GENERAL INTRODUCTION
ACHILLES, HIS HEEL AND THE TENDON

The best-known tendon of the human body was named after Achilles, the famous Greek hero in the Trojan War and main character of the Iliad by Homer. He was the son of the nymph Thetis and Peleus, the king of the Myrmidons. As with many ancient myths and sages there are various versions and interpretations of the story.

The Achilles Heel is globally known and often used when one is figuratively aiming at a certain weakness. This could be of the human body but also more metaphorically in a political system or else. The first time the Achilles heel was appointed as a certain weakness was probably around the eighteenth century. Of course the Achilles heel of humans, regardless of age, is the tendon itself and the surrounding structures. These are stressed with substantial forces, have limited blood supply and are protected merely by soft tissue.

ANATOMY

The region of the Achilles tendon consists foremost of soft tissue. The Achilles tendon itself is the posterior border of this region; due to its marginal vascularization it is prone to both traumatic and especially chronic pathology. (Fig 1) Four osseous structures border the anterior region: the tibia, fibula, talus and calcaneus. The posterior part of the talus, known as

![Figure 1: The blood supply of the Achilles tendon. The arteries were filled with black latex. 1 Sural nerve and small saphenous vein; 2 Plantaris tendon; 3 Tibialis posterior tendon; 4 Flexor digitorum longus tendon; 5 Flexor retinaculum 6 Extensor retinaculum. Copyright Pau Golano 72.](image-url)
Figure 2: Posterior view of the anatomic dissection of the ankle ligaments. 1 Tip of the fibula; 2 peroneal groove of the fibula; 3 tibia; 4 superficial component of the posterior tibiofibular ligament; 5 deep component of the posterior tibiofibular ligament or transverse ligament; 6 posterior calcaneofibular ligament; 7 lateral talar process; 8 medial talar process; 9 tunnel for flexor hallucis longus tendon; 10 flexor hallucis longus retinaculum; 11 calcaneofibular ligament; 12 subtalar joint; 13 posterior intermalleolar ligament; 14 flexor digitorum longus tendon (cut); 15 tibialis posterior tendon; 16 peroneal tendons. Copyright Pau Golano. 71.

Figure 3: Transversal section at the level of the tibiofibular syndesmosis. 1 Lateral malleolus; 2 Tibia; 3 Achilles tendon; 4 Plantaris tendon; 5 Tibialis anterior tendon; 6 Extensor hallucis longus tendon; 7 Extensor digitorum longus tendon; 8 Peroneus tertius tendon; 9 Peroneus longus tendon; 10 Peroneus brevis tendon; 11 Tibialis posterior tendon; 12 Flexor digitorum longus tendon; 13 Flexor hallucis longus tendon; 14 Deep sural/crural fascia; 15 Kager fat pad; 16 Anterior neurovascular bundle; 17 Posterior neurovascular bundle; 18 Saphenous nerve and great saphenous vein; 19 Sural nerve and small saphenous vein. Copyright Pau Golano. 72.
the posterior talar process is frequently associated with a secondary ossification centre. This additional osseous structure is known as os trigonum, which is closely related to the flexor hallucis longus tendon (FHL). When ossification results in a bony bridge with the posterior part of the talus the structure is known as an hypertrophied posterior talar process. Multiple vital structures are located between the Achilles tendon posteriorly and the crural bones anteriorly (Fig. 3). The fat tissue in this larger region is known as the pre-Achilles fat pad or Kager triangle/fat pad. The Kager triangle is bordered inferiorly by the superior part of the calcaneus, anteriorly by the FHL and posteriorly by the Achilles tendon. Besides the Achilles tendon and FHL, nearby the Kager triangle lie the flexor digitorum longus, peroneal tendons, the posterior tibial tendon and plantaris tendon. The Achilles tendon inserts crescent shaped halfway at the posterior tuberosity of the calcaneus (Fig. 4). Just anterior to the distal portion of the Achilles tendon and posterior to the posterosuperior calcaneal prominence the retrocalcaneal bursa is situated. Unlike other tendons in the leg the Achilles tendon lacks a synovial sheath. Instead it has a paratenon, a thin fibrous tissue containing blood vessels (Fig. 1). Within the paratenon, the plantaris tendon runs with the Achilles tendon.

**Figure 4:** Transversal section at the level of the tibiofibular syndesmosis. 1 Medial head of gastrocnemius muscle; 2 Lateral head of gastrocnemius muscle; 3 Soleus muscle 4 Achilles tendon; 5 Calcaneal insertion of the Achilles tendon 6 Deep sural/crural fascia; 7 Peroneal tendons; 8 Postero-lateral inter-muscular septum (cut); 9 Lateral malleolus; 10 Tibialis posterior and flexor digitorum tendon; 11 Posterior neuro-vascular bundle 12 Medial malleolus. Copyright Pau Golano.
PATHOLOGIES OF AND NEAR THE ACHILLES TENDON

Generally, Achilles tendon pathology can be divided in (acute) traumatic and chronic pathology. Acute Achilles tendon pathology consists of (partial) rupture of the tendon. Chronic pathology can be further specified by anatomic region, proximal, midportion and distal or insertional. Pain near the Achilles tendon and/or the posterior ankle in children and adults can result from many different pathologies. The pathologies addressed throughout this work, often eponymous, are mostly due to repetitive trauma and loading. They consist of bony posterior ankle impingement, Achilles tendinopathy, retrocalcaneal bursitis and calcaneal apophysitis.

Posterior Ankle Impingement

Posterior ankle impingement is a very important diagnosis in the differential diagnosis of distal Achilles tendon pathology. Patients with posterior ankle impingement often complain of pain near the Achilles tendon, it is therefore easily mistaken for an Achilles tendon disorder. A meticulous physical examination, supported by radiologic imaging, can differentiate between posterior ankle impingement and Achilles tendon pathologies. Impingement may be due to bony structures or soft tissue. Pain is provoked by plantar flexion of the foot, causing entrapment of tissue (bony or soft) between the calcaneus...
and distal tibia. Osseous structures that may impinge are an os trigonum, or an enlarged posterior talar process. Soft tissue can impinge due to synovitis, hypertrophic ankle capsule and/or FHL tenosynovitis. Impingement is often seen in certain patient groups: those who often plantar flex their ankle by standing tip toe (ballet) and kicking a ball (soccer). An os trigonum may be found on conventional imaging and is easily distinguished on CT images.

**Retrocalcaneal bursitis**

Retrocalcaneal bursitis is an inflammation of the bursa in the recess between the anterior inferior side of the Achilles tendon and the postero-superior aspect of the calcaneus (retrocalcaneal recess). It results in a visible and painful soft tissue swelling, medial and lateral to the AT at the level of the postero-superior part of the calcaneus. Patients complain of pain near the insertion of the Achilles tendon after strenuous activity or when restarting activity after a period of rest. Frequently, a postero-superior calcaneal prominence can be identified on plain radiographs.

**Achilles Tendinopathy**

Tendinopathy of the Achilles tendon can be divided in Insertional Achilles tendinopathy (IAT), Midportion Achilles tendinopathy and Achilles paratendinopathy. IAT is located at the insertion of the Achilles tendon onto the calcaneus, possibly with formation of bone spurs and calcifications in the tendon. Patients complain of pain, stiffness, and sometimes (a solid) swelling. On physical examination, the tendon insertion is recognisably tender. A swelling may be visible and a bony spur may be palpable. Non-insertional Achilles tendinopathy refers to any tendinopathy of the Achilles tendon aside from the insertion, in practice this often refers to mid-portion Achilles tendinopathy. Mid-portion Achilles tendinopathy is characterized by pain and swelling located at 2-7 cm from the insertion onto the calcaneus, often combined with impaired performance. Swelling can be diffuse or localized. This part of the tendon has also been described as the “main body of the Achilles tendon”. Paratendinopathy, often coexisting with midportion tendinopathy, is defined by acute or chronic inflammation and/or degeneration of the thin membrane around the Achilles tendon. The symptoms are clinically comparable with mid-portion tendinopathy. Differentiation between these pathologies can be made with ultrasound and MRI: showing extratendineous adhesions and fluid in paratendinopathy while the tendon itself is unaffected.

**Calcaneal apophysitis**

The apophysis is a secondary ossification center that serves as the attachment site for a muscle-tendon unit. In the growing body, the apophysis is the biomechanically weak point of the muscle-tendon-bone attachment and is subject to injury from repetitive stress or an acute avulsion injury. Apophysitis refers to the pain, irritation, inflammation, and microtrauma resulting from overuse injury to the apophysis. Calcaneal apophysitis, also
known as Sever's disease is common pathology in children aged between 8- and 15-years. Complaints consist of pain at the posterior part of the calcaneus, often worse shortly after activity. Diagnosis is made based on the clinical evaluation as radiologic imaging does not demonstrate and pathologic aspect of the specific region.

IMAGING

As explained in the previous sections, a variance of structures is anatomically related to the Achilles tendon. These structures can be visualized and studied using different imaging techniques. Often used techniques are conventional imaging, ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI). Each entity has its advantages and disadvantages; some are preferable for bony pathologies (conventional imaging and CT, Bonescan) other for soft tissues (US and MRI). An important difference lays in radiation exposure: none for US and MRI, a little for conventional and substantially more with CT. There is a tendency to keep exploring and extend the boundaries of what can be visualized at the best definition. Although it is very important for the future of visual diagnostics and the entire (medical) community to explore new techniques and possibilities, it is equally important to extent and optimize the current imaging techniques. The Kager triangle, due to its superficial location, can be visualized by means of multiple techniques. Osseous structures (os trigonum or posterior talar process hypertrophy) can be visualized by means of conventional radiography. If the accuracy is comparable to MRI or CT, it would be preferential over these alternatives due to lower cost and less radiation. Previous studies have evaluated optimization of beam direction for certain pathologies. Some of these, for example the AMI view for anteriomedial ankle impingement, are used extensively, other views have been shown to be less useful in daily practice. Hitherto, only one study has focused imaging of the posterior ankle region, so far without major clinical implications.

The diagnostic options for retrocalcaneal bursitis are numerous, proper visualization can be obtained by US, MRI or Bonescan, but also by means of conventional imaging. A previous study evaluated the diagnostic value of conventional imaging in patients with retrocalcaneal bursitis. The authors found that lateral conventional radiography of the ankle is a reliable method to diagnose retrocalcaneal bursitis, which has become a standard clinical tool ever since. It is however unknown whether this radiograph is still reliable after surgery once symptoms reoccur.
THE ACHILLES HEEL IN ADULTS

The treatment of Achilles tendinopathy and retrocalcaneal bursitis has both been studied extensively. As both pathologies are different entities, each will be discussed separately.

Achilles tendinopathy

After the diagnosis of midportion Achilles tendinopathy is made, a conservative strategy is the primary treatment of choice. This often focuses on eccentric exercises, in addition, or in more refractory cases the injection of platelet-rich-plasma (PRP) has become popular. The theory is that growth factors, released by platelets promote tissue healing, and with that healing of the tendinopathy. The healing process is furthermore supported by some factors that carry anti-inflammatory qualities. To create such a local reaction PRP is often, although not always, injected under ultrasound guidance at the site of inflammation. The effect of PRP has been studied in both randomized trials as well as case series, the results of which vary substantially. The reason for that is unsure; there may be several. An important factor could be that the PRP was injected at the correct site but after injection the substance would spread uncontrolled to non-inflamed sites of the Achilles tendon, hereby having no substantial therapeutic effect. The feasibility of such ultrasound guided PRP injections and the location of PRP directly after injection remains unsure and may be important for the therapeutic effect of the injected substance.

Insertional Achilles tendinopathy is preferably treated by means of conservative treatment. Many options are available: for instance rest, immobilization, stretching and/or strengthening exercises, shockwave therapy. All have been evaluated individually, however as the current options have not been outlined against each other the most effective choice is unsure. After conservative treatment fails surgical intervention is often chosen. As with conservative treatment, there are multiple surgical techniques to address insertional Achilles tendinopathy. The techniques may vary substantially or just marginally. Most studies show good results for the single evaluated procedure. However, it is unknown if any -and which- surgical option is superior.

Retrocalcaneal bursitis

Retrocalcaneal bursitis is preferably treated conservatively. Treatment may consist of RICE (Rest, Ice, Compression, Elevation) therapy, pain inducing activity cessation in combination with a change in footwear, NSAIDs (Non Steroid Anti Inflammatory Drugs). Frequently, however, the underlying cause is osseous and therefore insusceptible to conservative treatment. Therefore, some prefer surgical intervention as the primary treatment of choice. Numerous procedures have been evaluated and proven to be effective, both open and minimal invasive. Open intervention consists of osteotomy or excision of the excessive bone. Through a variance of approaches the excessive bone is resected under
direct vision\textsuperscript{15,44-53}. It is thought to provide a good sight over the pathology and important surrounding structures\textsuperscript{14}. Due to the extensive incision it is also thought to come with more wound complication compared to minimal invasive techniques\textsuperscript{14,16,54}. Minimal invasive intervention, first described by van Dijk et al., termed endoscopic calcaneoplasty is believed to be more attractive due to its less extensive approach\textsuperscript{16,54}. Due to the arthroscopic indirect view it reasoned to be more difficult than an open approach, although in experienced hands the consensus is that the view is superior compared to an open approach\textsuperscript{14,16,54}. With the current individual studies it is not possible to identify the superior surgical technique. Almost every study on surgical intervention, regardless of technique, reports acceptable or very good results\textsuperscript{15,16,44-54}. A systematic overview on the treatment options would give the necessary insight regarding the studies published so far, and possible advantages and disadvantages of available treatment modalities.

THE ACHILLES HEEL IN CHILDREN

Whereas adults seemingly rupture their Achilles tendon easily, develop midportion-, insertional Achilles tendinopathy or retrocalcaneal bursitis over time; children rarely develop substantial injury to the Achilles tendon itself\textsuperscript{55}. Occasionally, retrocalcaneal bursitis or posterior impingement may develop in adolescents. Prior to adolescence the most common cause of pain in the distal Achilles tendon region appears to be calcaneal apophysitis or Sever’s disease\textsuperscript{56-58}. Although some studies have reported on this pathology, little remains known. The exact pathophysiology is largely unknown; it has been suggested to be substantially influenced by foot alignment, weight and activity level in children, however once this was evaluated in a study, no difference was found between symptomatic and asymptomatic children\textsuperscript{59}. In addition, the incidence has never been studied meticulously. Amongst other musculoskeletal injuries the incidence is reported to be between 2 and 16\%\textsuperscript{60-62}. The incidence of non-specified heel pain was studied in Dutch children aged 0-17 years and found to be 1.7 per 1000 registered persons\textsuperscript{63}. As no differentiation between pathologies was made, the incidence of calcaneal apophysitis is unknown\textsuperscript{63}.

Treatment of calcaneal apophysitis

Multiple case series have shown the positive effects of multiple treatment modalities, like insoles, casting, rest and physical therapy\textsuperscript{56,64-69}. It is currently unsure which option is most effective\textsuperscript{56,58}. In a recent study, it was found that calcaneal apophysitis significantly decreases the quality of life of affected children\textsuperscript{70}. Symptoms may vary substantially: relatively mild with some discomfort after activity, or severely as children are not able to bear weight or walk\textsuperscript{56}. With the knowledge of the decreased quality of life and lack of evidence on which treatment is most effective more research in the field of calcaneal apophysitis is justified.
AIMS AND OUTLINE OF THE CHAPTERS

The aim of this thesis is to provide insight into the figurative Achilles heel of the human body: the Achilles tendon insertion and its surrounding structures and pathologies. The structures and troublesome annotation thereof will be discussed (Section I). New diagnostic options and assessments are evaluated (Section II), treatment of adults with Achilles tendon related pathologies are studied (Section III). Finally more insight is provided on the pathology and treatment of insertional problems in children (Section IV).

Section I: Terminology and Pathology
The terminology of the Achilles tendon region is difficult. This difficulty is multicausative: numerous eponyms are used in a relatively small anatomic region with a variance of interpretation of the exact definition. This is further complicated by a constant change of preference influenced by both history and current trends. Over the years many have tried to address the terminology issues. The most recent suggestions included a more evidence and anatomy based use of definitions and proposal to use eponyms as least as possible. To provide an overview on pathologies and eponyms of the region, the aim of the second chapter is to outline the frequently seen pathologies and often used eponyms as well as to weigh the advantages and disadvantages of eponyms.

Section II: Imaging
The second section focuses on the advancement of conventional radiography. The first part reports on a new imaging technique that may be more accurate in the detection of bony impingement. Theoretically the altered beam direction should result in less overprojection and should focus on the posterior part of the ankle joint, hereby providing more information and a higher diagnostic accuracy for pathology of this region. The aim of the third chapter is to test the theory in a prospective comparative study between the original lateral view and the new Posterior Impingement (PIM-)view. The second study of the diagnostic section also discusses the use of conventional radiography. Instead of the common aim of conventional imaging; osseous structures, this is the report of the detection of soft tissue pathology. The diagnostic options for retrocalcaneal bursitis are numerous. It can be visualized using ultrasound and MRI or bonescan, but also by means of conventional imaging. A previous study evaluated the diagnostic value of conventional imaging in patients with retrocalcaneal bursitis, concluding that it is a reliable method\(^\text{12}\). The studied population however consisted of ankles that were not operated on; as retrocalcaneal bursitis may reoccur after surgery it is unknown whether conventional radiography is still reliable after surgery once symptoms reoccur\(^\text{13-17}\). The aim of this chapter is to evaluate the reliability of conventional radiography of the ankle after surgical intervention for retrocalcaneal bursitis.
Section III: The Achilles Heel in Adults

The third section of this thesis discusses the treatment of Achilles tendon (related) problems in adults. After the diagnosis of midportion Achilles tendinopathy is made a conservative option is the treatment of choice. PRP is an often proposed treatment option, however with an unpredictable effectiveness. The location of PRP directly after injection may be important and is currently an unsure variable. The aim of the fifth chapter is to evaluate the spread of PRP after ultrasound guided injection into and around the Achilles tendon. Three frequently used techniques are evaluated and compared. In the sixth chapter, the treatment of insertional Achilles tendinopathy is evaluated. Although some studies have provided a general overview of the treatment of insertional Achilles tendinopathy, a systematic comparison of the effectiveness of available treatment options has never been made\textsuperscript{36}. The purpose of this systematic review was to meticulously analyze the effectiveness of different available surgical and/or nonsurgical treatment modalities for insertional Achilles tendinopathy. Chapter seven evaluates the surgical treatment of retrocalcaneal bursitis, separate studies have been performed yet it is unknown which surgical treatments for chronic retrocalcaneal bursitis is preferable. The aim of chapter seven is to systematically evaluate and analyse the current literature to determine which surgical treatment is the most effective for retrocalcaneal bursitis.

Section IV: The Achilles Heel in Children

The fourth and final section discusses the treatment of Achilles tendon (related) problems in children, more specifically calcaneal apophysitis. Although some studies have reported on this pathology little is known\textsuperscript{56,58,67}. The incidence is unsure, and was never studied specifically. Although it is known to cause a significant decrease in the quality of life of affected children the most effective treatment is unknown\textsuperscript{70}. The aim of the eighth chapter is to determine the incidence of calcaneal apophysitis in the Dutch general practitioner’s practice. The ninth chapter is the report of the first randomized controlled therapeutic trial on calcaneal apophysitis. The aim is to determine which treatment is most effective.
REFERENCES