Management of chronic lateral ankle instability: alternatives for diagnosis and treatment

de Vries, J.S.

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Chapter 1

Introduction
Chronic lateral ankle instability

Chronic ankle instability can be defined as the inability to control normal motion of the ankle leading to recurrent sprains or giving way. Ankle instability can be divided in lateral, medial, subtalar or syndesmotic instability. Lateral ankle instability is the most common form and it is the subject of this thesis. The term ‘chronic’ implies a certain period of time and persistence or recurrence of the symptoms. In many studies the term ‘chronic ankle instability’ is not specifically defined; e.g. the duration of symptoms or the number of recurrent sprains. If mentioned, six months is usually the period of time and multiple – two or more – episodes of symptoms used to define chronic ankle instability. Six is an arbitrary number of months needed for recovery after an injury. Six weeks to three months has been suggested as the period needed for (ligament) healing. Six months does not only reflect time to healing but includes the time needed for complete recovery with return to previous level of activity as well. Although two sprains during the six months is the minimum of recurrent injuries needed for the diagnosis, the number will usually be higher. The possibility of two or more primary sprains with an adequate injury mechanism should be kept in mind.

Throughout this thesis chronic lateral ankle instability is defined as recurrent inversion sprains or giving way for more than six months in spite of a period of conservative treatment. Originally, conservative treatment meant proper training of strength and neuromuscular control of the ankle. For this thesis any form of conservative treatment, e.g. the use of bandages, braces or rest, was accepted for inclusion of patients.

Epidemiology and socioeconomic considerations

Chronic lateral ankle instability usually starts with an acute ankle inversion trauma, one of the most frequent (sports) injuries. Acute ankle sprains occur at a rate of about one injury per 10,000 people a day, whereas injury to the lateral ankle ligaments form a quarter of all sports traumas. In the Netherlands the incidence is about 12.8 per 1000 patients per year. It has been estimated that the annual costs to society for ankle injuries is approximately 40 million Euro per one million people.
Recurrent or persistent complaints and disability after acute ankle inversion injuries have been reported in up to 89% of the patients, although after 3 years 36% to 85% of the patients report full recovery. With an acute ankle sprain being a strong predictor for future sprains, up to 80% of the patients sustain at least one recurrent sprain. Estimates of the occurrence of true chronic ankle instability after an acute ankle inversion trauma, as mentioned, range from 7% to 53%. Studies of higher quality generally show lower percentages up to 33%. Exact figures about prevalence and costs of chronic ankle instability are not available, but, considering the high incidence after acute ankle injuries in combination with its often long-lasting and invalidating character, this not only means a great medical burden; it also has a great socioeconomic impact.

**Anatomy, biomechanics and neuromuscular control of the ankle**

The ankle is the joint that connects the foot to the leg. This means in particular the talocrural joint, but, as lateral ankle sprains mostly occur with inversion of the subtalar joint in combination with plantar flexion of the ankle, both the talocrural and subtalar joint need to be included in the analysis of ankle joint instability. The two joints are often referred to as the ankle joint complex.

**Anatomy**

The talus is situated under the tibia within the ankle fork, or mortise, that is formed by the distal tibia at the cranial and medial side (respectively pilon tibiale and medial malleolus) and the fibula at the lateral side (lateral malleolus). As a part of the ankle fork, the tibia and fibula articulate at the distal tibio-fibular joint, or syndesmosis. The subtalar joint is formed by the talus articulating with the calcaneus.

Joint capsules and ligaments directly connect the bones of the ankle to each other. Most of the ligaments are orientated strands of connective tissue that are part of the capsules (capsular ligaments). At the level of the syndesmosis four ligaments connect tibia and fibula: the anterior and posterior tibio-fibular ligament, the transverse ligament (inferior edge of the posterior tibio-fibular ligament) and the interosseous ligament (continuous with the interosseous membrane). On the medial side the tibia is linked to the talus through the deltoid
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ligament. The talus is connected to the calcaneus through the medial, lateral and interosseus talocalcaneal ligaments.

The lateral ligaments, relevant for inversion injuries, are the anterior and posterior talofibular ligaments (ATFL and PTFL), running horizontally from the lateral maleolus to the talus in respectively anterior and posterior direction, and the calcaneofibular ligament (CFL) that runs from the fibula down- and backwards directly to the calcaneus without attaching to the talus. The ATFL and PTFL are capsular ligaments, whereas the CFL is an extra-capsular ligament.165

The muscles and tendons involved with movement of the ankle joint complex are the gastrocnemius, the soleus, the plantaris (not present in all persons), the peroneus brevis and longus, the tibialis posterior and anterior, and to a lesser extend the long toe extensors and flexors. The majority of these muscles originate from the lower leg and their tendons pass the talus and calcaneus to insert onto the mid- or forefoot. The gastrocnemius and the plantaris originate from the posterior side of the distal femur. The gastrocnemius and soleus, together called ‘triceps surae’, form the Achilles tendon that inserts onto the calcaneus. The plantaris has a small muscle belly with a long tendon that parallels the triceps surae and Achilles tendon on the medial side, to insert onto to the calcaneus as well. None of the muscles originate from or insert onto the talus.

Relevant nerves for the ankle originate from the lower lumbar and higher sacral spinal roots (L4-S2). Efferent fibers of the deep peroneal nerve innervate the anterior muscles of the leg, the superficial peroneal nerve innervates the peroneal muscles on the lateral side, and the tibial nerve innervates the muscles on the posterior side of the leg. The afferent path consists of all nerves that send proprioceptive information (see paragraph about neuromuscular control) from mechanoreceptors around the ankle to the central nervous system. Mechanoreceptors are located in muscles, tendons, joint capsules, ligaments and skin.62,108

Biomechanics

Three-dimensional kinematic analyses show that both joints have six degrees of freedom-of-motion.29 However, the main motion of the talo-crural joint is plantar- and dorsiflexion, with internal and external rotation as coupled motion. With dorsiflexion, the talus slightly rotates externally relative to the tibia and with plantarflexion it rotates internally.65 The main motion of the subtalar joint is in- and eversion, with internal- and external rotation as coupled motion as well.8,29 Inversion and supination and eversion and pronation are often used as synonyms.
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Supination and pronation relate to the motion of the foot relative to the leg, with the sole of the foot turning inside and outside, respectively, whereas inversion and eversion relate to motion in the hind- and midfoot.\textsuperscript{29,113}

Each motion of the ankle is usually provided by one principle muscle, assisted by one or more other muscle(s).\textsuperscript{84} The main plantar flexor of the ankle is the triceps surae muscle, supported by the tibialis posterior, peroneal and the toe flexor muscles. The main dorsal flexor of the ankle is the tibialis anterior muscle, in combination with the long toe extensors. Inversion is mainly provided by the tibialis anterior and posterior with some help of the triceps surae and long toe flexors, whereas both peroneal muscles generate eversion.

Stability of the ankle can be divided in passive and active stability. Compared to, for example, the shoulder, knee and subtalar joint, the talocrural joint has more inherent passive stability due to the bony congruency of the talus embedded in the ankle fork.\textsuperscript{15} In general, the capsule and especially the ligaments give the ankle passive stability at the extremes of motion. With regard to the lateral ankle ligaments: maximum tension of the ATFL occurs with the foot in plantarflexion and supination, maximum tension of the CFL occurs in dorsiflexion and supination and maximum tension of the PTFL occurs in dorsiflexion.\textsuperscript{6,93} In addition to the passive motion constraints of the ankle, muscles provide active stability by controlled, stable motion within the free range of motion.\textsuperscript{125} Active stability prevents sudden forceful motion towards the extremes of the range of motion and, with this, preventing damage to ligaments, cartilage and bones.

**Neuromuscular control**

Neuromuscular control of body movement and posture, including active joint stability, is achieved through the integrated voluntary and reflexive effect of the central motor cortex, the cerebellum, and visual, vestibular and somatosensory perception on muscle activity.\textsuperscript{1,5,30,31,42,71,141} Although some include vestibular perception as well, somatosensory perception is synonymous to proprioception and relies on mechanoreceptor input. Mechanoreceptors are found in muscles, tendons, ligaments, capsules and the skin.\textsuperscript{62,108,132,167,177}

Active joint stability is achieved by a combination of co-contraction and fast muscle reflexes when unexpected movements occur.\textsuperscript{4,47,126,127,149} Co-contraction is the combined action of opposing muscles that leads to increased joint stiffness and a well-coordinated anticipatory joint motion. Both co-contraction and fast reflexes depend on mechanoreceptor
input in muscles and ligaments. Co-contraction is also modulated by anticipation to inversion and probably by a late reflexive response to a sudden inversion, anticipating a possible progressive inversion. Whereas a great part of the stability of a fully loaded ankle is provided by the articular surfaces, stability during the early landing phase, when inversions injuries often occur, depends much more on co-contraction.

All muscles around the ankle are involved in the co-contraction strategy, but the peroneal muscles mainly provide for the fast reflexive eversion. Whereas the contribution of mechanoreceptors in muscles to the fast reflexes is rather clear, the role of mechanoreceptors in ligaments is not yet fully understood. Although mechanoreceptors have been identified in the lateral ankle ligaments, it seems that their response to strain is too slow for a fast muscle reflex. They probably act indirectly by modifying co-contraction and facilitating the fast reflex of the peroneal muscles induced by their muscle spindle mechanoreceptors.

**Etiology**

Chronic ankle instability usually starts with an acute ankle inversion trauma. This first sprain can be the onset of subsequent chronic ankle instability. There are predisposing factors that may make a person susceptible to recurrent sprains or chronic ankle instability.

Morrison et al performed a systematic review concerning foot characteristics associated with acute and chronic lateral ankle injuries. A high longitudinal arch, greater foot width, cavovarus foot deformity, women with increased calcaneal eversion range of motion, greater metatarsophalangeal joint extension, subtalar joint instability, and a gait on the lateral side of the foot were identified as risk factors. However, the need for further evaluation of these risk factors and investigation of the role of (abnormal) ankle and foot motion was suggested as well.

Congenital joint hypermobility is intuitively associated with symptomatic chronic ankle instability. Hypermobility of multiple joints is a generalized disorder of the connective tissue. The number of joints involved and the severity of the hyperlaxity vary. A minority of these patients has disorders like Ehlers-Danlos, Marfan’s syndrome or osteogenesis imperfecta. Chronic ankle instability may be present but is usually not the only problem, whereas the most common symptom with hyperlaxity is pain.
It is of interest whether disturbed neuromuscular control is the cause or a possible consequence of a primary ankle sprain.\textsuperscript{55,134} In patients sustaining major central or peripheral neurologic damage or injury to the musculotendineus units followed by weakness of the ankle stabilizing muscles that may lead to ankle instability, the preexistence of the disturbance may be obvious. It is less obvious in otherwise healthy persons. At least three prospective studies report that worse neuromuscular control predicts the occurrence of ankle sprain in athletes in the following season.\textsuperscript{114,130,157} This suggests that a primary sprain may occur as a consequence of preexistent disturbed neuromuscular control.

Although not consequently found, a large number of studies report that disturbed neuromuscular control is present in most - if not in all - patients with chronic lateral ankle instability.\textsuperscript{7,53,55,68,115,117,134,142,146,175} This is probably caused by subtle neurological damage; i.e. the mechanoreceptors in the lateral ankle capsule and ligaments or more proximal to the common or superficial peroneal nerve.

Several methods have been used to evaluate neuromuscular control. Peroneal muscle reaction after sudden inversion, peroneal muscle strength, joint position sense and balance tests may all reveal a pathologic state. Peroneal reaction after sudden inversion can be evaluated by electromyography (EMG), that measures the occurrence of electrical activity in the peroneal muscle, or by measuring the actual slowing down of the inversion movement by the peroneal muscles.\textsuperscript{9,49,88,143,159} A larger delay suggests a slower or pathologic reflex. A deficit in evertor muscle strength leads to worse dynamic stability against ankle inversion and can be assessed in a static and a dynamic way.\textsuperscript{63,88,123,160,175} Disturbed sense of joint position or movement implicates worse proprioception of the ankle that may lead to a delayed or inadequate reaction to inversion.\textsuperscript{36,44,87,97,175} Balance tests can be static or dynamic; they evaluate the afferent and efferent part of neuromuscular control at the same time.\textsuperscript{3,33,44,56,140} A poor balance may indicate worse proprioception or muscular control and therefore a higher susceptibility to recurrent sprains.

As with the joint hypermobility syndrome, increased laxity of the lateral ankle ligaments after an acute ankle inversion injury may seem an obvious cause of chronic ankle instability. However, not every person with increased laxity of the lateral ligaments has symptomatic instability and not every patient with chronic lateral ankle instability has increased laxity of ligaments.\textsuperscript{7,18,43,53,54,58,64,65,67,68,134,158} Not withstanding these reservations, increased laxity of the lateral ankle ligaments remains an important factor in a large part of
the patient population with chronic ankle instability, that needs attention during the diagnostic phase.\textsuperscript{66}

**Diagnosis**

**Differential diagnosis**

During the evaluation for chronic lateral ankle instability, the presence of concomitant pathology or an alternative diagnosis should be kept in mind and ruled out.\textsuperscript{19,22,48,54,59,60,66,74,82,85,119,120,152,173} As alternatives for lateral ankle instability, subtalar, medial and syndesmotic instability should be considered. All may occur without pain. Especially subtalar instability may be difficult to differentiate from lateral ankle instability. Posterior and anterior impingement, sinus tarsi syndrome, cartilage or osteochondral lesions, loose bodies, tendon pathology, general or focal (teno-)synovitis, nonunions of avulsion fractures and osteoarthritis of the talocrural or subtalar joint may all accompany lateral ankle instability and some may induce instability themselves. Most of these pathologies will primarily present with pain. Pain as main symptom, especially when persisting in between sprains, should therefore raise a high suspicion of the presence of additional or alternative pathology.\textsuperscript{19,85}

**History**

According to the definition, the diagnosis ‘chronic lateral ankle instability’ is based on the patients’ history.\textsuperscript{73,93} Pure lateral instability is characterized by recurrent inversion sprains or giving way as the main symptom. Pain and swelling may accompany an episode of recurrent spraining but are usually not present in between sprains. As stated above, pain as main symptom warrants considering concomitant pathology that might need treatment first or in addition. The location of pain gives an indication what structure is affected. Deep ankle pain on weight bearing fits the diagnosis osteochondral defect.\textsuperscript{164} In long standing ankle instability pain, swelling and stiffness are signs of posttraumatic osteoarthritis of the talocrural joint.\textsuperscript{52,104,161} Locking may occur due to a loose body. If possible, the mechanism of (recurrent) sprains should be elucidated. Lateral ankle instability typically occurs with inversion and slight plantar flexion.\textsuperscript{73,74,82,169,170}
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Duration of the symptoms and earlier treatment should be evaluated. The period of six months before chronic ankle instability is diagnosed, although arbitrary, is more or less the time to wait for recovery after the initial sprain by conservative treatment.\textsuperscript{73} Clarifying what was actually done as ‘physical therapy’ may reveal whether the patient has had proper instability training or not. The use of ankle support (tape, brace, when applied and its effect) gives an idea about the severity of the instability. Level of work and sports and changes compared to pre-injury levels provide an indication to what extent the patient is invalidated by the instability.

**Physical examination**

Gait and stance examination may show a lateral gait or a rigid or supple (cavo-)varus of the (hind)foot that predisposes for inversion injuries or that is caused by recurrent spraining. General swelling of the ankle reflects recent injury or intra-articular pathology. Focal swelling may be due to pathology to an underlying structure; i.e. ligaments or tendons. Range of motion of the ankle, subtalar and foot joints should be tested for restrictions, pain, crepitus, and locking. Restricted dorsiflexion of the talocrural joint can be due to a short Achilles tendon, anterior impingement or osteoarthritis.

Increased laxity of the lateral ankle ligaments is clinically best tested with the anterior drawer test with the foot in slight plantar flexion.\textsuperscript{169} Laxity should be compared to the other side. With increased laxity of the lateral ligaments, the foot can be moved anterior and in internal rotation relative to the leg. With medial instability, the foot will move in external rotation.\textsuperscript{59} Talar tilt can be increased as well, although this may also indicate subtalar instability.\textsuperscript{57} Syndesmotic stability, although not very reliable, can be tested as well.\textsuperscript{12} Instability of the peroneal tendons may be appreciated with active eversions, moving the foot from plantar- to dorsiflexion.\textsuperscript{39}

The ankle region should be carefully palpated for tenderness. After a recent inversion sprain, the lateral ligaments can be painful. A tender deltoid ligament or tibiofibular syndesmosis may indicate respective injury or instability.\textsuperscript{12,59} Tenderness over the tendons is an indication of injury. A painful (medial and/or lateral) anterior ankle joint is typical for anterior ankle impingement.\textsuperscript{168} The presence of posterior ankle impingement is best tested by forced plantar flexion of the ankle, which causes posterior ankle pain in that case.\textsuperscript{168}
Stress testing of muscles, especially the peroneal muscles, may cause pain, as a sign of injury, and/or show weakness, which may indicate damage to the musculo-tendinous unit as well, or even complete rupture.\textsuperscript{48}

**Radiology**

For lateral ankle instability, standard ankle radiographs (AP, lateral and mortise) usually suffice to rule out or confirm concomitant pathology, like osteophytes, bony spurs, (nonunion of) avulsion fractures, osteochondral lesions or osteoarthritis.\textsuperscript{48,152,163,173} On indication, specific radiographs for anterior or posterior impingement can be made.\textsuperscript{168}

Ankle stress radiographs may help to confirm the diagnosis of mechanical instability. Good observer reliability has been reported, but normal values in the literature vary greatly and many patients test falsely negative due to muscle guarding, which leads to low sensitivity and a low positive predictive value.\textsuperscript{16,43,105} Although ankle stress radiographs are used in many studies, usually to quantify the effect of a surgical treatment, the clinical application as a diagnostic tool in individual patients remains questionable.

Other imaging modalities are mainly used to confirm or rule out concomitant pathology.\textsuperscript{16,48,82,173} Especially with MRI(-arthrography) most extra- and intra-articular ankle lesions can be evaluated very well. Ultrasound is a quick and cost-effective way to evaluate tendon pathology but requires experience.\textsuperscript{48}

**Additional investigations**

Additional investigations are usually not part of clinical practice and are mainly used for research purposes to evaluate neuromuscular control. Electromyography, joint position sense, peroneal strength, postural sway and balance tests are often used to compare groups or evaluate effects of strength or proprioceptive training in a group.\textsuperscript{68}

Several devices have been developed to test and quantify laxity of the anterolateral ligaments.\textsuperscript{67,75-78,83,89,90,103,138} Most devices have been tested on cadavers and groups of healthy and affected subjects, showing reproducible measurements and differences between affected and non-affected ankles. The reliability and validity for their use in individual patients, as with the neuromuscular control test, still have to be assessed.
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Treatment

Acute ankle inversion trauma
In the earlier days, many patients with an acute ankle inversion trauma were treated surgically, whereas nowadays practically all patients are treated conservatively. The majority of the patients returns to their previous level of activity.\textsuperscript{80,81,171} Although individual RCT’s show a better outcome for operative treatment of acute lateral ankle ligament ruptures, pooling of the data of all RCT’s comparing surgical with conservative treatment, does not show a convincing difference between these treatment modalities.\textsuperscript{79} Of the conservative modalities, functional treatment, with tape or a brace supporting the ankle, leads to earlier return to work and sports and higher patient satisfaction than immobilization with a cast, with a similar long-term outcome.\textsuperscript{80} Functional conservative treatment is therefore the treatment of choice, even for competitive athletes.\textsuperscript{79-81,107}

Chronic ankle instability
The primary aim of treatment of chronic ankle instability is restoring functional stability. A secondary aim is to prevent long-term sequelae, mainly osteoarthritis of the ankle joint. Most cases of ankle osteoarthritis are posttraumatic (71\% to 78\%).\textsuperscript{161,162} Fractures are the most common cause, but in 13\% to 16\% of the cases, ankle osteoarthritis is caused by previous ligament injuries, single or multiple. The majority of these ligament injuries are sustained during sports.\textsuperscript{161} Lateral lesions are far more often seen than medial.\textsuperscript{161}

The true natural course of chronic ankle instability is not known. There are two studies that suggest describing the outcome of longstanding, untreated or conservatively treated, ankle instability.\textsuperscript{52,104} However, both studies do not provide exact data about the incidence or severity of osteoarthritis in the long term. A study by Harrington describes 36 patients with a history of ankle instability for at least ten years but they seek medical care because of symptoms of osteoarthritis, not instability.\textsuperscript{52} Lofvenberg et al retrospectively describe a cohort of 37 patients with longstanding conservatively treated chronic ankle instability. It is not explained why conservative treatment instead of surgery was chosen.\textsuperscript{104} Instability in these patients might have been judged not severe enough to justify a ligament reconstruction. However, the studies by Harrington and Valderrabano show at least that osteoarthritis is a long-term sequel of chronic ankle instability that should be accounted for.\textsuperscript{52,161,163}
The consensus in literature is that conservative measures should be the first form of treatment of chronic ankle instability.\textsuperscript{2,51,106,109,163} In case of functional instability without increased ligament laxity, no malalignment of the ankle and no concomitant pathology, conservative treatment is the only option. Conservative measures consist of the use of ankle supports to improve mechanical stability and training programs to improve neuromuscular control. Training programs usually consist of balance exercises directed at improving strength and neuromuscular control. A Cochrane systematic review, based on high quality RCT’s, showed that a semi-rigid ankle orthosis or an Aircast brace is a good preventive measure for recurrent sprains during high risk activities.\textsuperscript{51} Although a positive effect of training programs is suggested by many non-comparative studies, a systematic review, based on lower quality RCT’s and non-randomized trials, only found lower level of evidence that patients with chronic ankle instability may actually benefit from it.\textsuperscript{106}

When conservative treatment fails and increased ligament laxity is present, operative treatment is considered.\textsuperscript{93,109} Since long standing instability is thought to result in ankle osteoarthritis, early intervention is advocated.\textsuperscript{135,161,162} The numerous procedures that have been described to reduce laxity of the lateral ankle ligaments can generally be divided into anatomical and non-anatomical reconstructions.\textsuperscript{7,93,163} With an anatomical reconstruction the original ligaments are sutured or imbricated. With non-anatomical reconstructions the anterolateral side of the ankle is stabilized, using (a part of) the peroneus brevis tendon. Comparing both groups, anatomical reconstructions provide better results in the long term with regard to functional stability and ligament laxity, patient satisfaction and they are a better prevention for osteoarthritis in the long term.\textsuperscript{91,94-96}

Alternative options for reconstruction are the use of other autografts, like the plantaris, palmaris and toe extensor tendons, the fascia lata, or allografts.\textsuperscript{35,61,109,128,147,154} More recently, thermal arthroscopic capsular shrinkage has been used to reduce ligament laxity, showing promising short and mid-term results.\textsuperscript{10,24,69,111,129} Another surgical option is the correction of a varus hindfoot alignment, if present, with a Dwyer calcaneal osteotomy.\textsuperscript{21,163}

**Remaining questions**

There are several remaining questions regarding chronic lateral ankle instability. Its true natural history has not yet been clarified, as are the advantages of any treatment over no
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treatment and the relative advantages and disadvantages of different conservative and surgical treatment options. Regarding the diagnosis, the relative contribution of increased ligament laxity, disturbed neuromuscular control and concomitant ankle pathology to symptomatic chronic ankle instability needs further clarification. Although increased lateral ankle ligament laxity may contribute to symptomatic instability, the gold standard to reliably quantify this increase is not available. An important question is also which patients will develop chronic lateral ankle instability after and acute primary inversion.

Some of these questions are addressed in this thesis as is shortly explained in the following section introducing the individual studies.

Introduction to the individual studies

Chapter 2 - Interventions for treating chronic ankle instability - a Cochrane systematic review

Aim of this study was to provide high-level evidence for the best treatment available for chronic lateral ankle instability. A Cochrane systematic review was conducted based on the available evidence from randomized controlled trial. The aim of Cochrane Collaboration is to provide for ‘high-quality, independent evidence to inform healthcare decision-making’. Systematic reviews based on randomized controlled trials, generally seen as the highest level of evidence, are the corner stone to reach this goal. Several reviews have been published about the treatment of chronic ankle instability but no systematic review based on randomized controlled trials alone was yet available. Assisted by the ‘Cochrane Bone, Joint and Muscle Trauma Group’ a systematic search, study selection, data extraction and data analyzes was performed to come to a conclusion about the best treatment for chronic ankle instability and an advise for future research.

Chapter 3 - Treatment of chronic anterolateral ankle instability in athletes

The risk of sustaining an inversion trauma is high in sports which involve cutting maneuvers, jumping and direct body contact (e.g. volleyball, basketball, and soccer) and residual problems are more disabling for athletes than for people with a more sedentary lifestyle. The aim of this review was to provide guidelines for the diagnosis and treatment of chronic ankle instability in this important subgroup based on the best evidence available.
Chapter 4 – Arthroscopic capsular shrinkage for chronic ankle instability with thermal radiofrequency – a prospective multicenter trial

Arthroscopic thermal capsular and ligament shrinkage is a relatively new option for the treatment of joint instability. Potential advantages of the procedure, compared to an open procedure, are the minimally invasive character, reduced operating time, outpatient setting, less surgical morbidity, fast recovery and quick return to work and sports. Most clinical experience exists with thermal capsular shrinkage of the glenohumeral joint capsule for shoulder instability. Good short-term results were reported but mid-term results showed a failure rate of more than one-third of the patients.\(^{28}\) The ankle joint, however, is intrinsically more stable compared to the shoulder due to its bony congruency and seems therefore more appropriate for the application of arthroscopic capsular shrinkage of a ligament with increased laxity.\(^{15}\) Only retrospective studies about the procedure had been published until recently.\(^{10,24,69,111,129}\) A prospective clinical study was performed to assess the mechanical and clinical benefit, including proprioception, of arthroscopic capsular shrinkage for chronic lateral ankle instability.

Chapter 5 - Long-term results of the Weber operation for chronic ankle instability - 37 patients followed for 20-30 years

Surgical procedures for repair of the lateral ankle ligaments can be divided in two groups: Non-anatomical reconstructions, in which a functional reconstruction is created, usually with the peroneus brevis tendon, and anatomical reconstructions, in which the ligaments itself are sutured or reattached to the fibula.\(^{14,17,23,26,35,37,46}\) The Weber technique, using the plantaris tendon for reconstruction of the anterior talofibular ligament, is considered to be an anatomical reconstruction, since the tendon graft is attached to the original sites of insertion of the ATFL.\(^{110,174}\) In recent comparative studies long-term results of anatomical reconstruction techniques appeared to be superior to that of non-anatomical reconstruction and are therefore the surgical treatment of choice in chronic lateral ankle instability.\(^{92,94-96}\) The study was performed to evaluate the long-term results of the Weber procedure for patients with chronic ankle lateral instability.

Chapter 6 - Clinical evaluation of a dynamic test for lateral ankle ligament laxity

Increased ligament laxity of the ankle in clinical practice is usually tested manually or by radiographic stress testing. The manual test is subjective in nature and radiographic stress
testing requires röntgen radiation.\textsuperscript{45,78} Other instrumented tests were developed for objective measurement of ankle instability without the use of radiation. They have the disadvantage of applying a constant force when testing ankle instability, allowing for false negative results due to apprehensive muscle contractions.\textsuperscript{75,83,150} Kerkhoffs et al developed a dynamic anterior ankle tester (DAAT) to overcome the effects of involuntary muscle contractions.\textsuperscript{75,76} A prospective longitudinal study was performed to evaluate the reliability and ability to detect increased lateral ligament laxity of the DAAT in 39 patients treated surgically for chronic ankle instability. Results of the DAAT were compared to the results of ankle stress radiographs and the manual anterior drawer test.

\textbf{Chapter 7 - Difference in balance measures between patients with chronic ankle instability and patients after an acute ankle inversion trauma}

It is assumed that disturbed neuromuscular control plays an important role in the development of chronic lateral ankle instability and that it is probably caused by a primary acute ankle inversion trauma.\textsuperscript{7,53,55,68,115,117,134,142,146,175} To be able to provide for preventive measures in selected patients, it would be necessary to identify those patients after an initial ankle inversion trauma that have disturbed neuromuscular control and will develop chronic ankle instability. Preferably, it should be a simple test that can by used in a routine clinical setting outside the laboratory. Based on the literature, static balance tests were thought to be a good choice for this.\textsuperscript{7,27,34,99,114,134,136,137,156,158} For that reason, a study was performed to compare healthy subjects with patients after an acute ankle inversion trauma and patients with chronic ankle instability to evaluate whether there is a difference in static balance measures between these groups in the first place.
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