evaluates strength, speed, energy, and dexterity and estimates power jumps. The athlete squats and jumps upward into full extension, reaching for a cardboard disk above. The distance jumped is measured: efficiency index = weight (kg) × jump (cm) / height (cm). [7]

2.8. Management of the sprained ankle

The management of ankle sprains includes a wide variety of treatment modalities and many different rehabilitation techniques. Ankle sprains are usually treated conservatively and involve symptom management during the acute phase followed by a period of rehabilitation. [34] The therapist is also often involved in the treatment of the main problematic of ankle sprains: chronic ankle instability.

The acute sprain

a well optimized acute management of sprains and strains is the first part and most important part for a successful recovery. Soft-tissue injuries go through three phases of healing: inflammation, proliferation and maturation. During the initial inflammatory phase, patients experience erythema, swelling and pain, which naturally prevent physical activity. In ankle sprains, the inflammatory phase typically

lasts between two and seven days.

Prostaglandin is responsible for the localized swelling during this initial phase and NSAIDs work by inhibiting the action of cyclooxygenase-1 (COX-1) and cyclooxygenase-2 (COX-2), which reduce prostaglandin production. The inflammatory phase is followed by the proliferative phase, when macrophages remove the hematoma, fibroblasts produce collagen, and the capillary networks begin to rebuild. During the final maturation phase, collagen organization increases and capillary networks return to normal levels. [6]

Acute treatment is of major importance as it focuses on minimizing swelling, control pain, offer protection from possible re-sprains, promote healing, and speed up the initiation of a rehabilitation program in order to limit the long-term deficits in strength, flexibility, and endurance.

The goals of early mobilization with rehabilitation include restoration of range of motion (especially dorsiflexion), restoration of strength (especially the peroneal muscles), maintenance of proprioception, and safe return to activity. Acute treatment begins after initial injury and continues until pain and swelling resolve. [10] During this acute phase experts usually advice the use of topical non-steroidal anti-inflammatory drugs (NSAIDs) as ibuprofen, diclofenac and naproxen together with protection, rest, ice, compression and elevation as first-line treatment for ankle sprains.

There is a variety of available treatments for the acute lateral ankle ligament injuries. Three of the most common used modalities are: [26, 35]

1) Immobilization with plaster cast or splint

2) Functional treatment which include an early mobilization program and the use of an external support

3) Operative treatment.

2.9. Conservative approach

Most type of ankle sprains can be managed conservatively by finding an optimal combination of therapeutic interventions depending on the stage and severity of the injury. A typical conservative treatment programme often includes the use of RICE, a short period of immobilization and protection with a tape or bandage, an early mobilization stage, as also weight-bearing and neuromuscular training exercises. [35, 43, 48]

P.R.I.C.E.

Protection

An external joint support/brace is usually used to provide mechanical stability by restricting the inversion and eversion movements of the injured ankle, while at the same time maintaining dorsiflexion and plantar flexion. [38] Clinicians often recommend that this kind of joint support should be used until swelling, strength deficits, and flexibility deficits resolve. [10] Taping and bracing techniques are adjunct interventions used to offer, pain relief, swelling control, protection of the injured anatomical structures as also to enhance proprioception and sensory feedback through the stimulation mechanoreceptors responding to skin stretch and compression during joint motion. [38] Although there are controversial opinions regarding their effectiveness, lots of clinicians choose athletic taping techniques, elastic bandages and other similar procedures due to high patient satisfaction rates that those applications offer.

Rest

Rest is an important part of the treatment for any musculoskeletal injury. A period of rest is able reduce the metabolism of the injured tissue and therefore maintain the blood flow into a desired level. Rest is also important as its preventing the injured tissues from excess stress that might damage the fragile fibrin bond, which is the first element of the repair process. The amount of rest period can be modulated to allow some general activity, but the patient must avoid any activity that induces stress or strain to the injured area which can subsequently compromise the healing process. [10, 52]

Ice

Cryotherapy is one of the oldest yet simplest therapeutic modalities in the treatment of acute soft-tissue injuries. It is proposed that by decreasing tissue temperature, ice can diminish pain, modulate localized metabolism, control muscle spasm, minimizing the inflammatory process and therefore support the whole recovery after soft-tissue trauma. Cryotherapy is able to reduce the temperature of the deep tissues but the level of cooling is directly connected to the method, the duration, the initial temperature of the ice as also the depth of subcutaneous fat.

The bibliographic recommendations on the clinical use of ice have many shortcomings and most clinicians seem to rely on empirical evidence as the selection of optimal parameters is still performed pragmatically. While cryotherapy is being used in both

the immediate and rehabilitative care, the basis for its application at each stage is very different. When we consider its use immediately after an injury, ice is principally used to reduce metabolism, therefore minimizing secondary hypoxic injury and the degree of tissue damage. However when applied for rehabilitative purposes, it is used primarily to relieve pain, which allow patient to participate earlier and into more intensive exercise units. The patient's ankle temperature should be maintained at about 12 °C by applying ice means onto the injured site, which should be cooled for 15 minutes every couple of hours over the first two days, until stabilized. [5, 10, 24]

Compression

The goal of compression is to stop hemorrhage and reduce swelling. Direct compression helps to promote resorption of edema out of the joint space, which allows for earlier range of motion and mobility [5, 10, 24]

Elevation

Elevation of the injured part above the heart level is a very commonly used procedure which improves the venous return thus influencing the pressure in local blood vessels and helps to limit the bleeding of the damaged tissues. Elevation is also supporting the drainage of the inflammatory exudate through the lymph vessels, thus reducing and limiting edema and its resultant complications. [10, 24, 52)

Medication

As mentioned before medication such as analgesics and nonsteroidal anti-inflammatory drugs, have an important role in the management pain and inflammation after acute injury but also throughout the whole recovery period by directly control the inflammation and swelling as also contributing into the pain relief thus enabling earlier mobilization of the patient. [6, 10, 24, 43]

Modalities

In many physiotherapy practices as also in many ambulatory departments, electrotherapeutic modalities as are used. Those are often used with a goal to control pain during the acute stage, support the edema resolution and maintain muscle strength and range of motion in physiologic levels. [10, 15, 24] Ultrasound is a common used physical modality that is used to treat excessive swelling but latest findings recommend it after the sprain injury move to a subacute phase.

Mobilization

Early movement of the traumatized ankle is very often seen in clinical practices. Active plantar-dorsi flexion within a limited painless range of motion is an often used approach to promote edema reduction, restoring the function and improve circulation of the injured area. [10, 24]

Strength training

Muscle strengthening is by far the most accepted part of the therapeutic procedure. It is of the highest importance to facilitate the injured region and specifically peroneal and gastrocnemius muscles as early as possible. [10, 24]

2.10. Long term rehabilitation

As described before, the standard care for grade I and II lateral ankle sprains must include functional rehabilitation, which consists of ankle stabilization, followed by progressive weight bearing and exercise.[24] Therapeutic can have many types and disciplines and their possible effects are directly connected to the state of the injury and the goal of the therapy accordingly. Regaining normal function and strength of the ankle as also preventing future re-sprains are the primary goals of rehabilitation. [37] Therapeutic exercise, or functional treatment, includes interventions to restore ROM, strength, and sensorimotor function, which may be impaired after injury. It is important to always implement and alternate exercise programs so the mechanical stress of the ankle will be progressively increased.

Patients are usually push themselves to return to sports and normal physical activities when pain and swelling are resolved but the lack of proper rehabilitation places them at risk for recurrent into a more severe ankle injury with increased chances to develop chronic instability. Activities such as strength training, jogging, swimming, and cycling help to improve strength, range of motion, and proprioception while maintaining cardiovascular fitness. It is an important part of the therapeutic protocol to maintain the patient's the cardiovascular fitness in an adequate level in order to resume normal daily activities full recovery will be present.

Balance and coordination training are within the most used and effective types of training for reducing the risk of ankle sprains, especially in patients with history of ankle sprains. [43] In this type of training the main focus of the therapist is to improve the ability of the patient to control the activation of many different muscles so that they act

together simultaneously as a single functional unit and the process of integrating different body parts in specific movement patterns.

One of the most commonly examined outcomes for assessing a LAS is the single leg postural control. Impaired postural control is associated with an increased risk of ankle injury. For that reason balance training is a common component of therapeutic intervention programs used by allied health care practitioners to treat acute LAS. [21] At this part of the rehabilitation process, experts are using many different techniques and equipment in order to achieve their goals. The use of balance beams, wobble-rocker boards and other inflatable devices are therapeutic tools are often seen and regularly used by patients with ankle sprains as they have demonstrated great results into the prevention of recurrence. [8, 19, 35, 38]

Proprioceptive neuromuscular facilitation (PNF) is a typical form of progressive strength training that emphasizes movement in multiple planes. The goal of PNF techniques is to promote functional movement through facilitation (strengthening) and inhibition (relaxation) of muscle groups. Based on the deficits seen in patients with CAI, PNF may be a beneficial treatment approach as PNF training patterns are similar to functional movement patterns. PNF strength techniques may contribute into the improvement dynamic balance and functional performance. [18]

2.11. Ankle instability

Functional performance deficits are usually measured by functional tests that are used to measure joint stability muscle flexibility, muscle strength and power, proprioception, dynamic balance, and agility and enable us to select the optimal treatment according to their outcomes. [2, 4]

About 40% of all patients that sustain an ankle sprain they experience FAI, which is defined as a "disabling loss of reliable static and dynamic support of a joint" and a "tendency for the foot to give away". [3, 24] Balance is usually altered in patients with ankle instability, especially during dynamic balance tasks. This seems to be due to a deficit in proprioception and in the neuromuscular control of the injured ankle, and decreased balance is deemed to be a risk factor for recurrent ankle sprain. Joint mobilizations are linked to positive effects in postural control, which is reported to be impaired in those suffering from CAI [10]

After ankle injuries, functional rehabilitation has a highly positive effect, and in addition can help patients perform normal activities and prevent the possibility of CAI. At this phase semi-rigid ankle braces are typically used in order to offer a sufficient foot support. Motion exercises such as foot circles, mild stretching, alphabet exercises, eversion, inversion, dorsiflexion, picking up objects with the toes, and walking are also advised to assist lymphatic drainage. It is also recommended to wrap the ankle with an elastic bandage to control the edema. After injury, patients can be provided with crutches to facilitate mobility when the ankle sprain is painful. To facilitate rehabilitation, ankle-foot orthoses can be used along with ankle braces filled with air or gel, which can be used to limit plantarflexion-dorsiflexion. As mentioned before, clinicians must focus on maintaining proper levels of proprioception as it is very likely to be affected. Occupational and sports activities that require strenuous physical efforts are restricted over the first period of time to prevent pain and poor outcomes. For ankle injuries of Grade I and II, it is recommended that patients must start functional rehabilitation when the exercises can be performed unrestricted and without pain or irritation. To prevent recurrence, the rehabilitation programme should last between 3 and 6 weeks. During the functional rehabilitation braces, elastic bandages, taping or splints are could be used in order to decrease ankle instability and control swelling. [1]

2.12. Surgical procedures

Acute ankle injuries are almost always managed by non-operative methods. Previously, in ankle sprains of Grade I and Grade II, the emphasis was placed on early application of RICE guidelines, while ankle sprains of Grade III might possible require surgical intervention. However clinicians must deeply analyze the patient's needs before considering surgery as the main therapeutic method as clinical literature have presented evidence, that the benefits of surgical intervention has not been forthcoming. [43] Only in complicated cases where chronic ankle instability is persistent and does not respond to conservative treatment then surgery is indicated. [12, 39]

Various surgical procedures aim to provide stability when conservative treatment fails, which often occurs. Surgical treatment of chronic ankle instability is either via anatomic repair or tenodesis stabilization.

Common anatomic repairs include the following: [10, 12, 39]

- Brostrom technique: midsubstance imbrication and suture of the lateral ankle ligaments.
- Gould augmentation: augmentation of the Brostrom repair with mobilized lateral portion of the extensor retinaculum.
- Karlsson technique: anchoring the proximal ligament ends through drill holes (Fig. 9).

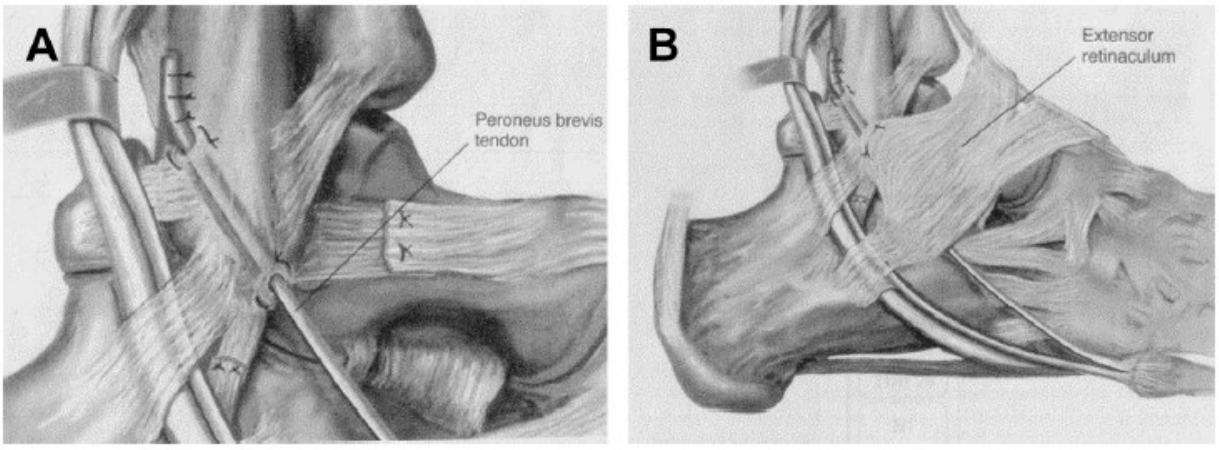

Figure 9. Illustration demonstrating anatomic repairs of chronic lateral ankle instability. (A) Brostrom technique. (B) Gould modification. [10]

Common tenodesis stabilization procedures include the following:

- Watson-Jones procedure: peroneus brevis graft tenodesis to fibula and talus.
- Evans procedure: peroneus brevis graft tenodesis to fibula.
- Chrisman-Snook procedure: split peroneus brevis graft tenodesis to fibula and calcaneus (Fig. 10)

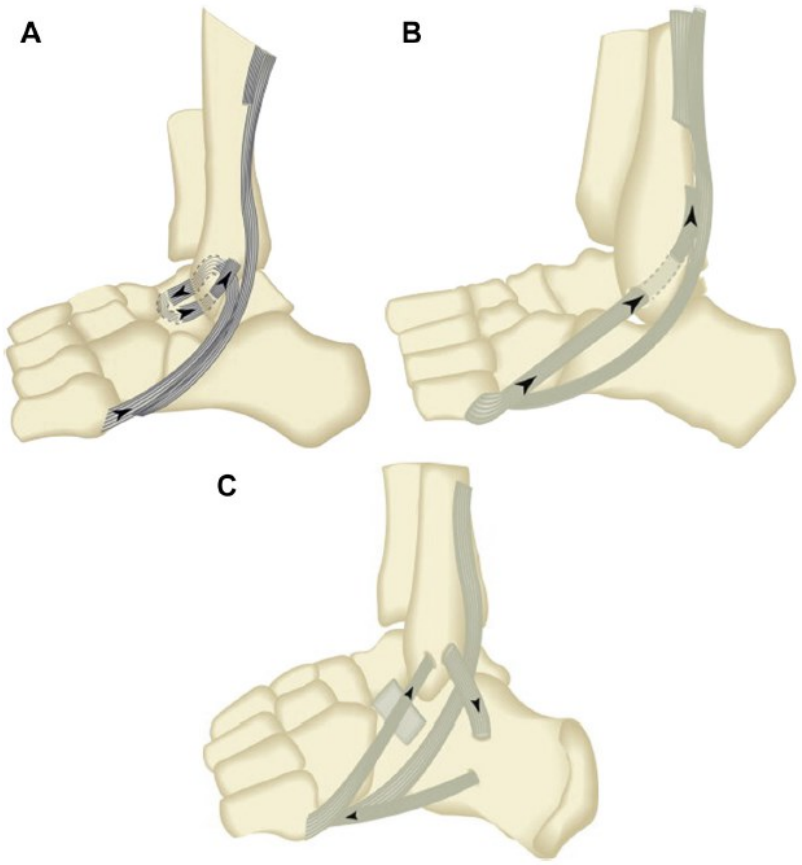

Figure 10. Illustration demonstrating tenodesis reconstruction for chronic lateral ankle instability.
(A) Watson-Jones procedure. (B) Evans procedure. (C) Chrisman-Snook procedure. [10]

3. Methodology

3.1. Objectives and research method

This systematic review discusses treatment methods for ankle sprain using evidence from recent systematic reviews and randomized controlled trials.

Aim of the thesis

The main objective of this research is to investigate the efficacy of conservative and surgical interventions for the treatment of ankle sprain injuries and offer medical recommendations regarding the optimal selection of treatment respectively.

Investigative questions

1. Which type of treatments scientifically proven advantageous in the treatment of ankle sprain injuries?

2. Which type of intervention provides the faster and more efficient therapeutic effect?

3. Which type of intervention can prevent ankle related injuries more effectively?

Hypothesis

Conservative treatment is the fastest, effective and cost efficient way to treat a sprained ankle. Surgical approaches should only be considered only in severe sprains, or special population.

3.2. Criteria of the research

Types of studies

Randomized control trials, prospective studies, systematic reviews and meta-analysis published between 1980-2016 years and performed in Europe, Northern America and Far East.

Languages

Studies originally in English language or translated to English were included.

Types of participants

Patients of all ages, with an acute (less than 6 weeks), subacute (6-12 weeks) or chronic (12 weeks or more) case of ankle sprain as primary diagnosis were included. Children from 1-5 years were excluded.

Types of interventions

All types of conservative treatment and surgical approach were included.

3.3. Search strategy for identification of studies

Studies were collected from following database: PubMed, EMBASE, CINAHL, The Cochrane Library (Cochrane Database of Systematic Reviews), Medline and Web of science.

Literature search was performed through electronic database using the keywords:
Ankle sprain, acute sprain, lateral ankle sprain, ankle sprain treatment, ankle instability, sports injury, athletic injury, treatment, therapy.

Different combinations of these words were used in strategy of searching.

3.4. Assessment of methodological quality and data extraction

All eligible articles were rated for methodological quality, using the the ‘’Preferred reporting items for systematic reviews and meta-analyses’’ (PRISMA) and ‘’Realist and meta-narrative evidence syntheses: evolving standards’’ (RAMESES) guidelines to ensure the quality standards of this review. [41, 64]

Evaluation of the final RCTs, performed by the ‘’Downs and Black’’ quality assessment tool and the AMSTAR checklist for the systematic reviews. The ’’Downs and Black’’ quality assessment scale (QAS) assesses study reporting, external validity, and internal validity (i.e. bias and confounding). A slight modified version was used in this review. Specifically, the scoring for question 27, dealing with statistical power was simplified to a choice of awarding either 1 point or 0 points depending on whether there was sufficient power to detect a clinically important effect. Downs and Black score ranges were grouped into the following 4 quality levels: excellent (26 to 28), good (20 to 25), fair (15 to 19), and poor (less than 14). [14]

Appraisal of the included systematic reviews, performed by the ‘’AMSTAR’’ assessment tool. The tool consists of an 11 question checklist, where each question counts for one point. Scoring is classified in: Low quality (AMSTAR score 0–4), moderate quality (AMSTAR score 5–8), and high quality (AMSTAR score 9–11). [49]

3.5. Study selection and quality assessment scheme

The database searches were performed as described previously, by a single reviewer. The procured articles were sequentially reviewed for eligibility in three turns: first on the basis of their title, followed by the review of their abstract, and finally after thorough examination of the full text. Duplicate articles were also removed (Table. 1).

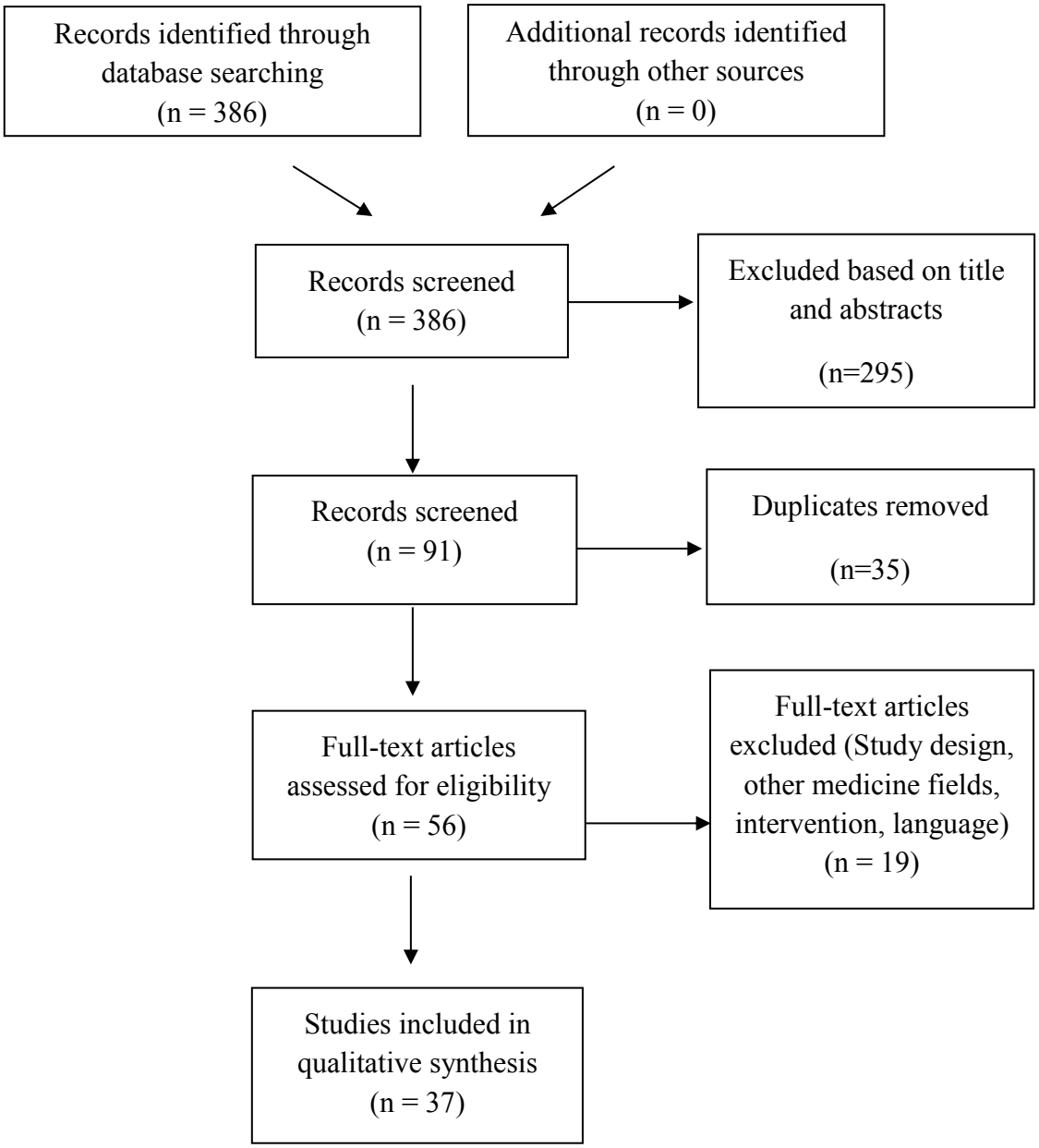

Table 1. Flowchart illustrating the database search and article elimination process, along the PRISMA guidelines

3.6. Data extraction

The key data of the reviewed articles were extracted and summarized, in an attempt to allow for the easier comparison and contextualization of results by reviewers and readers. The extraction forms included data about the studies' author, year of publication, aim and type of study, participant characteristics (their number, gender, age and symptoms/ diagnosis), intervention (including control intervention, where applicable), outcome measures, and results. The full data extraction form can be seen analytically in tables below.

4. Results

In this chapter, the included studies were thoroughly analyzed and compared to isolate their findings and reach into conclusions. The studies were allocated into comparison tables to provide a reader-friendly experience and were additionally sorted and divided according their study type, into systematic reviews and randomized control trials tables. In the final part of this chapter a detailed summarization was performed describing the study parameters, their findings and their conclusions.

4.1. Comparison tables

Systematic Reviews

Author/Year	Title	Study Design	Participants	Findings/Conclusion	ARMSTAR Score
Aaltonen et. al. (2007).	Prevention of sports injuries: systematic review of randomized controlled trials.	Systematic Review	32 studies (n=24,931)	Evidence in favor of insoles of any type, ankle, knee & wrist external supports and training programs as means to prevent sports injuries. Stretching & warm-up programs, mouth guards, and video-assisted instruction were not clearly effective.	4/11
Bleakley et. al. (2004).	The use of ice in the treatment of acute soft-tissue injury	Systematic Review	22 RCT (N=1469)	Marginal evidence in favor of ice plus exercise as an effective mean to treat swelling and pain after ankle sprain injury and post-surgery.	7/11
de Vries et al. (2011).	Interventions for treating chronic ankle instability.	Systematic Review	7 RCTs	Significant evidence in favor of early functional rehabilitation compared to immobilization after surgical reconstruction. Insufficient evidence to support any specific surgical or conservative intervention for chronic ankle instability.	9/11
Feger et. al. (2015).	Electrical stimulation as a treatment intervention to improve function, edema or pain following acute lateral ankle sprains	Systematic Review	4 RCTs	No evidence to support ES for reducing edema, decreasing pain, or improving function following acute lateral ankle sprain.	7/11

Kannus et. al. (1991).	**Treatment for acute tears of the lateral ligaments of the ankle. Operation, cast, or early controlled mobilization**	**Systematic Review**	**12 Studies**	**Evidence in favor of functional treatment as the treatment of choice for acute complete tears of the lateral ligaments of the ankle. ROM exercises, as well as neuromuscular training of the ankle, should begin early. Authors claimed that this program offer the quickest recovery to a full range of motion and return to work and physical activity.**	**3/11**
Kerkhoffs et al. (2007).	**Surgical versus conservative treatment for acute injuries of the lateral ligament complex of the ankle in adults**	**Systematic Review**	**20 RCTs (N=2562)**	**Slight evidence against the use of surgical treatment as it contributes to longer recovery times, and higher incidences of ankle stiffness, impaired ankle mobility and complications. Insufficient high-quality RCTs available to conclude regarding the effectiveness of surgery compared with conservative treatment in LAI.**	**8/11**
Kerkhoffs et. al. (2012).	**Diagnosis, treatment and prevention of ankle sprains: An evidence-based clinical guideline.**	**Systematic Review**	**27 Studies**	**Functional Treatments:** A lace-up brace or a semi rigid brace is preferable and recommended. **Immobilization:** Facilitates the decrease of pain and swelling and can be helpful in the acute phase of the treatment of LAI **RICE:** The use of RICE, is an important aspect of treatment in the acute phase of LAI. **Exercise therapy:** Exercise therapy seems to prevent a recurrence in patients with LAI **Manual mobilization:** Manual mobilization of the ankle has limited added value and is not recommended. ***Continued**	**5/11**

Kerkhoffs et. al. (2012).	**Diagnosis, treatment and prevention of ankle sprains: An evidence-based clinical guideline.**			***Continued** **Other therapies:** Ultrasound, laser and electrotherapy have no added value and are not recommended. **Surgical therapy:** Functional treatment is preferred over surgical therapy but it is recommended that in (top-professional) sports surgical treatment can be considered on an individual basis.	
Kerkhoffs et.al. (2013).	**Different functional treatment strategies for acute lateral ankle ligament injuries in adults.**	**Systematic Review**	**9 RCTs, N=892**	**Elastic bandages caused fewer complications than tape, but were associated with a delayed return to work and sports.** **Instability was reported more frequently with a semi rigid ankle brace.** **A lace-up brace or a semi rigid brace seems preferable to the use of an elastic bandage.**	**7/11**
Lauersen et. al. (2013).	**The effectiveness of exercise interventions to prevent sports injuries**	**Systematic Review**	**25 RCTs, N=26610**	**Favorable evidence for strength training. Sports injuries were reduced to less than 1/3 and overuse injuries could be almost halved.**	**8/11**
Leppänen et. al. (2013).	**Interventions to prevent sports related injuries**	**Systematic Review**	**68 RCTs**	**Insoles, external joint support and specific training programmes appeared to be effective in reducing the risk of sports injuries.** **Stretching, modified shoes, and preventive videos, showed no effect.**	**8/11**

Lin et. al. (2010).	**Evidence-based treatment for ankle injuries: a clinical perspective.**	**Systematic Review**	**N/A**	**Supporting evidence for functional support, augmented by non-steroidal anti-inflammatory drugs in the early phases after injury. Manual therapy demonstrated only short-term benefits after ankle sprain. Evidence in favor of the additional benefits caused by exercises, particularly balance exercises, in reducing the risk of a recurrent sprain. Electro-physical agents showed no effect into the enhancement of the treatment. In chronic ankle instability, balance and strengthening exercises may be advantageous in reducing resprain episodes and improving function.**	**2/11**
Osborne et. al. (2003).	**Prevention and treatment of ankle Sprain in athletes.**	**Systematic Review**	**N/A**	**Ankle braces found to be effective means for reducing recurrent ankle sprains, although their role in primary prevention is less evident. Functional rehabilitation of an acute ankle injury must be the initial treatment of choice, while surgery for ankle sprain must be reserved for patients who fail a comprehensive non-operative treatment programme.**	**3/11**
Petersen et. al. (2013).	**Treatment of acute ankle ligament injuries: A systematic review.**	**Systematic Review**	**3 Meta-analysis, 17 RCTs**	**Authors claimed the majority of grades I, II and III lateral ankle ligament ruptures can be managed without surgery. The indication for surgical repair should be always made on an individual basis. This systematic review supports a phase adapted non-surgical treatment of acute ankle sprains with a short-term immobilization for grade III injuries followed by a semi-rigid brace.**	**6/11**

Polzer et. al. (2012).	**Diagnosis and treatment of acute ankle injuries: development of an evidence-based algorithm.**	**Systematic Review**	**117 studies**	**Study supports the use of functional treatment for the treatment of ankle sprains. Authors stated that the current treatment of choice, should consist of PRICE, NSAID, early weight-bearing, and exercises for range of motion. For unstable injuries (grades II and III), a semi-rigid ankle brace and supervised rehabilitation should be provided. Operative treatment is recommended in cases of chronic instability only.**	**3/11**
Terada et. al. (2013).	**Therapeutic Interventions for Increasing Ankle Dorsiflexion After Ankle Sprain**	**Systematic Review**	**9 studies**	**Static-stretching intervention as a part of standardized care yielded the strongest effects on dorsiflexion after acute ankle sprains. Current evidence suggests that clinicians need assess the limiting factors of ankle dorsiflexion to select the most appropriate treatments and interventions.**	**6/11**
Van den Bekerom et. al. (2011).	**Therapeutic ultrasound for acute ankle sprains.**	**Systematic Review**	**6 trials N=606**	**No evidence to support the use of ultrasound in the treatment of acute ankle sprains. However, there is no evidence available to rule out the possibility that there is an optimal dosage schedule for ultrasound therapy that may be of benefit. Ultrasound therapy had few beneficial effects on overall improvement, pain, or ability to bear weight in acute ankle sprain**	**9/11**

Van den Bekerom et. al. (2012).	**What Is the Evidence for Rest, Ice, Compression, and Elevation Therapy in the Treatment of Ankle Sprains in Adults?**	**Systematic Review**	**11 studies N=868**	**Insufficient evidence to support the effectiveness of RICE therapy for acute ankle sprains in adults. Treatment decisions must be made on an individual basis, carefully weighing the relative benefits and risks of each option, and must be based on expert opinions and national guidelines.**	**7/11**
Van der Wees et. al. (2006).	**Effectiveness of exercise therapy and manual mobilization in acute ankle sprain and functional instability**	**Systematic Review**	**17 studies**	**Favorable evidence for the effectiveness of exercise therapy in the prevention of recurrent ankle sprains. Exercise therapy, including the use of a wobble board, found to be effective in the prevention of recurrent ankle sprains. Manual mobilization has an (initial) effect on dorsiflexion range of motion, but the clinical relevance of these findings for physiotherapy practice may be limited.**	**8/11**
Van Ochten et. al. (2014).	**Chronic complaints after ankle sprains: A systematic review on effectiveness of treatments**	**Systematic Review**	**20 RCTs**	**Supporting evidence for training programs to offer better results for pain and function, and a decrease of recurrent ankle sprains, than a wait-and-see policy. Insufficient evidence to determine the most effective surgical treatment, but limited evidence suggests that postoperative, early mobilization was more effective than a plaster cast.**	**7/11**
Van Os et. al. (2005).	**Comparison of conventional treatment and supervised rehabilitation for treatment of acute lateral ankle sprains**	**Systematic Review**	**7 Studies N=714**	**Insufficient evidence to demonstrate a superior treatment approach, although preliminary support exists for supervised exercises. High-quality RCTs are needed that are appropriately designed and reported.**	**5/11**

Van Rijn et. al. (2010).	**Effectiveness of additional supervised exercises compared with conventional treatment alone in patients with acute lateral ankle sprains**	**Systematic Review**	**11 Studies**	**Limited evidence in favor of adding supervised exercises to conventional treatment compared with conventional treatment alone** **There was no strong evidence for effectiveness of additional supervised exercises for any of the outcome measures.**	**7/11**
Verhagen et. al. (2000).	**The effect of preventive measures on the incidence of ankle sprains.**	**Systematic Review**	**8 RCTs**	**Evidence found that tape or braces reducing the incidence as also the severity of ankle sprains.** **Authors stated that brace, seem to be more effective in preventing ankle sprains than tape.** **Braces, however, seem to be effective only in athletes with previous ankle sprains; this cannot be concluded for the use of tape.** **The efficacy of shoes in preventing ankle sprains is unclear. It is likely the newness of the footwear plays a more important role than shoe height in preventing ankle sprains.** **Proprioceptive training reduces the incidence of ankle sprains in athletes with recurrent ankle sprains to the same level as subjects without any history of ankle sprains**	**7/11**

Table 2. Comparison table for systematic reviews

Randomized control trials

Author/Year	Title	Study Design	Participants	Findings/Conclusion
Beynnon et. al. (2006).	A Prospective, Randomized Clinical Investigation of the Treatment of First-Time Ankle Sprains.	RCT	N=212	Evidence in favour of sprain treatment with Air-Stirrup brace combined with an elastic wrap for grade I and II sprains compaired to use of the Air-Stirrup brace alone, an elastic wrap alone, or a walking cast for 10 days.
Coté et. al. (1988).	Comparison of Three Treatment Procedures for Minimizing Ankle Sprain Swelling	RCT	N=30	Evidence in favor of cold therapy as being the most favorable procedure to minimize edema for I and II degree sprains.
de Bie, et. al. (1998).	Low-level laser therapy in ankle sprains: a randomized clinical trial.	RCT	N=217	Insufficient evidence for the effectiveness of both high and low-dose laser therapy is in the treatment of lateral ankle sprains.
Hall et. al. (2015).	Strength-Training Protocols to Improve Deficits in Participants With Chronic Ankle Instability	RCT	N=39	Resistance-band protocol and proprioceptive neuromuscular facilitation strength protocol found to be an effective treatment to improve strength in individuals with CAI. Both protocols showed clinical benefits in strength and perceived instability.
Hupperets et. al. W. (2009).	Effect of unsupervised home based proprioceptive training on recurrences of ankle sprain: randomized controlled trial.	RCT	N=522	The use of a proprioceptive training programme after usual care of an ankle sprain found to be effective for the prevention of self-reported recurrences. This proprioceptive training was specifically beneficial in athletes whose original sprain was not medically treated. The intervention programme was associated with a 35% reduction in risk of recurrence.

Lamb et. al. (2009).	**Mechanical supports for acute, severe ankle sprain: A pragmatic, multicenter, randomized controlled trial.**	**RCT**	**N=584**	**Evidence in favor of below-knee cast as a faster recovery mean compared to tubular compression bandage.** **A short period of immobilization in a below-knee cast or Aircast results in faster recovery than if the patient is only given tubular compression bandage. Below-knee casts was recommended because they show the widest range of benefit.**
Lardenoye et. al. (2012).	**The effect of taping versus semi-rigid bracing on patient outcome and satisfaction in ankle sprains: A prospective, randomized controlled trial.**	**RCT**	**N=100**	**Treatment of acute ankle sprain with semi-rigid brace leads to significantly higher patient comfort and satisfaction, both with similar good outcome.**
Nunes et. al. (2015).	**Kinesio taping does not decrease swelling in acute, lateral ankle sprain of athletes: A randomized trial.**	**RCT**	**N=36**	**No evidence in favor in the effectiveness of the application of Kinesio Taping, with the aim of stimulating the lymphatic system, in decreasing acute swelling after an ankle sprain in athletes.** **Kinesio Tape for the reduction of ankle swelling did not significantly reduce swelling, as measured by volumetry or perimetry. A further 12 days after the Kinesio Tape was removed, no effect of the Kinesio Taping on the swelling was evident.**
Petrella et. al. (2007).	**Periarticular Hyaluronic Acid in Acute Ankle Sprain.**	**RCT**	**N=158**	**HA treatment for acute ankle sprain was highly satisfactory in the short term and the long term versus PL. This was associated with reduced pain and more rapid return to sport, with few associated adverse effects.**
Petrella et. al. (2004).	**Efficacy of Celecoxib, a COX-2–Specific Inhibitor, and Naproxen in the Management of Acute Ankle Sprain.**	**RCT**	**N=397**	**Celecoxib is as effective as naproxen in treating acute first-degree or second-degree ankle sprains but causes significantly less dyspepsia.**

Truyols-Domínguez et. al. (2013).	**Efficacy of thrust and Nonthrust manipulation and exercise with or without the addition of Myofascial therapy for the management of acute inversion ankle Sprain: A Randomized clinical trial.**	**RCT**	**N=50**	**Evidence that, in the treatment of lateral ankle sprains, the addition of myofascial therapy to a plan of care consisting of thrust and nonthrust manipulation and exercise may further improve outcomes compared to a plan consisting of thrust and nonthrust manipulation and exercise. However, the difference in improvement in the primary outcome between groups was not greater than what would be considered a minimal clinically important difference.**
Van Rijn et. al. (2007).	**Supervised exercises for adults with acute lateral ankle sprain: A randomized controlled trial.**	**RCT**	**N=102**	**Conventional treatment combined with supervised exercises compared to conventional treatment alone during the first year after an acute lateral ankle sprain does not lead to differences in the occurrence of re-sprains or in subjective recovery.** **There was no significant difference between treatment groups concerning subjective recovery or occurrence of re-sprains after 3 months and 1-year of follow-up.**
Verhagen et. al. (2004).	**The effect of a proprioceptive balance board training program for the prevention of ankle sprains**	**RCT**	**N= 1127**	**Evidence in favor of the use of proprioceptive balance board program as an effective mean for prevention of ankle sprain recurrences.**
Watts et. al. (2001).	**A randomized controlled trial to determine the effectiveness of double Tubigrip in grade 1 and 2 (mild to moderate) ankle sprains.**	**RCT**	**N=400**	**Treatment of grade 1 and 2 ankle sprains with DTG does not seem to lead to a shorter time to functional recovery and may increase the requirement for analgesia.**
Zouita et. al. (2013).	**The effect of 8-weeks proprioceptive exercise program in postural sway and isokinetic strength of ankle sprains of Tunisian athletes.**	**RCT**	**N=16**	**Evidence in favor of proprioceptive training exercises as a mean that can effectively stabilize an unstable ankle above for muscular and postural control.**

Table 3. Comparison table for randomized controlled trials

Downs & Black Checklist

Author(s) (Publication year)	Reporting	External validity	Bias	Confounding	Power	Total score
Beynnon et. al. (2006).	8	3	6	6	0	23
Coté et. al. (1988).	8	1	3	3	0	15
de Bie, et. al. (1998).	9	3	5	4	1	22
Hall et. al. (2015).	7	1	4	3	0	15
Hupperets et. al. W. (2009).	9	3	5	4	1	22
Lamb et. al. (2009).	10	3	6	5	1	25
Lardenoye et. al. (2012).	8	3	4	5	1	21
Nunes et. al. (2015).	8	1	3	5	0	17
Petrella et. al. (2007).	8	3	5	4	1	21
Petrella et. al. (2004).	9	3	4	4	1	21
Truyols-Domínguez et. al. (2013).	9	3	3	4	1	20
Van Rijn et. al. (2007).	8	2	5	4	1	20
Verhagen et. al. (2004).	8	3	6	5	1	23
Watts et. al. (2001).	7	2	4	4	1	18
Zouita et. al. (2013).	6	1	4	1	0	12

Table 4. Downs & Black Checklist [14]

4.2. Summarization of results

Aaltonen et. al. in their systematic review examined 32 randomized controlled trials with an objective to review the interventions targeted at preventing sports injuries. Several therapeutic interventions were evaluated including insoles, external joint supports, training programmes, stretching and warm-up programmes, mouth guards, modified shoes and videos.

All 5 studies evaluating insoles described a risk reduction of a minimal 30%, with four of these reporting a reduction of at least 50%. From the 7 studies evaluating external joint supports all 7 reported a reduction in risk of at least 30%, with six of these reporting a reduction of at least 50%. All 6 multi-intervention studies reported a reduction in the risk of injury of at least 30%, with five of these reporting a reduction of at least 50% and 4 studies assessing balance board training yielded differing results.

Their final conclusion stated that Insoles of any type, ankle external supports as also training programs were found to be effective in preventing ankle injuries.

In a systematic review of 22 randomized controlled trials **Bleakley et. al.** assessed the evidence ice (cryotherapy) in the treatment of acute soft-tissue injuries. 22 RCTs were included in their research. The actual treatments used were: cryocuffs or cold compressive devices, crushed ice, commercial ice machines, ice gel or ice packs, and ice submersion. The authors measured subjective or objective function, pain, swelling and range of motion as their main outcomes in their study.

Their conclusions stated that there is marginal evidence that treatment with ice and exercise is most effective after ankle sprain, and post-surgery.

However there is small evidence to suggest that the addition of ice to compression has any significant effect. Due to limitation of studies assessing the effectiveness of ice treatment on closed soft-tissue injuries, there was no evidence of an optimal type or duration of treatment.

de Vries et al. reviewed 10 randomized controlled trials. Neuromuscular training in conservative treatment was evaluated in first 4 trials. Another 4 studies compared surgical procedures for chronic ankle instability and last 2 included trials compared functional mobilization with immobilization after surgery.

The authors concluded that neuromuscular training alone appears effective in the short

term evaluation but further investigation must be done as the long term advantages are not known. Comparison of surgical interventions over another surgical intervention for chronic ankle instability showed that there is insufficient evidence to support any specific procedure but it is likely that there are limitations to the use of dynamic tenodesis. Their findings showed also that after surgical reconstruction; early functional rehabilitation appears to be superior to six weeks immobilization in restoring early function.

In their systematic review **Feger et. al.** attempted to assess whether electrical stimulation (ES), when used in conjunction with a standard treatment, is able to improve the condition of functional impairments, edema, and pain compared to a standard treatment, in patients with lateral ankle sprain.

The analysis of the included RCTs concluded that electrical stimulation have no effect into the improvement of function, reduction edema or pain modulation compared to standard treatments without ES in patients with acute ankle sprains.

In a relatively older systematic review in 1991, **Kannus et. al.** analyzed the result of 12 studies which compared surgical procedure together with an immobilization period of distal part of the leg, with only immobilization or other functional approaches.

The conclusion showed that functional treatment was the most optimal treatment of choice for acute complete tears of the lateral ligaments of the ankle as it clearly provides the quickest recovery to a full range of motion and return to work and physical activity. In their result section they claimed that functional approach does not, compromise the late mechanical stability of the ankle more than the other treatments, and it does not produce more bate symptoms (giving-way, pain, swelling, stiffness, or muscular weakness) with cast alone or operation and immobilization in a cast.

In their study **Kerkhoffs et al.** compared surgical and non-operative treatment methods for acute injuries of the lateral ligament complex of the ankle. In their evaluation of 20 studies they found that there was some evidence for a lower incidence of long-term ankle swelling in surgically treated patients but there was also evidence for longer recovery times, and higher incidences of ankle stiffness, impaired ankle mobility and complications after surgical treatment.

The result of this review concluded that there are insufficient high-quality RCTs available

to make a statement regarding the effectiveness of surgery compared with conservative treatment in LAI. However based on consensus of their reviewers they concluded that functional treatment is preferred over surgical therapy. For top-professionals they recommended that sports surgical treatment must be considered on an individual basis.

In a second meta-analysis, **Kerkhoffs et al.** compared the effect of different types of external support for non-operative treatment of ankle sprains.
This study showed that lace-up ankle support offered better results for persistent swelling at short-term follow-up when compared with semi-rigid ankle support; elastic bandage; and tape. The use of a semi-rigid ankle support showed significantly lower rates of instability, shorter return to work and return to sports times when compared with an elastic bandage. Tape treatment however showed significantly more complications, while the majority of those being skin irritations, when compared with an elastic bandage.

In a third study **Kerkhoffs et al.** made an attempt to set up an evidence-based clinical guideline based on high quality scientific studies in order to provide a considered, unbiased, evidenced, accessible, transparent and easy-to-use summary of the implications of current medical data about diagnosis, treatment and prevention of ankle sprains.
The results regarding the treatment procedures are better explained on comparison tables of systematic reviews.

Lauersen et. al. performed a systematic review of randomized controlled trials to evaluate the effectiveness of exercise interventions to prevent sports injuries and perform stratified analyses of strength training, stretching, proprioception and combinations of these approaches. They analyzed 25 studies with 26.610 participants and their results showed that physical activity was able to effectively reduce sports injuries.
Stretching proved no beneficial effect, whereas multiple exposure programmes, proprioception training, and strength training, in that order, showed a tendency towards increasing effect. Strength training was found to able to reduce sports injuries to less than one-third.

In a similar study **Leppänen et. al.** attempted to summarize the effects of sports injury prevention interventions. 68 RCTs met their criteria and were included in their systematic review and 60 trials were also included in their meta-analysis. They analyzed several preventive intervention methods including insoles, external joint supports, training programs, stretching, protective shoes, supplements and injury prevention videos. Trials were divided into seven groups (insoles, external joint supports, training programs, stretching, protective head equipment, modified shoes, and injury prevention videos) according to the type of the intervention. Their conclusion exhibited that insoles, external joint supports, and specific training programs appear to be effective in reducing the risk of sports injuries, while stretching, modified shoes, and injury prevention videos didn't showed any preventive effects.

In a smaller review, **Lin et. al.** discussed the effectiveness of several types of treatments for ankle injuries. The review lead the authors into making several important statements. The use of functional support and non-steroidal anti-inflammatory drugs was found to be beneficiary. Small evidence in favor of the use of manual therapy was found that may lead to positive short-term effects.
Physical exercise found to reduce the occurrence of recurrent ankle sprains and may be effective in managing chronic ankle instability. Electrophysical agents on the other hand had no evidence into enhancing the outcomes. Regarding surgical fixation for ankle fracture, an early introduction of activity, administered via early weight-bearing or exercise during the immobilization period, found to lead to better outcomes, however, the use of a brace or orthosis to enable exercise during the immobilization period found to have a higher rate of adverse effects.

In a different study **Osborne et. al.** investigated the prevention and treatment approaches for ankle sprains in athletes. Evaluation of the four most common approaches available which are: ankle supports, functional rehabilitation, multifaceted prevention programmes and surgery. As a mean to prevent resprain, ankle braces found to be very effective but their role in primary prevention was less evident. Regarding functional rehabilitation it was found to be the treatment of choice for acute ankle injuries while surgery was reserved for patients who failed a comprehensive non-operative treatment programme. Nonetheless

surgery for chronic ankle instability found typically successful also. Aspects of such as proprioceptive training have been shown to reduce the frequency of recurrent sprain. Likewise, multifaceted ankle sprain prevention programs are effective in sprain prevention. However, the relative importance of each component of such programs remains unknown and warrants further research.

In a very similar study **Petersen et. al** evaluated the evidence regarding the treatment and prevention of lateral ankle sprains. 3 meta-analysis and 17 prospective randomized trials were identified and reviewed. Their study compared surgical and non-surgical treatment, immobilization versus functional treatment, different external supports, balance training for rehabilitation, balance training for prevention and braces for prevention.

Their results showed that the main advantage of surgical ankle ligament repair was that objective instability and recurrence rate was less common when compared with non-operative treatment. Evaluating the pros and cons of surgical and non-surgical treatment, they concluded that the majority of grades I, II and III lateral ankle ligament ruptures can be managed without surgery. For non-surgical treatment, long-term immobilization was stated that it should be avoided. For grade III injuries, however, a short period of immobilization (max. 10 days) in a below knee cast was found to be advantageous. After the immobilization phase, a semi-rigid ankle brace was the most optimal and was recommended. Sufficient evidence was also found that treatment of acute ankle sprains should be supported by a neuromuscular training. Balance training was also found to be effective for the prevention of ankle sprains in athletes with the previous sprains. Finally they concluded that the use of a brace had strong evidence from high quality RCTs as a preventive measure for ankle sprains.

Polzer et. al. performed a thorough analysis of 117 studies with a goal to develop and evidence based strategy for the diagnosis and treatment of acute ankle injuries. Initially they compared surgery to conservative treatment.

The results favored conservative approaches over surgery due to comparable results with fewer complications and significantly lower costs. The study claimed that surgery should be reserved only for patients with persistent symptoms. Consistent evidence in favor of functional treatment was found also when it was compared to immobilization and

authors recommended it as a treatment of choice. When they searched for the most beneficial functional treatment they found that ankle braces were more convenient and cost effective than tape or elastic bandage. Furthermore, they found that supervised rehabilitation was also shown to reduce time to return to sport and/or work. Finally they investigated for other treatment procedures that could influence positively the course of acute ankle ligament injuries. They analyzed cryotherapy, drug treatment, homeopathic therapy, hyperbaric oxygen therapy, prolotherapy, platelet rich plasma, hyaluronic acid and physical therapy including laser, ultrasound and electrotherapy. From the previously mentioned interventions, only cryotherapy found to be effective in reducing pain and swelling in acute injuries of the soft tissues as also NSAIDs for reducing of pain during short-term follow up.

Terada et. al. in their systematic review investigated the magnitude of therapeutic intervention effects and the most effective therapeutic interventions for restoring normal ankle dorsiflexion after ankle sprain. 9 studies met their criteria and analyzed. Those studies incorporated the use of movement with mobilization, passive oscillatory joint mobilization, local vibration therapy, high-voltage pulsed stimulation, static stretching, hyperbaric oxygen, and psychological interventions.

Static-stretching intervention as a part of standardized care yielded the strongest effects on dorsiflexion after acute ankle sprains although it was recommended that clinicians need to consider what may be the limiting factor of ankle dorsiflexion to select the most appropriate treatments and interventions.

Van den Bekerom et. al. performed a systematic review with an objective evaluate the effects of ultrasound therapy in the treatment of acute ankle sprains. Five trials compared ultrasound therapy with sham ultrasound and three trials included single comparisons of ultrasound with three other treatments.

The evidence from the five small placebo-controlled trials included in their review didn‘t support the use of ultrasound in the treatment of acute ankle sprains. However, the available evidence was insufficient to rule out the possibility that there is an optimal dosage schedule for ultrasound therapy that may be of benefit.

In a second study **Van den Bekerom et. al.** analyze the effectiveness of applying rest, ice, compression, and elevation (RICE) therapy in the initial period after ankle sprain. 11 studies were selected concerning the different elements of RICE therapy.

Their results showed that there are insufficient evidence from available RCTs to determine the effectiveness of RICE therapy for acute ankle sprains in adults. Mild evidence for the benefit of the urgent posttraumatic mobilization was found. Evidence that ice provides no effect in the treatment of acute ankle sprains was limited. Evidence supporting the use of compression in the treatment of acute ankle sprains was also found limited. Regarding the last component of R.I.C.E. no evidence was found to support or reject the use of elevation in the treatment of acute ankle sprains. The authors concluded that treatment decisions must be made on an individual basis, cautiously evaluating the benefits and risks of each option, and must carefully selected based on expert opinions and national guidelines.

Van der Wees et. al. in their study attempted to critically reviews the effectiveness of exercise therapy and manual mobilization in acute ankle sprains and functional instability by conducting a systematic review of randomized controlled trials. 17 studies were included in total. In 13 studies the intervention included exercise therapy and in 4 studies the effects of manual mobilization of the ankle joint was evaluated.

The main finding of this review supported that exercise therapy is effective in the prevention of recurrent ankle sprains. The authors mentioned that those findings were of significant importance for strategies which treat both acute ankle sprains and functional instability. Regarding manual mobilization it was found that there was only initial effect on dorsiflexion range of motion, but the clinical relevance of these findings for physiotherapy practice may be limited. The conclusions of this study are that exercise therapy, which includes the use of a wobble board, is effective for patients with functional instability in the prevention of recurrent ankle sprains.

In a similar study **Van Ochten et. al.** attempted to determine the effectiveness of treatments for patients with chronic complaints after ankle sprain. A total of 20 RCTs and 1 controlled clinical trial were included in the analysis. The included studies compared different treatments (training programs, physiotherapy, chiropractic/manual therapy,

surgery, postoperative training, and functional treatment).

Their result showed that for pain and function outcomes, limited to moderate evidence was found for effectiveness of a training program compared to conservative treatment. Two studies found a decrease of recurrences after a proprioceptive training program. Four studies showed good results for different surgical methods but did not include a nonsurgical control group for comparison. Finally limited evidence was found for the effectiveness of an early mobilization program after surgery. The authors claimed that there is insufficient evidence to determine the most effective surgical treatment, but limited evidence suggests that postoperative, early mobilization was more effective than a plaster cast. Additionally in their final conclusion stated that in chronic ankle complaints after an ankle sprain, a training program gives better results for pain and function, and a decrease of recurrent ankle sprains, than a wait-and-see policy.

A systematic review by **Van Os et. al.** compared the effectiveness of conventional treatment combined with supervised rehabilitation training with conventional treatment alone for acute lateral ankle sprain. Seven RCTs were included in their study and were grouped by type of outcome. In their review the authors measured assessing time to return to sports and work, pain, swelling, subjective instability, objective instability, range of motion, and patient satisfaction.

Regarding pain one high-quality trial demonstrated a statistically significant effect in favor of the supervised rehabilitation group. In relation to swelling another study showed favor results of supervised rehabilitation group at short-term follow-up. Compared with standard treatment, supervised rehabilitation didn't present any significant effect on swelling improvement, immediately or at intermediate follow-up. Favor of the exercise group was found in another study in the incidence of functional instability. However three other studies did not find any statistically significant differences between the treatment groups. Another study demonstrated a statistically significant beneficial effect of supervised rehabilitation (early exercise instruction combined with balance training) on the incidence of re-injury at long-term follow-up. Regarding return to work, one study reported a statistically significantly shorter time in the supervised exercise group at immediate follow-up, while no statistically significant between group differences were shown in another (high-quality) trial at short-term or intermediate follow-up.

Still no study showed a statistically significant effect between treatment groups on time taken to return to sport after injury. An additional study showed greater patient satisfaction was reported with the supervised rehabilitation group at long-term while another study reported no benefit of supervised rehabilitation at long-term follow-up. Finally no statistically significant difference was shown on passive dorsal and plantar flexion at immediate or intermediate follow-up. The author final conclusions stated that there is limited evidence available that conventional treatment combined with supervised rehabilitation training could be superior to conventional treatment alone for acute lateral ankle sprains.

An additional systematic review by **Van Rijn et. al.** aimed to summarize the effectiveness of adding supervised exercises to conventional treatment compared with conventional treatment alone in patients with acute lateral ankle sprains. Their main goal was to compare any conventional treatment versus conventional treatment with additional supervised exercises. Secondary they attempted to evaluate the results of the main comparison in specific vulnerable populations with a high risk for re-sprains (such as athletes) or with increased risk for slower improvement (such as those with a severe injury). In their review 11 studies met then inclusion criteria. Van Rijn et. al. found limited evidence of effectiveness in favor of additional supervised exercises compared with conventional treatment alone, both on outcome measures of recovery and return to sport at short term follow-up. In a more specific population (athletes and soldiers) they found moderate evidence that supervised treatment leads to an earlier return to work and return to sports. Furthermore, limited evidence was also found for the effectiveness of supervised treatment in addition to conventional treatment in patients with more severe injuries. However, only a few studies, most were assessed as having high risk of bias, and most were lacking power. The authors stated that more high quality RCTs, concentrating on the effectiveness of additional supervised treatment in specific study populations, are required in order to present more sensitive results.

A systematic review by **Verhagen et. al.** had the objective to critically review the efficacy of preventive measures described in the literature, on the incidence of lateral ankle ligament injuries. A total of eight studies were identified relevant including injury prevention

programs, outside-the-boot brace, low & high-top shoes, prophylactic taping, semi rigid ankle orthosis, ankle disk training as also tape and laced ankle stabilizers. The majority of studies described the restrictive effects that braces, taping and shoes have on the range of motion of the ankle, as also their effects on ankle proprioception. Based on the clinical evidence found the authors concluded that the use of either tape or braces reduces the incidence of ankle sprains. Next to this preventive effect, it seems that the use of either tape or braces also results in less severe ankle sprains. Braces, however, seemed to be more effective in preventing ankle sprains than tape. It was unclear which type of athletes could benefit more from the use of preventive measures; those with or those without previous ankle sprains. Braces, however, seem to be effective only in athletes with previous ankle sprains; this cannot be concluded for the use of tape. The efficacy of shoes in preventing ankle sprains was also unclear. It was more likely that the newness of the footwear played a more important role than shoe height in preventing ankle sprains. Finally it was found that proprioceptive training reduced the incidence of ankle sprains in athletes with recurrent ankle sprains with a similar success to subjects without a history of sprain. Similar to other authors final conclusions, Verhagen et. al. mentioned the need for more RCTs, which should try to establish the clinical effect of braces in ankle sprain incidence reduction as also the cost effectiveness and ease of use of braces against tape.

Beynnon et. al. performed an RCT with a goal to find the differences between elastic wrapping, bracing, bracing combined with elastic wrapping, and casting for treatment of acute first-time ankle sprains in terms of return to normal function. Patients with a first-time sprain were selected and stratified by the severity of the sprain (grades I, II, or III) and then randomized to functional treatment procedures followed by several types of external supports. The patients completed daily logs until they returned to normal function and were followed up at 6 months. The results showed that treatment of first-time grade I and II ankle ligament sprains with the Air-Stirrup brace combined with an elastic wrap offered an earlier return to function compared to use of the Air-Stirrup brace alone, an elastic wrap alone or a walking cast for 10 days. When treatment of first-time grade III sprains was performed with an Air-Stirrup brace, patients returned to preinjury function in the same time interval compared with treatment with a walking cast for 10 days followed by

the use of an elastic wrap. After 6 months follow-up, all treatments produced comparable outcomes in terms of clinical testing, activity level, functional status, and patient satisfaction.

Coté et. al. in a relatively older RCT compared the effects of cold, heat, and contrast bath treatments on the amount of edema in ankle sprains of I-II degree during the postacute phase of rehabilitation. Thirty post-acute subjects with sprained ankles were assigned to a cold (n=10), heat (n=10), or contrast bath (n=10) treatment group and evaluated with volumetric measurements before and after the treatment procedure. The results of the study showed that all three treatments produced an increase of the edema in the postacute sprained ankles of the patients. Heat and contrast bath therapy produced an almost identical increase of the edema within the whole study period. The final conclusion by the authors was that cold therapy is the most appropriate treatment if the therapeutic objective is to minimize edema before rehabilitative exercise.

de Bie, et. al. conducted a trial to test the efficacy of low-level laser therapy on lateral ankle sprains as an addition to a standardized treatment regimen. In the trial 217 were included and then randomized into three groups in order to compare high-dose laser ($5J/cm^2$), low-dose laser ($0.5J/cm^2$), and placebo laser therapy ($0J/cm^2$). The intervention included twelve treatments of 904nm laser therapy in 4 weeks as an adjunct to a standardized treatment regimen of 4 weeks of brace therapy combined with standardized home exercises and advice. The laser therapy device that had been used was a 904nm Ga-As laser, with a 25-watt peak power, 500Hz frequency and pulse duration of 200nsec. The researchers measured pain and function as reported by the patient and their results concluded that neither high nor low-dose laser therapy was proven to be effective in the treatment of lateral ankle sprains.

In a different RCT **Hall et. al.** attempted to measure whether strength-training protocols affect strength, dynamic balance, functional performance, and perceived instability in individuals with CAI. A total of 39 patients with CAI were included and then further randomized into a resistance-band protocol group, a proprioceptive neuromuscular facilitation (PNF) strength-protocol group or a control group. Both training groups underwent their strength training protocols for 3 times per week for 6 weeks. The study showed that although the resistance-band protocol is common approach in rehabilitation,

the proprioceptive neuromuscular facilitation strength protocol is also an effective treatment to improve strength in individuals with CAI. Both protocols showed clinical benefits in strength and perceived instability.

Hupperets et. al. evaluated the effectiveness of an unsupervised proprioceptive training programme on the recurrences of ankle sprain after usual care in athletes who had sustained an acute sport related injury to the lateral ligament complex. In their RCT 522 athletes with a two month limit sustained sprain were included and randomized into intervention and control groups. Both groups received treatment according to usual care but intervention group received an eight week home based proprioceptive training programme. The results after one year follow-up showed, 145 athletes reported a recurrent ankle sprain: 56 (22%) in the intervention group and 89 (33%) in the control group. The authors claimed a reduction of 35% in risk of recurrence for the athletes followed the intervention programme. Their final conclusion supported the fact that the use of a proprioceptive training programme after usual care of an ankle sprain is effective for the prevention of self-reported recurrences. Additionally, the proprioceptive training was specifically more beneficial for athletes whose original sprain was not medically treated.

Lamb et. al. aimed to assess the effectiveness of three different mechanical supports (Aircast brace, Bledsoe boot, or 10-day below-knee cast) compared to a double-layer tubular compression bandage in promoting recovery after severe ankle sprains. 584 patients with severe ankle sprains were included in the study. Participants were provided with a mechanical support within the first 3 days of the treatment, and were given advice on reducing swelling and pain. Quality of ankle function was measured at 3 months and a follow-up was done over 9 month period to evaluate the functional outcomes. The results of the study showed that patients who received the below-knee cast had a more rapid recovery than those given the tubular compression bandage. Moreover Bledsoe boots offered no benefit over tubular compression bandage, which was found to be the least effective treatment throughout the recovery period.

In a similar RCT **Lardenoye et. al.** to compared the effect of taping and semi-rigid bracing on patient with ankle sprains. 100 patients with grade II and III sprains were randomized into two groups: one group was treated with tape and the other with a semi-rigid ankle brace, both for 4 weeks. Post-injury physical and proprioceptive training was standardized. As primary outcome the researchers evaluated skin complications. the level of satisfaction and ankle joint functionality. The result of this study showed that patient-reported comfort and satisfaction during treatment with a semi-rigid brace was significantly increased. The rate of skin complications of this group were also significantly lower compared to the tape group Additionally the functional outcomes of the ankle joint it was found to be similar between the two treatment groups, as well as reported pain. Regarding those results the authors concluded that treatment of acute ankle sprain with a semi-rigid brace leads to significantly higher patient comfort and satisfaction with both of them presenting similarly good outcome.

Nunes et. al. in their RCT they searched if Kinesiotaping is able to reduce swelling in athletes who have suffered an acute, lateral ankle sprain. 36 athletes with a recently occurred sprain (48 and 96 hours) and visible swelling were included in the study. Participants then evaluated by means of volumetry and randomized into taping and sham kinesiotaping control group. The experimental group received the Kinesiotaping application called a 'fan cut' that said to stimulate the reabsorption of the interstitial liquid via the lymphatic system. The results of this study showed that application of Kinesio for the reduction of ankle swelling didn't significantly reduce swelling, as measured by volumetry or perimetry and after 12 days of Kinesiotape removal no effect was evident. Regarding those finding the authors noted that the application of Kinesiotaping with the aim of stimulating the lymphatic system is not effective in decreasing acute swelling after an ankle sprain in athletes and further research must be done to investigate the different phases of the inflammatory process.

Petrella et. al. attempted to investigate the efficacy and safety of periarticular hyaluronic acid injections in acute lateral ankle sprains. 158 athletes with an acute grade 1 or 2 lateral ankle sprains were randomized within 48 hours of injury to periarticular injection with hyaluronic acid (HA) and standard of care (RICE) or placebo injection (PL) and standard

of care (RICE) treatment 4 days prior to injury. Assessments at baseline and days 4, 8, 30, and 90 included pain on weight bearing-walking, global ankle assessment, patient satisfaction, time to return to sport, and adverse events were measured. The findings of this study showed that periarticular hyaluronic acid injections proven highly satisfactory in short and long term.

Truyols-Dominguez et. al. studied the efficacy of manipulation and exercise procedures when they were combined with or without myofascial therapy for the treatment of acute ankle inversion sprains. 50 patients with post-acute inversion ankle sprain were randomized into 2 groups: a comparison group that received a thrust and nonthrust manipulation and exercise intervention, and an experimental group that received the same protocol and myofascial therapy. The primary outcomes that were measured were ankle pain at rest and functional ability. This study provided with evidence that, the addition of myofascial therapy to thrust and nonthrust manipulation and exercise therapy plan may further improve outcomes compared to a plan of care solely consisting of thrust and nonthrust manipulation and exercise. However, the difference in improvement in the primary outcome between groups was not greater than what would be considered a minimal clinically important difference.

In their RCT **Van Rijn et. al.** aimed to evaluate the effectiveness of conventional treatment alone and with supervised exercises in patients with an acute ankle sprain. 102 patients with acute lateral ankle sprain were included and then randomized to conventional treatment alone or conventional treatment combined with supervised exercise. The primary outcomes were subjective recovery and the occurrence of a resprain. Measurements were done at intake, 4 weeks, 8 weeks, 3 months, and 1 year after injury.

Verhagen et. al. studied the effectiveness of proprioceptive balance board program into the prevention of ankle sprains in volleyball players. 116 volleyball teams (N=1127) were followed prospectively for 2 seasons. Teams were then randomized to an intervention group (66 teams, 641 players) and control group (50 teams, 486 players). Intervention teams followed a prescribed balance board training program while control teams followed a normal training routine. Exposure was recorded on weekly basis and injuries were registered within 1 week after onset. The results of this study showed significantly evidence in favor

of balance training as fewer ankle sprains were found in the intervention group when compared to the control group. While proprioceptive balance board program found to prevent recurrence of ankle sprains it was also found that there was an association with an increase in recurrence of overuse knee injuries. Authors stated that such a program in volleyball is recommended for players with a history of ankle sprains because in volleyball the risk of ankle sprains outweighs the risk of knee injuries.

Watts et. al. in their RCT aimed to evaluate the functional outcomes of patients with ankle sprain underwent treatment with double tubigrip bandage. 400 patients were included and further randomized into treatment with or without a double tubigrip bandage. The number of days with impaired walking, the amount of days off work, the disturbances in sleeps and if analgesia was received were the main outcomes evaluated. Although only 197 patients completed the follow-up the results showed that treatment of grade I-II ankle sprains with double tubigrip bandage didn't contributed to shorter time of functional recovery and could also increase the requirement for analgesia.

Zouita et. al. investigated the effects of proprioceptive exercises rehabilitation in athletes with sprain ankle. 16 subjects were included in the study. 8 of them in the experimental group had unilateral ankle sprain symptoms, and another 8 in the control group had bilateral non-injured ankles. The subjects took part into a testing procedure which evaluated the sensory and voluntary motor control, assessed their static balance and measured their isokinetic strength. The subjects then followed a 24 session plan displayed over 8 weeks (3 sessions/week) where each session lasted between 20 and 30 minutes. The results showed evidence in favor of proprioceptive training exercises to stabilize an unstable ankle for muscular and postural control. However, 8 weeks didn't assess if the maximum effect have been reached.

5. Discussion

5.1. The Hypothesis

Based on the findings that were analyzed in the relevant included studies the hypothesis which was initialy proposed at the inception of this topic can be considered as confirmed. According to this it must be accepted that conservative treatment is the most optimal treatment offering high patient satisfaction, faster recovery rates, minimizing the treatment costs for ankle sprain recovery. Surgical interventions must be considered only for severe type of ankle sprains who does not respond to conservative treatment, or in cases of special population.

5.2.Preventive interventions for ankle sprains

A very important fact that we should take into consideration is which types of intervations are also able to reduce the risk for first time sprains or re-sprains of the ankle. According to expert opinions the use of specific training programs oriented to functional strength, neuromuscular training and stability as also the use of external supports like bracing and insole could be used as means to prevent ankle injuries. The analysis of the included studies verify this belief as many of the findings claim that use of external supports, functional rehabiliton and specific exercise program are highly contributing into reduce of recurrence risk. [18, 23, 32, 33, 34, 43, 44, 47, 54, 60, 65]

It's essential, especially for proffesional athletes that have already underwent treatment for ankle sprain to set up a proper strategy in order to deal with the one very frequent but serious complication of ankle sprain injuries; the chronic ankle instability. Functional rehabilitation is the most commonly used method to deal with CAI directly. However there are many cases where the patient's condition is very severe or the patient is not responding optimally to the selected treatment. In those kind of situations a passive therapeutic model must be deployed. Ankle braces, elastic bandages, taping and specialized insoles were found to be beneficial for the passive support of an unstable ankle as also for the prevention of resprain and are recommended. [1, 13, 26, 43, 44, 47, 54, 60]

5.3. Evidence based treatment procedures for ankle sprain injuries.

RICE is definitely one of the most commonly used treatment approaches regardless the severity or the stage of the ankle sprain. Rest, ice, compression and elevation have been repeatedly questioned by researchers regarding their effectiveness and therapeutic benefits throughout the recovery term from an ankle sprain. Rest is an essential part for the recovery from an injury as an optimal balance between rest and activity is what influencing our body regeneration factors directly. Ice has been proven very beneficial in the control of pain and swelling especially during the acute state of injury. Two systematic reviews and a RCT support the ice and characterized it as one of the most optimal approaches to handle the early complications of the sprain. [5, 9, 26] As far as compression and elevation components, professional experience has shown that they are both beneficial but more research must be done to underline their true benefits. The evidence of RICE within the literature contradicts. Some studies were able to find individual effects for ice or compression components alone but not the whole procedure as a unit. RICE is the number one intervention that is recommended for acute intervention so it's really important to investigate more about its effects. However it must be noted that some authors found some more beneficial approaches when compared specific interventions of RICE alone to other treatments. A direct comparison of each component of RICE with other type of treatments must be performed in order to find out if the RICE itself is the most updated acute intervention method and secondly if any modifications should be made on it.

Pharmacotherapy has been always part of the treatment of ankle sprains either the procedure were conservative or surgical. NSAIDs and analgesics are the main most widely used during the recovery of many sports injury and highly contribute in a faster recovery. In this study there is supporting evidence for the use and positive effects of Cox-2 inhibitors, NSAIDs and hyaluronic acid into a successful therapeutic plan but their possibly adverse effects must be taken also into consideration.

Passive external supports, is a commonly selected measure that has been used over time in order to control acute state sprains and prevent their re-occurrence. While there is controversial opinion if supporting equipment should be used in recovering ankle sprains as their use could possibly limit the ability of injured tissues to readapt themselves and

regain sufficient proprioception their effectiveness into prevention new re-sprains has been supported by several reviewed studies. Our current knowledge regarding the selection of the optimal treatment as also which patients would benefit more from the use of passive supports is still unclear. Although the results indicated evidence in favor for the use of passive preventive interventions more high quality RCTs focusing in different sports activities and broader range of patients and populations are needed in order to create precise and sensitive recommendations.

Only a few studies within the included ones criticized the use of **physical agents** as an effective measure to treat ankle sprains. Ultrasound, laser and electrotherapy are within the most popular treatment choices for many athletic and soft tissue injuries, however none of them presented any favorable evidence into the management of the ankle sprain or enhance of the clinical outcomes. Taking into consideration their popularity and how frequently those procedures are used within clinicians, more new, high quality studies focused directly into the efficacy of physical agents must be performed.

Functional rehabilitation has shown the biggest impact on the findings on this study. Regardless if the direct treatment approach will be surgical or conservative, functional rehabilitation was always considered within the standard procedures of a therapy program. The benefits of functional treatment into the treatment of sports related injuries have been illustrated many times. A big number of studies analyzed in this review support this evidence regarding the effectiveness and efficacy of functional treatment. Either when functional rehabilitation compared to surgery or several other conservative methods it was proven beneficial for the patient treatment and progression. It is important to state that in a number of studies functional treatment proven not only to offer better results regarding strengthening and prevention of re-sprains but also that positively influence the analgesic and antiedematic effects of other applications. Additionally when immobilization approach was compared to functional treatment the findings clearly favored the functional treatment with a noticeable improvement on therapy outcomes. Thus initializing the functional treatment protocol as early as possible is recommended.

5.4. Conservative versus surgical approach

Ankle sprains are very common type of injuries that are initially treated in the emergencies. Most common ankle injuries are those related to sports activity but some of them also occur during daily activities. Ankle injuries are able to cause notable disabilities and interferences in activities of daily living for an individual. Ankle sprains are frequent, however there is no clinical consensus among physicians about the management of ankle sprains and there is still no gold standard regarding the optimal treatment method yet. The objective of this review is to compare the two most commonly used therapeutic approaches for treating ankle sprain injuries; conservative and surgical approach. A widespread research of publicated literature was performed in order retrieve and further analyze the current scientific findings regarding this topic. The majority of these studies are investigating for the most optimal method available rather than comparing directly conservative to surgical approaches. This caused some complications regarding cross-comparison across the study results. However in the analysis of these publications it was found that conservative approaches are considered in general, the treatment of choice for most ankle sprain cases with significant evidence for better, faster and cost effective results over surgical procedures.

Conservative and surgical procedures are two very different approaches not only in relation to the invasive-non invasive part but also when concerning their recovery time, treatment cost, effectiveness as also the patient's peciliarities. A proffesional athlete, a militiant or some other special type of individuals must not be categorized and treated the same way as an individual within the norm of the population. Surgical approaches are objectively much more expensive than conservative treatment however, having a pro athlete out of play is considered much more costly for a professional team than the cost a surgery. The main reason that professionals, receive surgical treatment more ofter can be interpreted by the fact that there are no financial limit regarding the cost of the treament as also the fact that there is always a medical team that intensively monitoring and controling the nutrition, training and rest the athlete, securing that regenerating factor is optimal and no complications would be present. On the other hand a non-professional patient who would receive surgical treatment wouldn't be able to receive all those therapeutic priveleges and their therapy progression would be much more complicated. In this review there was

a number of studies connecting surgery with longer recovery times, increased expences, bigger complications and and higher risk of appearance of CAI. [26,27,43]

While this study is trying to discover the most optimal and efficient treatment approach we should realize that in some special populations (pro athletes, military) or severe ankle sprains (grade III) cases, surgery is recommended. However early functional rehabilitation combined with physical therapy has been evident throughout many studies and proven beneficial in treating post-surgical complications and must be taken into serious consideration. Many authors reported in their results that functional rehabilitation is prefered over surgery as its offering great benefits including less pain, increased patient satisfaction, less ankle rigidity, fewer complications and faster return-to-sport and work. [5, 25, 26, 27, 43, 44, 47]

Surgery is generally not recommended as a main treatment approach and must be recommended only in chronic cases of very unstable ankles.

Nevertheless conservative methods have proven their therapeutic effectivity in an vast repertoire of sports injuries more high quality studies are needed in order to formulate high quality evidence based guideline on treatment of ankle sprains.

5.5. Limitations of this study

While this review has been written within some explicit methodological borders in mind, limits imposed by potential sources of bias exist within this study. Initially it must be stated that the main author/reviewer was not blinded to publication information (e.g. authors, institution names) at any point while the review was being executed. Moreover, despite the attempt at being systematic and complete regarding searches, some potentially useful articles that were not available in English, weren't available through affiliated academic databased or couldn't be accessed due to expensive pre-required subscription were excluded.

6. Conclusion

This study investigated the efficacy of conservative and surgical interventions in search of the most optimal therapeutic approach. Systematic reviews and randomized controlled trials were retrieved, analyzed and directly compared in order to answer this question. Taking into consideration the advantages and disadvantages of conservative versus surgical treatments this study concludes that the majority of ankle sprains can be managed without surgery regardless of their grade.

A comprehensive assessment and a proper selection and customization of the treatment plan is a primary part for an optimum clinical management. As the reappearance of ankle sprains is very often seen in previously injured subjects, clinicians must focus to enhance the available treatment methods in order to prevent re-injury and promote a safe return to sports and daily life activities. More high quality studies are required in order to discover the optimal therapeutic procedures and create a ‘’gold’’ therapeutic guideline.

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