MIKA PAAVOLA

Achilles Tendon Overuse Injuries

Diagnosis and Treatment

■

ACADEMIC DISSERTATION

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with love
to Mirva and Artturi

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, referred to as I-IV in the text:

I Paavola M, Paakkala T, Kannus P and Järvinen M (1998): Ultrasonography in the differential diagnosis of Achilles tendon injuries and related disorders. A comparison between pre-operative ultrasonography and surgical findings. Acta Radiol 39: 612-619.

II Paavola M, Kannus P, Paakkala T, Pasanen M and Järvinen M (2000): Long-term prognosis of patients with Achilles tendinopathy. An observational 8-year follow-up study. Am J Sports Med 28: 634-642.

III Paavola M, Kannus P, Orava S, Järvinen M (2001): Surgical treatment for chronic Achilles tendinopathy. A prospective 7-month follow-up study. Br J Sports Med. Submitted.

IV Paavola M, Orava S, Leppilahti J, Kannus P and Järvinen M (2000): Chronic Achilles tendon overuse injury: Complications after surgical treatment. An analysis of series of 432 consecutive patients. Am J Sports Med 28: 77-82.

ABBREVIATIONS

GAGPS	Glycosaminoglycan polysulphate
CT	Computed tomography
MRI	Magnetic resonance imaging
NSAID	Nonsteroidal anti-inflammatory drug
US	Ultrasonography

INTRODUCTION

Achilles, the warrior and hero of Homer´s Iliad, has lent his name to the Achilles tendon, the thickest and strongest tendon in the human body. The anatomical terms chorda Achillis or Tendo Achillis were adopted during the 17th century (Couch 1936).

Hippocrates, in the first recorded description of an injury to the Achilles tendon, concluded that "this tendon, if bruised or cut, causes the most acute fevers, induces choking, deranges the mind and at length brings death" (Couch 1936). Ambroise Paré, in 1575, recommended that a ruptured Achilles tendon be strapped with bandages dipped in wine and spices, but warned that the result was dubious (Malgaigne 1840). Since these first reports of subcutaneous Achilles tendon ruptures, the etiology and optimal treatment of Achilles tendon disorders has attracted continuously growing interest among researchers.

The spectrum of various Achilles tendon disorders and overuse injuries ranges from irritation of the peritendinous tissue (peritendinitis), structural degeneration of the tendon (tendinosis), insertional disorders (retrocalcaneal bursitis and insertional tendinopathy) to partial or complete tendon rupture and these conditions may co-exist (Kvist 1994, Schepsis et al. 1994, Jozsa and Kannus 1997). For the patient, the most common practical problem of the Achilles tendon overuse injury is the pain-induced limitation in sports and related activities, while the daily activities are normally not affected. The goal of treatment of the Achilles tendon complaint is to return the patient to the desired level of physical activity without significant residual pain. In athletes, an additional demand is that the recovery time should also be as quick as possible.

The diagnosis of the Achilles tendon overuse injury is mainly based on history and clinical examination. During the 1990s, ultrasonography (US) and magnetic resonance imaging (MRI) have also become valuable aids for the clinicians in assessment of the intratendinous and extratendinous pathology (Jozsa and Kannus 1997, Sandmeier and Renström 1997).

The etiology, pathogenesis and natural course of the Achilles tendon overuse injuries are largely unknown. Also, current conservative and surgical treatments modalities vary considerably and rely mainly on empirical evidence without much

scientific support. Most of the studies on Achilles tendon overuse injuries are retrospective and few of them include any objective evaluation.

The purpose of this study series was to evaluate the suggest value of ultrasonography (US) in the diagnosis of various Achilles tendon injuries and related disorders, to describe the long-term course of acute-to-subchronic Achilles tendinopathy, and to prospectively evaluate the results of surgical treatment of Achilles tendinopathy and the associated postoperative complications.

REVIEW OF THE LITERATURE

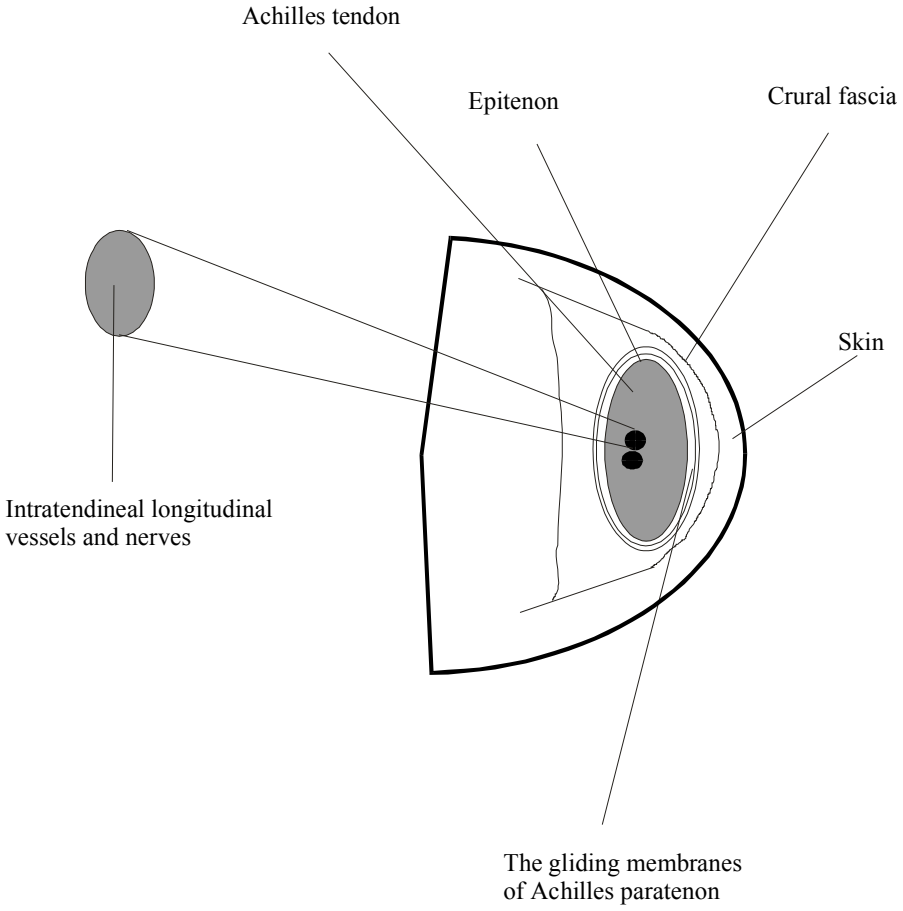
1. Functional anatomy of the Achilles tendon

The Achilles tendon constitutes the distal insertion of the gastrocnemius – soleus musculotendinous unit (i.e., the triceps surae muscle) (Figure 1). The former muscle, with two bellies, arises from the posterior surface of the femoral condyles and the latter from the posterior surfaces of the upper end of the tibia and fibula and the interposed tendinous arch. The tendon aponeuroses from the three muscle bellies join to form the Achilles tendon which transmits loads generated by the gastrocnemius and soleus muscles to the calcaneus. The origin of the Achilles tendon is the musculotendinous junction, and it inserts into the middle part of the posterior surface of the calcaneus from which it is separated proximally by the retrocalcaneal bursa. The arrangement of the inserting fibers is rectangular and the fibers themselves are anchored within bone at the osteotendinous junction. The soleus is the prime mover in plantarflexion of the ankle and gastrocnemius also contributes to this movement. Gastrocnemius can also flex the knee joint (Perry 1997).

Figure 1. Posterior view of the calf. The origin of the Achilles tendon is the musculotendinous junction of the gastrocnemius - soleus musculotendinous unit. It inserts into the middle part of the posterior surface of the calcaneus.

The Achilles tendon is surrounded throughout its length by the paratenon. It is proximally continuous with the fascial envelope of the muscle and distally blends with the periosteum of the calcaneus. The paratenon functions as an elastic sleeve (although probably not so effectively as a true tendon sheath) and permits free movement of the tendon within the surrounding tissues (Hess et al. 1989). Paratenon consists of several thin gliding membranes and forms a thin space between the tendon and crural fascia (Figure 2). Crural fascia is then covered by subcutaneous tissue and skin (Kvist and Kvist 1980). Under the paratenon, the entire tendon is surrounded by a fine, smooth connective tissue sheath called the epitenon. Together the paratenon and epitenon are sometimes called peritenon. On its outer surface, the epitenon is continuous with the paratenon. The inner surface of the epitenon is continuous with the endotenon, which binds the collagen fibers and contains neural, vascular and lymphatic supply.

Figure 2. Achilles tendon and surrounding membranes. The Achilles tendon is covered by a thin, smooth connective tissue sheath called the epitenon. The epitenon is surrounded by several thin gliding membranes of paratenon which forms a thin space between the tendon and crural fascia. Crural fascia is covered by subcutaneous tissues and skin.



The Achilles tendon receives blood supply from three regions: 1) at the musculotendinous junction, 2) through the paratenon surrounding the tendon and, 3) at the osteotendinous junction (Carr and Norris 1989). Anteriorly, the tendon is attached to a richly vascularized tissue that supplies vessels to the tendon. These vessels provide the most important blood supply (Barfred 1973). The sparse intratendinous vessels are found in the endotenon running longitudinally between the collagen bundles. Angiographic injection techniques have demonstrated a zone of relative avascularity between 2 and 6 centimeters proximal to the tendon insertion (Lagergren and Lindholm 1958, Carr and Norris 1989). Using an epoxy resin injection technique, poor vascularization has been observed in the middle part and posterior distal part of the Achilles tendon (Schmidt-Rohlfing et al. 1992). Åstöm and Westlin (1994) evaluated microvascular perfusion in the human Achilles tendon by laser Doppler flowmetry. Blood flow was significantly lower near the calcaneal insertion but otherwise was distributed evenly in the tendon.

The Achilles tendon is innervated by nerves of the attaching muscles and by small fasciculi from cutaneous nerves, in particular the sural nerve (Stilwell 1957). The number of both nerves and nerve endings are relatively low in large tendons such as the Achilles tendon and many nerve fibers terminate on the tendon surface or in the paratenon (Jozsa and Kannus 1997). Inside a tendon, the nerves, which are relatively few in number, follow the vascular channels within the long axis of the tendon, anastomose with each other via obliquely and transversely oriented nerve fibers, and finally terminate in the sensory nerve endings (Jozsa and Kannus 1997). These endings may differ in function depending on the stimulus. Mechanoreceptors function as transducers that convert physical energy, expressed as pressure or tension, into afferent nerve signals (Jozsa et al. 1993). Nociceptors, defined as receptors responding to stimuli that may cause tissue damage, are abundant in the skin as well as in paratenon and tendon tissue (Stilwell 1957). Some nociceptors respond only the intense mechanical stimuli, others to mechanical and thermal stimuli and yet others, called polymodal nociceptors, to chemical stimuli as well (Brodal 1981).

2. Terminology of the Achilles tendon overuse injuries

The location of Achilles tendon overuse injuries and related disorders can be divided clinically into the musculotendinous junction, tendon mid-portion and osteotendinous junction. There are no unique time criteria for the classification of overuse tendon injuries from acute to chronic. El Hawary et al. (1997) suggested that symptoms are experienced for less than 2 weeks in acute, for 2 to 6 weeks in subacute, and for greater than 6 weeks in chronic "tendinitis". These somewhat arbitrary distinctions are not based on histopathological, or clinical outcome criteria. Nevertheless, they provide a descriptive framework for future investigations.

The terminology used in the literature for the painful conditions of the Achilles tendon is confusing, and most often does not reflect the pathology of the tendon disorder. Terms such as "tendinitis", "tenonitis" and "tendonitis" have been widely used, even though inflammatory cell infiltration in the tendon is not shown in biopsies of chronic Achilles tendon problems (Clancy et al. 1976, Williams 1986, Schepsis and Leach 1987, Nelen et al. 1989, Jozsa and Kannus 1997). Furthermore, prostaglandin E_2 (a marker of the inflammatory process) is no more abundant in patients with chronic Achilles tendon pain than in normal controls (Alfredson 1999). Note that the absence of inflammatory cell infiltration in the chronic phase does not exclude previous inflammation.

The terms "tendinopathy", "tenopathy", "tendinosis", "partial rupture", "paratenonitis", "tenosynovitis", "tendovaginitis", "peritendinitis" and "achillodynia" have been previously used to describe the non-insertional overuse problems of tendons. Åström (1997) preferred the term "achillodynia" as a symptomatic diagnosis and recommended "tendinosis" and "peritendinitis" be reserved for cases where the pathology was verified by surgical exploration or by histological biopsies. In Finland, the term "Achilles peritendinitis" has been used in clinical practice to describe activity-related Achilles pain and tenderness on palpation, provided that there is no suspicion of intratendinous pathology on the basis of patient history, clinical examination, or imaging examinations. Maffulli et al. (1998) stated recently that combination of pain, swelling, and impaired performance should be given the clinical label "tendinopathy". This clinical term, "tendinopathy", encompasses histopathological entities such as "peritendinitis"

and/or “tendinosis”. The necessity to differentiate these two histopathological entities (Achilles peritendinitis and tendinosis) in clinical practice is uncertain as there have been no studies comparing outcome in these two conditions.

The term “partial Achilles tendon rupture” has been used in cases with macroscopic disruption of the Achilles tendon fibers. The amount of tendon disruption has been varied from almost the whole thickness to just a few fibers representing the whole spectrum between complete rupture and focal degeneration (i.e., tendinosis). Reports of “partial Achilles tendon rupture” were sparse and the existence of partial rupture even questioned until the report of Ljungqvist (1968). The pathologic entity “partial Achilles tendon rupture” could be used in patients with sudden onset of pain, large hypoechoic area in the US examination, and macroscopic tear in surgery.

In this thesis, the terms Achilles tendon overuse injury or Achilles tendinopathy are used, both of them indicating a combination of Achilles pain and swelling, and, impaired muscular performance. In addition to tendon mid-substance problems, the term Achilles tendon overuse injury includes the insertional disorders (i.e., retrocalcaneal bursitis and insertional tendinopathy).

3. Epidemiology of the Achilles tendon overuse injuries

The occurrence of Achilles tendon overuse injuries is highest in middle- and long-distance running, orienteering, track and field, tennis, and other ball games (Kvist 1991b and 1994, Leppilahti et al. 1991). Johansson (1986) and Lysholm and Wiklander (1987) reported an annual incidence of between 7% and 9% in Achilles tendon overuse injuries in top-level runners. The most common clinical diagnosis of Achilles overuse injuries is tendinopathy (55% to 65%), followed by insertional problems (retrocalcaneal bursitis and insertional tendinopathy) (20% to 25%). Anomalous soleus muscle is found in less than 2% among patients needing surgery for Achilles tendon symptoms (Leppilahti et al. 1994). In cohort study with an 11-year follow up, Kujala et al. (1999) found questionnaire-reported Achilles tendon overuse injury in 79 of 269 male orienteering

runners (30%) and 7 of 188 controls (4%), the age-adjusted odds ratio being 10.0 in runners compared with controls.

Kvist (1991a&b) studied the epidemiologic factors associated with Achilles tendon injuries in a large sports patient group. In this report, consisting of 698 cases, 66% had tendinopathy and 23% Achilles tendon insertional problems; in 8% of the patients, the injury was located at the myotendinous junction, and 3% of all patients had a total tendon rupture. Of the patients with Achilles tendon injury, 89% were men. Running was also the main sporting activity in patients with Achilles tendon injury (53%) while running sports patients represented 27% of all patients studied in this clinic. Some malalignments of the lower extremity were found in 60% of patients with Achilles tendon overuse injury.

Achilles tendon overuse injuries occur at a higher rate in older athletes than do many other typical overuse injuries (Kannus et al. 1989). In the report of 470 patients with Achilles tendinopathy and insertional complaints, about 25% of the subjects were young athletes, including 10% who were younger than 14 years, most of whom were diagnosed with calcaneal apophysitis (Sever´s disease) (Kvist 1991a).

4. Pathophysiology of the Achilles tendon overuse injuries

By definition, an overuse tendon injury is caused by a repetitive strain of the affected tendon so that it can no longer endure tension and stress, its structure begins to disrupt microscopically, and inflammation, edema and pain result (Renström and Kannus 1991). However, the exact pathogenesis of Achilles tendon overuse injuries remains largely unknown and neither prospective observational studies on the natural course of this complaint nor randomized treatment interventions with long-term follow-up have been published.

Achilles peritendinitis, insertitis (insertional tendinitis), retrocalcaneal bursitis, calcaneal apophysitis (Sever's disease), or a combination of these conditions may be the earliest clinical manifestation of tendon injury due to overuse (Hess et al. 1989). According to current knowledge, progressive damage (where the basal ability of the

tissue to repair itself is outpaced by the repetition of strain) may lead to tendinosis (a focal area of intratendinous degeneration), partial tears, and complete ruptures (Jozsa and Kannus 1997).

In acute Achilles peritendinitis, caused by acute overexertion, blunt trauma, or acute muscle fatigue, inflammatory cell reaction, circulatory impairment, and edema formation occur (Puddu 1976, Leach et al. 1981, Kvist 1991a and 1994, Jozsa and Kannus 1997). Crepitus, due to movement of the Achilles tendon within the paratenon with fibrin exudate, may appear. If the treatment of this acute condition fails, or has been overlooked, the fibrin may organize and form adhesions to the tendon, paratenon and crural fascia. This may lead to the chronic form of the disease (Puddu 1976, Kvist 1991a and 1994, Kvist and Kvist 1980).

The development of acute and chronic forms of retrocalcaneal bursitis follows the same pathogenetic pathways as described for peritendinitis. Increased friction of the bursa with subsequent edema formation and wall thickening is a characteristic pathologic phenomenon. A prominent posterosuperior tuberosity of the calcaneus (Haglund's deformity) may be a predisposition for increased friction and development of the retrocalcaneal bursitis (Jozsa and Kannus 1997)

The pathways and cellular mechanism that lead to tendinosis or tendon degeneration are not well understood (Kannus and Jozsa 1991). Frequently, tendinosis can be found in conjunction with the chronic forms of peritendinitis, although this does not indicate a causal relationship (Jozsa and Kannus 1997). Decreased arterial blood flow, with local hypoxia and impaired metabolic activity and nutrition, and persisting inflammatory reaction has been regarded as a key factor leading to tendon overuse injury and degeneration (Archambault et al. 1995, Jozsa and Kannus 1997). In addition, free radicals and exercise-induced hyperthermia may play a role in the development of the Achilles tendon degeneration (Archambault et al. 1995).

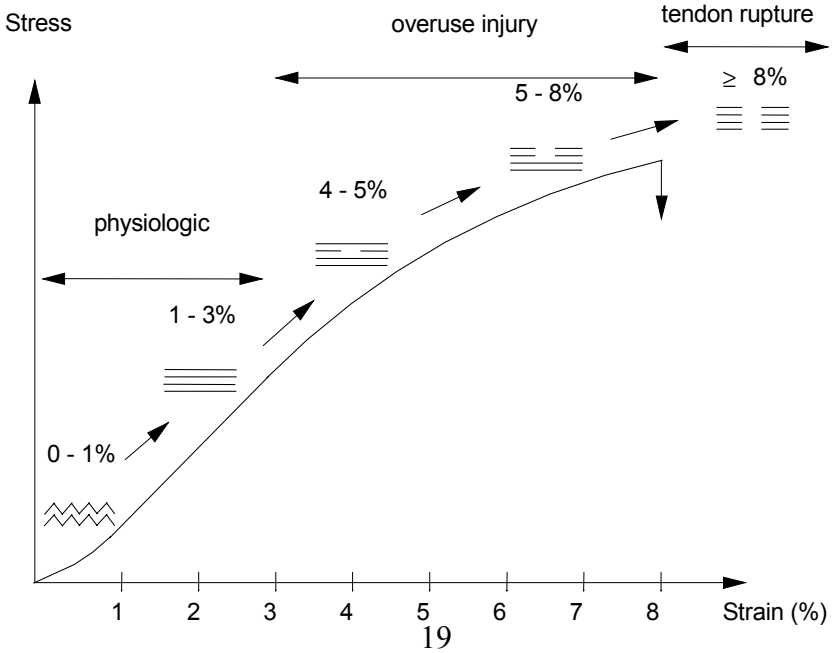
A popular theory in the literature suggests that tendon degeneration goes thorough acute to chronic phases of tendinitis before actual degeneration develops (Clancy et al. 1976, Puddu et al. 1976, Renström and Johnson 1985). However, inflammatory cell infiltration in the tendon is not shown in the biopsies of the Achilles tendons with a chronic overuse injury (Åström 1995, Movin et al. 1997) or ruptured Achilles tendons

with degenerative changes (Kannus and Jozsa 1991). On the other hand, biopsy studies from subacute – subchronic phases of Achilles disorders are lacking.

Leadbetter (1992) states that one explanation for tendinosis is the failure of the cell-matrix to adapt to excessive changes in load. He suspects that continued abusive load and irritation might stimulate the local release of cytokines, resulting in both autocrine and paracrine modulation of further cell activity.

The mechanical theory of "tendon overuse" states that when tendon has been strained repeatedly to 4-8 % strain it is unable to endure further tension, whereupon injury occurs (Figure 3). The tendinous tissue becomes fatigued as its basal reparative ability; i.e. the ability of the tendon cells to repair the fiber damage, is overwhelmed by repetitive microtraumatic process. The structure of the tendon is disrupted micro- or macroscopically by this repetitive strain (often eccentric by nature), and collagen fibers begin to slide past one another (causing breakage of their cross-linked structure) and denature (causing inflammation edema and pain) (Jozsa and Kannus 1997, Kannus 1997). This cumulative microtrauma is thought to weaken collagen cross-linking and the non-collagenous matrix and vascular elements of the tendon, and finally lead to tendinosis. Leadbetter (1992) has termed this the tendinosis cycle.

Figure 3. A schematic presentation of the development of chronic tendon disorders. According to this model, repetitive tendon strain (4-8% strain) may lead to cumulative fiber microtrauma. If the reparative capacity of the tendon tissue is exceeded, inflammation, edema, pain and tendon degeneration (overuse injury) can ensue.



Although physiological forces or loads usually cause less than 4% strain (Elliot 1965), certain sport activities may repeatedly go beyond these loads (4-8% of strain), cause breaks in the collagen cross-link structure, and thus, start the overuse problem. Also, if the muscle is weak or fatigued, the energy absorption capacity of the whole muscle-tendon unit is reduced and the muscle no longer protects the tendon from strain injury and subsequent inflammation, edema, and pain (Kannus 1997).

The existence of an anomalous or accessory soleus muscle has been well documented in the literature (Nichols and Kalenak 1984, Nelimarkka et al. 1988, Leppilahti et al. 1989, Brodie et al. 1996). Two types of anomalous soleus muscle have been described: extension of the muscle more distally than usual along the Achilles tendon, and separate insertion of the soleus into the upper surface of the calcaneus with a separate tendon, or directly without tendon (Leppilahti et al. 1991). Several hypotheses have been proposed to expalain why an anomalous or accessory soleus muscle may become symptomatic; diminished blood supply because of growth may result in an ischemic type of pain, increase in the size of the muscle can lead to a compartment syndrome or cause a compressive neuropathy of the posterior tibial nerve, and the pain may be caused by a traction phenomenon on the nerve supplying the accessory soleus muscle (Brodie et al. 1996).

Pain is the most disconcerning and irritating symptom of Achilles tendon overuse injuries. Traditionally, the pain associated with the chronic Achilles tendon overuse injuries has been proposed to arise thorough inflammation or separation of collagen fibers (Khan et al. 2000, Khan and Cook 2000). However, neither of these hypotheses holds up under scientific scrutiny (Alfredson 1999, Khan et al. 2000, Khan and Cook 2000). Therefore, alternative explanations have been sought for the origin of pain in chronic tendon disorders. Recently, as a new biochemical hypothesis it was suggested that as yet unidentified biochemical noxious compounds (candidates include matrix substances, such as chondroitin sulphate or nociceptive neurotransmitters, such as substance P) could irritate the pain receptors in chronically ill tendon tissue (Khan et al. 2000, Khan and Cook 2000).

5. Etiology of the Achilles tendon overuse injuries

Sports injuries can be caused by intrinsic or extrinsic factors, either alone or combination (Lorenzon 1988). In acute trauma, extrinsic factors predominate while overuse injuries are generally multifactorial in origin. In chronic tendon overuse injuries, an interaction between these two categories is common (Williams 1986).

Intrinsic etiological factors

The most common intrinsic risk factors for chronic Achilles tendon overuse injuries are listed in Table 1.

Table 1
Proposed intrinsic factors associated with chronic Achilles tendon overuse injuries

Malalignments
Foot hyperpronation or hypopronation
Pes planus or cavus
Forefoot varus or valgus
Hindfoot varus or valgus
Genu valgum or varum
Leg length discrepancy
Muscle weakness and imbalance
Decreased flexibility
Joint laxity
Joint stiffness
Female gender
Age: young or old
Overweight
Predisposing diseases
Blood supply
Ischemia
Hypoxia
Hyperthermia

The list of possible malalignments is numerous and, frequently, several of them occur simultaneously. The most common and perhaps most important malalignment in the foot is hyperpronation. It is hypothesized that if the foot remains pronated excessively as normal knee extension occurs, the Achilles tendon experiences unusually high forces secondary to pronation-induced contradictory rotational forces of the tendon (Fredericson 1996, Scioli 1994). Thus, increased pronation has been proposed to be associated particularly with Achilles tendinopathy and retrocalcaneal bursitis (Lorenzon 1988). James et al. (1978) observed that hyperpronation was present in 60% of subjects who had running injuries. Segesser et al. (1980) found that ankle joint instability and hyperpronation predispose people to Achilles tendon disorders. Kvist (1991a) demonstrated that limited subtalar joint mobility and rigidity of the ankle joint were found more frequently in athletes with Achilles tendinopathy than in other athletes. In addition, forefoot varus correlated significantly with Achilles tendinopathy (Clement et al. 1984, Kvist 1991a, McCrory et al. 1999, Nigg 2001). Recently, Kaufman et al. (1999) observed in their prospective study that increased hindfoot inversion and decreased ankle dorsiflexion with knee extension is associated with Achilles tendinopathy. In general, different malalignments and biomechanical faults are claimed to play an etiologic role in 60% to 70% of the athletes with Achilles tendon overuse injuries (Kvist 1991b). However, the mechanism by which they do this remains in dispute (Nigg 2001).

In addition to foot hyperpronation, the importance of leg length discrepancy (LLD) is one of the most controversial topics in orthopedic and sports medicine (Kannus 1997). The traditional orthopedic view is that discrepancies of less than 20 mm are mostly cosmetic (Lorenzon 1988). In elite athletes, however, a discrepancy of more than 5-6 mm may be symptomatic and, consequently, for a discrepancy of 10 mm or more, a built-up shoe or insert type of orthotics have been recommended to prevent overuse symptoms (Kannus 1997). However, it must be realized that the real occurrence of these proposed biomechanical alterations, their magnitude and, above all, their clinical significance are not well known.

The significance of muscle weakness and imbalance as well as disturbed musculotendinous flexibility in Achilles tendon injury prevention is also matter of debate. However, muscular strength, power, endurance, and flexibility are an important part of

physical performance, and are most likely also important in the prevention of certain sport injuries, particularly tendon injuries (Lorenzon 1988). Recently Alfredson et al. (1998) showed very good short-term effect on chronic Achilles tendinosis with heavy-load eccentric training, which is based on increasing the length, tensile strength and force of muscle tendon unit (Fyfe and Stanish 1992). This field is, however, open to speculation as the studies do not provide conclusive evidence on whether muscular weakness, imbalance and musculotendinous tightness are the causes or consequences of injuries.

In some people, especially in some women, joints can be hypermobile and permit excessive range of motion in normal physiological directions of movement. Joint hypermobility is often genetic and, in general, it does not require any special attention in injury prevention (Jozsa and Kannus 1997, Kannus 1997). However, a ligament injury may cause excessive joint laxity, which in the ankle is assumed to be a cause of Achilles tendinopathy (Segesser et al. 1980).

Men comprise the majority of patients with a tendon overuse injury, although the incidence in women seems to be increasing. Although 60% or more of all overuse injuries sustained in running are found in men, women under the age of 30 are considered to be at the greatest risk for these injuries. The proportion of women in sports injury surveys has increased during the past few decades, from 14% – 18% to 20% – 30% (Kvist and Järvinen 1980, Kannus et al. 1987, Kannus et al. 1990, Kvist 1991a, Leppilahti et al. 1991). Two reasons for the increased proportion of women sustaining injuries are suggested. First, there has been an increased female interest among women in sports and physical activity in general. Second, women are now much more interested in sports that have a high risk not only of acute injury (football, downhill skiing, judo, indoor ball games), but also of overuse injury (long-distance running, aerobics, cycling, triathlon, indoor ball games) (Järvinen 1992, Kannus et al. 1990). Differences in physical activity, however, make it difficult to evaluate gender as an independent etiological factor (Kvist 1991a, Åström 1997).

In adolescent, apophysitis and insertional tendinopathy are more frequent than tendon midsubstance problems (Järvinen 1992). Traction apophysitis of the calcaneus

(Sever´s disease) is common overuse injury in adolescents, representing 6% to 15% of all overuse problems in this group (Kujala et al. 1985, Orava and Puranen 1978).

The degenerative changes associated with increasing age may be detected as early as the third decade, when a progressive decline becomes apparent in cellular function in many tissues (Bosco and Komi 1980). With aging, various functions of the body gradually deteriorate. This also includes the musculoskeletal system, even if not so extensively as the cardiovascular system (Kuroda 1988). The sport injury profile of elderly athletes varies from that of their younger colleagues. In a 3-year prospective, controlled study, Kannus et al. (1989) showed that in elderly athletes sports injuries are more frequently related to overuse rather than acute trauma. Also, injuries more commonly have a degenerative basis, such as in Achilles tendinopathy with tendinosis. The tendon is subjected to early degenerative changes since both the collagen and non-collagenous matrix components of tendon show qualitative and quantitative changes. There are also many cellular as well as vascular changes within the aging tendon. As a result of all these physiological age-related changes, an aged tendon is weaker than its younger counterpart and is more likely to tear or suffer overuse injury (O'Brien 1992, Best 1994).

In attempting to prevent tendon injury, we should always take into account that a subject may have a predisposing disease making him or her prone to injury. There is an association between rheumatoid diseases and tendon overuse-type symptoms, although the truly chronic rheumatoid inflammation at the Achilles tendon has been considered rare (Jozsa and Kannus 1997).

Extrinsic etiological factors

Extrinsic predisposing factors are all those factors acting externally on the human body. The most common extrinsic factors related to chronic Achilles tendinopathy are presented in Table 2.

Table 2
Proposed extrinsic factors associated with chronic Achilles tendon overuse injuries

Excessive load
Type of movement
Speed of movement
Number of repetitions
Footwear
Training errors
Over distance
Fast progression
High intensity
Hill work
Poor technique
Fatigue
Suboptimal environmental conditions
Dark
Heat or cold
Humidity
Altitude
Slippery or hard surface
Poor equipment

Repeated overload in running and jumping activities is often associated with chronic tendon disorders, including Achilles tendon overuse injuries (Orava 1980). Training errors are suggested to be present in 60-80% of tendon overuse injuries, the most common being too long distance, too high intensity, too fast progression, and too much up- or downhill work (Clement et al. 1984, Kannus 1997). Monotonous, asymmetric and spesialized training, such as running only, as well as poor technique and fatigue play a role as risk factors of Achilles tendon overuse injuries. Also, poor environmental conditions, such as darkness, too high or low temperature and humidity, and slippery or hard running surfaces, particularly with poor equipment, have been suggested to promote Achilles tendon overuse injuries (Jozsa and Kannus 1997, Kannus 1997, Movin 1998). However, the lack of high quality prospective studies limit the strength of conclusions that can be drawn about these risk factors.

6. Diagnosis of the Achilles tendon overuse injury

The diagnosis of the Achilles tendon overuse injury is mainly based on a careful history and detailed clinical examination. No other diagnostic method substitutes for these procedures, not even such advanced radiological techniques as ultrasonographic (US) examination or magnetic resonance imaging (MRI) (Kvist 1991b). In most cases, an adequate history and physical examination should give the correct diagnosis, and all other diagnostic methods are recommended as complementary procedures to verify a clinical suspicion or, occasionally, to exclude other musculoskeletal disorders (Renström 1991, Jozsa and Kannus 1997, Khan et al. 1998). Differential diagnostic findings of history and clinical examination in Achilles tendon injuries are presented in Table 3.

6.1. History

The patient's history should provide the majority of the information to make the diagnosis (Sandmeier and Renström 1997). The time interval between the onset of symptoms and the first visit to a physician must be recorded, along with the onset of the symptoms, the injury mechanism in acute cases, and possible previous Achilles tendon problems and their treatment (Jozsa and Kannus 1997). The course of events since the onset of symptoms, with special emphasis on what activities seem to make the pain worse and what seems to relieve the pain, will provide valuable information (Sandmeier and Renström 1997).

Table 3.
Differential diagnosis of Achilles tendon disorders. There is a marked overlapping of the findings in history and physical examination, and, in clinical practice, overuse injuries have features of more than one pathophysiological entity (e.g., patients with tendinosis or with partial rupture have usually additional peritendinous pathology). However, in most cases, an adequate history and physical examination should give the correct diagnosis.

	Peritendinitis	Tendinosis	Partial rupture	Insertional disorder	Anomalous soleus	Complete rupture
History						
Pain in exertion	X	X	X	X	X	X
Pain only in tendon insertion				X		
Pain behind Achilles tendon					X	
Gradual onset of symptoms	X	X		X	X	
Sudden onset of symptoms			X			X
Stiffness and pain in the morning	X	X	X	X	X	
Clinical findings						
Tenderness in middle third of tendon	X	X	X		X	X
Tenderness of tendon insertion				X		
Swelling	X	X	X	X	X	X
Palpable nodules which does not move when ankle is dorsiflexed	X					
Palpable nodules moving when ankle is dorsiflexed		X	X			
Swelling or bulbous mass at medial or lateral side of Achilles tendon					X	
Crepitation	X					
Palpable gap			X			X
Thompson test positive						X

Pain is the cardinal symptom of Achilles tendon overuse injuries that leads a patient to seek medical help, and it is the most common measure used to classify the severity of tendinopathy (Jozsa and Kannus 1997). It has been suggested that the quality of the patient's symptoms can reflect the degree of tendon pathology. In the early phases, patients will complain primarily of pain following strenuous activities and later pain will accompany all the activities or at rest and will eventually make patient to unable to perform sports (Curwin and Stanish 1984, Galloway et al. 1992). Nelen et al. (1989) stated in their retrospective evaluation of 170 surgically treated patients with chronic tendinosis that the morning stiffness reflected the seriousness of the disorder. There were, however, no data to substantiate this claim. They also noted that acute sharp pain, felt during a sprint or an acceleration, almost always reflected marked tendinosis or partial rupture at surgery.

6.2. Clinical examination

The clinical examination of the Achilles tendinopathy is based on a thorough knowledge of the anatomy and function of the Achilles tendon – triceps surae muscle unit and the interaction of this unit during movements. As a rule of thumb, the physical examination should follow the classic orthopedic scheme of "look, feel, and move".

Inspection and palpation should provide a record of the contour, of the muscle tendon unit, possible areas of swelling and crepitation, increased erythema, local heat, and palpable tendon nodules or defects (Fredricson 1996, Jozsa and Kannus 1997). In addition, ankle instabilities and biomechanical faults should be sought in patients with Achilles complaints (Jozsa and Kannus 1997).

In the acute phase of Achilles tendinopathy, the tendon is diffusely swollen and edematous, and palpation tenderness is usually greatest in the middle third of the tendon. Sometimes, fibrin precipitated from the fibrinogen-rich fluid around the tendon can cause palpable crepitation (Kvist 1991b, Leppilahti et al 1991, Jozsa and Kannus 1997). Typically, in patients with acute symptoms, the area of swelling and tenderness does not move when the ankle joint is dorsiflexed.

In the more chronic phase of Achilles tendinopathy, exercise-induced pain is still the cardinal symptom while crepitation or effusion diminish (Jozsa and Kannus 1997). In chronic cases, a tender, nodular swelling is usually present and is believed to signify tendinosis (Leppilahti et al. 1991, Galloway et al. 1992). Particularly in patients with tendinosis, the focal tender nodules moves as the ankle is dorsiflexed and plantarflexed (DiGiovanni and Gould 1997).

Insertional Achilles tendinopathy involves swelling and tenderness at the insertion of the Achilles tendon onto the calcaneus, often posterolaterally (Clain 1995). There may be associated swelling and tenderness with occasional hyperemia in the adjacent retrocalcaneal bursa, usually in both sides of overlying Achilles tendon (Jozsa and Kannus 1997).

In patients with an anomalous soleus muscle, symptoms include pain and tenderness behind the Achilles tendon during physical activity. Clinically, swelling or a bulbous mass at the medial or lateral side of the Achilles tendon is occasionally visible (Leppilahti et al. 1989).

6.3. Soft tissue radiography and computed tomography

Before US and MRI techniques, soft tissue radiographic evaluation of the Kager's triangle was the most popular imaging examination in Achilles tendon disorders. Acute and chronic peritendinitis (Kvist and Kvist 1980, Kvist et al 1988), intratendinous calcifications (Karjalainen 2000), partial ruptures (Denstad and Roaas 1979, Allenmark 1992), and ossification (Resnick 1995) of the Achilles tendon were sought using soft tissue radiographs. Nowadays, pre- and postoperative radiographs are mainly used to determine the need for and size of, calcaneal osteotomy in cases of Haglund's syndrome (Sella et al. 1998, Karjalainen 2000).

Computer tomography (CT) has relatively low diagnostic value in the imaging of the Achilles tendon overuse injuries (Reiser et al. 1985, Ulrich et al 1991). CT is sensitive in detection of intratendinous calcifications and fractures of ossifications (Karjalainen

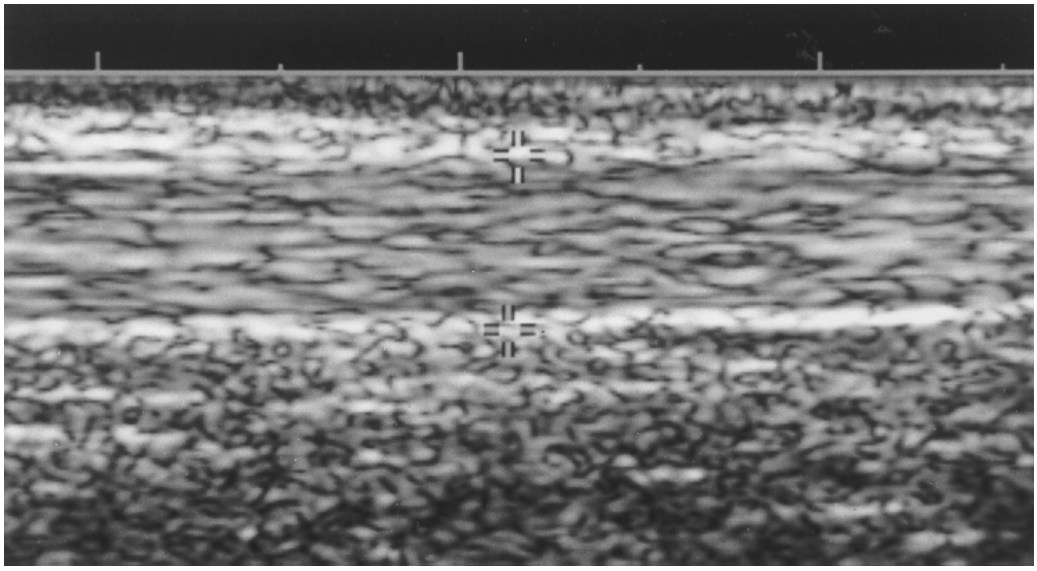
2000). However, CT only appears to be the imaging method of choice in demonstrating monosodium urate deposits in the entheses and tendons in gout (Gerster 1996).

6.4. Ultrasonography

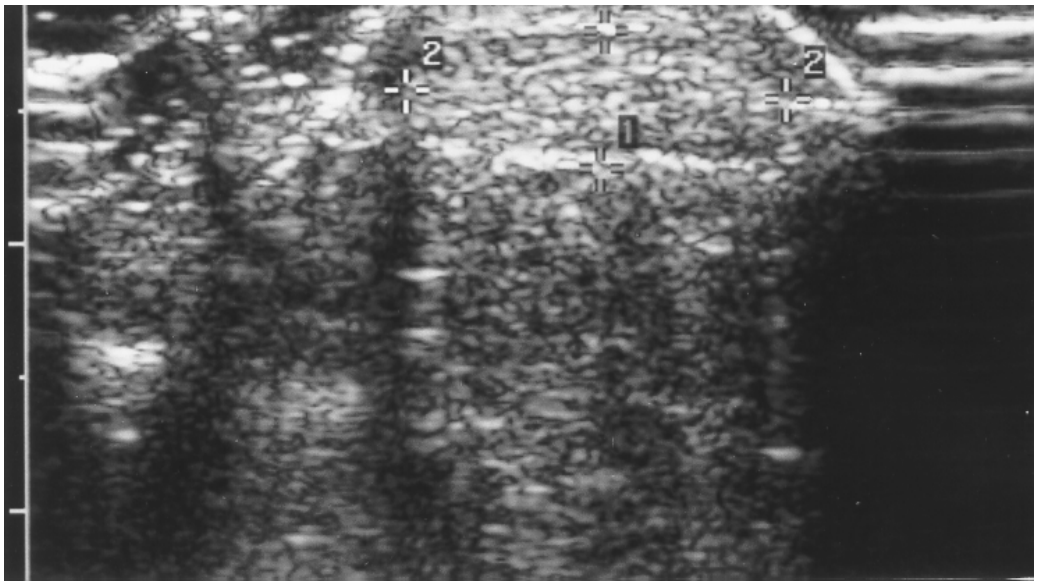
US has been increasingly employed to examine Achilles tendon injuries and other tendon disorders since it provides a readily-available, quick, safe, and inexpensive method to image tendon tissue structure (Figure 4) (Fornage 1986, Maffulli et al 1987, Laine and Peltokallio 1991, Allenmark 1992, Williams 1993, Jozsa and Kannus 1997). The primary disadvantages are that US is operator-dependent, has limited soft tissue contrast, and is not as sensitive as MRI (Sandmeier and Renström 1997). Complete Achilles tendon rupture has been diagnosed by US since the early 1980s (Bruce et al. 1982). Since then, the quality of the high resolution real-time US scanners has improved remarkably (Karjalainen 2000).

In patients with acute Achilles peritendinitis, US reveals fluid accumulation surrounding the tendon (Blei et al. 1986). In more chronic form, peritendinous adhesions could be shown by thickening of the hypoechoic paratenon with poorly defined borders (Laine et al. 1987, Kainberger et al. 1990, Jozsa and Kannus 1997). Discontinuity of tendon fibers, focal low-echoic intratendinous areas, and localized tendon swelling, edema, and thickening are the most characteristic findings in Achilles tendinopathy with surgically verified intratendinous lesion (tendinosis) (Figure 5) (Kälebo et al. 1992, Jozsa and Kannus 1997). Partial Achilles tendon tear could be difficult to distinguish from tendinosis by US. A large local increase in the sagittal diameter or severe intratendinous abnormalities of the Achilles tendon indirectly suggest a partial rupture rather than tendinosis, but there are no features specifically related to partial rupture (Åström et al. 1996). A sonolucent thickening of the paratenon and focal calcification were frequent additional findings in more chronic cases. In retrocalcaneal bursitis, US examination reliably reveals swelling of the bursa, intrabursal fluid, and bursal wall thickening (Jozsa and Kannus 1997). In patients with an anomalous soleus muscle, the Kager's triangle is occupied by a soft tissue mass (Leppilahti et al. 1989).

Figure 4. Longitudinal (**A**) and transverse (**B**) US images of the normal Achilles tendon. The tendon structure is homogenous. In the longitudinal view, the parallel fiber bundles are clearly visible, and normal paratenon delineates the anterior and posterior margins of the tendon (+ cursors). In the transverse view, the anterior border of the tendon is slightly concave (lower 1+).

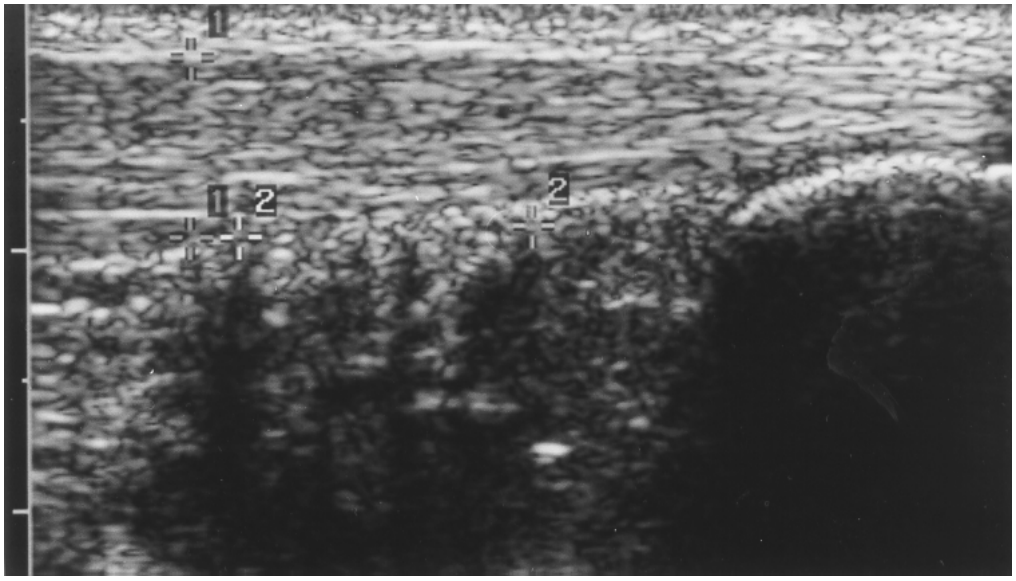


A

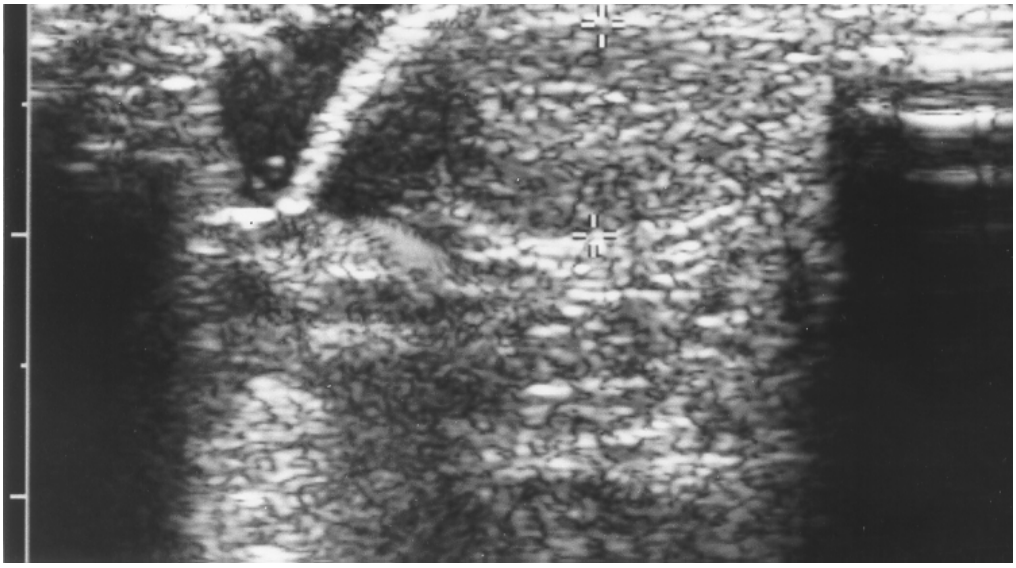


B

Figure 5. Longitudinal (**A**) and transverse (**B**) US images of the Achilles tendinopathy with intratendinous changes. The regular echostructure is altered as hypo- and hyperechoic lines are seen in the anterior part of the thickened tendon (1+). Hyperechoic adhesions in the anterior border of the tendon (2+) and moderate variety in the peritendinous echostructure are seen. In the corresponding transverse view, the anterior border of the tendon is convex (lower +).



A



B

Åström et al. (1996) compared the pre-operative US examination with operative findings in 26 patients with chronic Achilles tendinopathy and suggested that US has a great advantage as a prognostic instrument by indicating the severity of the lesion. Lehtinen et. al (1994) concluded that US is a reliable method for the diagnosis of local intratendinous lesion (called partial rupture in their study), but not for the diagnosis of Achilles tendinopathy restricted purely to the paratenon.

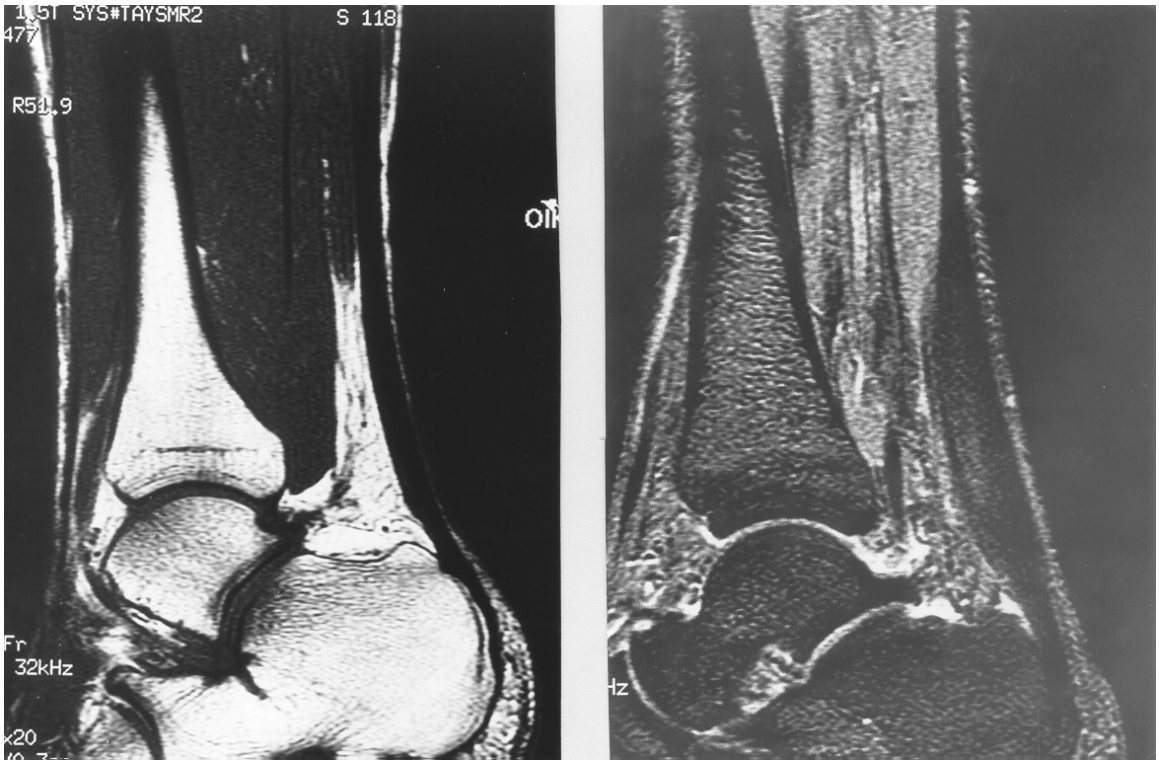
6.5. Magnetic resonance imaging

MRI has been regarded as gold standard for visualization of tendon pathology (Sandmeier and Renström 1997). It satisfies two fundamental principles of imaging: First, high intrinsic tissue contrast, which is able to separate normal from abnormal tendons, and, second, high spatial resolution, which allows detailed anatomic structures to be identified (Pope 1992). The ability of MRI to acquire images from multiple planes (longitudinal, transverse, oblique) is a clear advance in diagnostic technology (Kerr et al. 1990). Disadvantages of MRI are high cost, limited availability, time-consuming scannings, and slow and often incomplete resolution of signal changes after surgical intervention (Jozsa and Kannus 1997, Sandmeier and Renström 1997). In addition, Soila et al. (1999) has recently shown that the normal anatomy of an asymptomatic Achilles tendon varies and this may cause diagnostic misinterpretation.

In patients with chronic Achilles tendinopathy, MRI frequently reveals tendon thickening on sagittal images, and altered signal appearance within the tendon tissue (Figure 6) (Marcus et al. 1989, Weinstabl et al. 1991, Neuhold et al. 1992, Åström et al. 1996, Schweitzer and Karasick 2000). Movin et al. (1998) suggested that the intratendinous signal abnormality enhanced by gadolinium in patients with chronic Achilles tendinosis is related to an increased amount of interfibrillar non-collagenous extracellular matrix and altered fiber structure. In patients with insertional disorders of the Achilles tendon, MRI findings include altered signal intensity in the calcaneal bone marrow, and in the insertional area of the tendon, as well as an enlarged retrocalcaneal bursa that is occasionally associated with an abnormally prominent calcaneal tuberosity

(Haglund's syndrome) (Bottger et al. 1998, Karjalainen et al. 2000A, Schweitzer and Karasick 2000). In patients with the anomalous soleus muscle, MRI revealed a mass consistent with the surrounding muscle anterior to Achilles tendon (Brodie et al. 1996).

Figure 6. Longitudinal T1-weighted MR image of the normal Achilles tendon (**A**) and T2-weighted gradient echo (TR = 440; TE = 13) MR image of Achilles tendinopathy with intratendinous lesion (**B**). In the MR image of the Achilles tendon with tendinopathy, thickening of the tendon and intratendinous signal changes are seen.



A **B**

7. Treatment of the Achilles tendon overuse injuries

Little reliable experimental or clinical scientific work has been done on the pathophysiology, etiology, natural course, and treatment of Achilles tendon overuse injuries. Without scientific backing and thus, a firm understanding of the nature of tendon injuries and other tendon disorders, it is difficult to prescribe a proper treatment regimen for Achilles tendon problems. Both conservative and surgical treatments vary considerably among countries, clinics, and physicians. Most treatment regimens are based only on what empirically seemed to work without much scientific support (Jozsa and Kannus 1997, Sandmeier and Renström 1997, Alfredson and Lorenzon 2000). Thus, the therapies and treatment regimens reflect only current perceptions and therefore are likely to be replaced or modified in the coming years.

Studies on treatment of Achilles tendon overuse injuries are listed in Table 4. In most of these studies, the results of the treatment of Achilles tendon overuse injuries were excellent or good. However, only few of the studies were prospective by study design and the evaluation of the outcome was mainly based on subjective evaluation.

In early phases of Achilles tendon overuse injury, various forms of conservative treatment are normally used (Kvist and Kvist 1980, Leach et al. 1983, Clement et al. 1984, Kellet 1986, Williams 1986, Jozsa & Kannus 1997, Waterson 1998). Surgical treatment is recommended to those patients who do not adequately respond to conservative treatment, however, not until after 3 to 6 months of persisting symptoms (Kvist and Kvist 1980, Schepsis and Leach 1987, Nelen et al. 1989, Kvist 1994, Lehto et al. 1994, Leppilahti et al. 1994, Schepsis et al. 1994, Williams 1986). It has been observed that surgical treatment is needed in about 25% of the patients with chronic Achilles tendon disorder. The frequency of surgery increases with patient's age, duration of symptoms, and occurrence of tendinopathic changes (Kvist 1994).

Table 4
Studies on treatment of Achilles tendon overuse injuries

Reference	Study design	Number of patients at the follow-up	Diagnoses	Type of treatment	Evaluation of the results	Follow-up time
Kvist and Kvist (1980)	Retrospective	182	Peritendinitis, intratendinous lesion	Surgical	Subjective	Not given
Clement et al. (1984)	Retrospective	86	Tendinopathy	Conservative	Subjective	Not given
Subotnick and Sisney (1986)	Retrospective	338	Peritendinitis, tendinosis, insertional disorder, complete rupture	Conservative (266 patients), surgical (72 patients)	Subjective	Not given
Schepsis and Leach (1987)	Retrospective	37	Peritendinitis, tendinosis, insertional disorder	Surgical	Subjective, objective (ROM and palpation)	3 years
DaCruz et al. (1988)	Prospective, randomized, double-blind	28	Tendinopathy	Conservative (steroid injection, physical therapy)	Subjective, objective (ROM and palpation)	12 weeks
Nelen et al. (1989)	Retrospective	91	Peritendinitis, tendinosis	Surgical	Subjective	2 to 7 years
Fernandez-Palazzi et al. (1990)	Retrospective	13	Tendinopathy, insertional disorder	Conservative (2 patients), surgical (11 patients)	Subjective	Not given
Leppilahti et al. (1991)	Retrospective	273	Peritendinitis, tendinosis, partial rupture, insertional disorder	Conservative (152 patients), surgical (121 patients	Subjective	Not given
Read and Motto (1992)	Retrospective	83	"Tendo Achillis pain"	Conservative	Subjective	Not given
Åström and Westlin (1992)	Prospective, randomized	70	Tendinopathy (Piroxicam vs. placebo)	Conservative	Subjective, objective (ROM, palpation, muscle strength)	28 days
Niesen-Vertommen et al. (1992)	Prospective	17	"Tendonitis"	Conservative (eccentric vs. concentric exercise)	Subjective, objective (muscle strength)	12 days
Anderson et al. (1992)	Retrospective	48	Peritendinits, tendinosis, insertional disorder	Surgical	Subjective	52 months

Table 4
continues

Schepsis et al. (1994)	Retrospective	66	Peritendinitis, tendinosis, insertional disorder	Surgical	Subjective, objective (ROM, palpation)	1 to 13 years
Lehto et al. (1994)	Retrospective	49	Peritendinitis, tendinosis, retrocalcaneal bursitis	Surgical	Subjective	2 to 11 years
Leppilahti et al. (1994)	Retrospective	228	Peritendinitis, tendinosis, partial rupture, insertional disorder	Surgical	Subjective	1 to 10 years
Alfredson et al. (1996)	Prospective	13	Tendinosis, insertional disorder	Surgical	Objective (muscle strength)	1 year
Rolf and Movin (1997)	Retrospective	57	Peritendinitis, tendinosis	Surgical	Subjective	25 months
Johnston et al. (1997)	Retrospective	41	Peritendinitis, tendinosis	Conservative (24 patients) surgical (17 patients)	Subjective	2 years
Maffulli et al. (1997)	Prospective	48	Tendinopathy	Surgical (percutaneous longitudinal tenotomy)	Subjective, objective (muscle strength)	22 months
Morberg et al. (1997)	Retrospective	64	Intratendinous lesion, insertional disorder	Surgical	Subjective, objective (ROM)	6 years
Alfredson et al. (1998)	Prospective	11	Tendinosis	Surgical (and immobili-zation)	Objective (muscle strength)	52 weeks
Sammarco and Tylor (1998)	Retrospective	39	Haglund's deformity	Conservative (13 patients), surgical (26 patients)	Subjective	155 weeks
Alfredson et al. (1998)	Prospective	15	Tendinosis	Conservative	Subjective, objective (muscle strength)	12 weeks
Angermann and Hovgaard (1999)	Retrospective	22	Tendinopathy	Conservative	Subjective	5 years
Maffulli et al. (1999)	Retrospective	10	Tendinosis ("Central core lesion")	Surgical	Subjective	35 months

7.1. Conservative treatment

The initial conservative treatment is directed towards presumed etiological factors or towards relieving symptoms (Alfredson and Lorenzon 2000). Most commonly, initial treatment consists of a combination of strategies, including control of inflammation and correction of training errors, foot malalignments, decreased flexibility, muscle weakness, and poor equipment (Alfredson and Lorenzon 2000). In addition, anticogulant therapy and various modalities of physical therapy have been used in the treatment of Achilles tendon overuse injuries (Jozsa and Kannus 1997).

Initial control of inflammation is recommended in the early phase of Achilles tendon overuse injury by decreasing activity and by rest, cold, and anti-inflammatory medication (Hess 1989, Jozsa and Kannus 1997). Decreasing the intensity, frequency and duration of the activity that caused the injury, or modification of that activity, may be the only necessary action to control the tendinous inflammation and symptoms in the acute phase. Absolute rest of the whole body is seldom needed in the treatment of the Achilles tendon overuse injuries, but modified rest, which allows activity in the uninjured body parts but not in the injured site has been recommended (Jozsa and Kannus 1997, Alfredson and Lorenzon 2000). Cryotherapy has been regarded as single most useful intervention of tendinous inflammation in the acute phase of the Achilles tendon injury (Leadbetter 1993, Jozsa and Kannus 1997). Cold is able to control pain and edema as well as reduce regional blood flow and the metabolic demands of the tissue. It also has beneficial effects during rehabilitation by decreasing pain and muscle spasm to allow better mobilization (Hess et al. 1989, Galloway et al. 1992, Curl and Martin 1993, Swenson et al. 1996).

Nonsteroidal anti-inflammatory drugs (NSAIDs), in the form of pills or topical gels, and peritendinous corticosteroid injections are frequently used in the treatment of acute as well as chronic Achilles tendon overuse injuries. The benefit of these drugs is, however, controversial (Williams 1986, Galloway et al. 1992, Leadbetter 1993, Sandmeier and Renström 1997, Almekinders and Temple 1998). In an extensive literature review, Weiler (1992) concluded that short-term studies found no evidence of a serious delay in the healing process. Furthermore, healing of acute soft-tissue injury is

slightly more rapid and inflammation is slightly better controlled with the use of NSAIDs than without them. The effect of NSAIDs in chronic Achilles tendon problems is less clear. In patients with chronic Achilles tendinopathy, Åström and Westlin (1992) found no beneficial effect of NSAIDs. Recently, it has been claimed that anti-inflammatory medication (NSAIDs and corticosteroid injections) would not benefit patients with tendinosis as it is not regarded as an inflammatory disorder, at least not in the advanced stage (Khan et al. 1999, Khan et al. 2000). However, it is clear that NSAIDs do offer analgesic effect, and thus, NSAIDs have been used for short period to facilitate the rehabilitation (Jozsa and Kannus 1997, Sandmeier and Renström 1997).

The role of the corticosteroid injections in the treatment of overuse Achilles tendon injuries is also controversial. There are insufficient published data to determine the comparative risks and benefits of corticosteroid injections in Achilles tendinopathy (Shrier 1996, Jozsa and Kannus 1997, Almekinders and Temple 1998). Peritendinous corticosteroid injection, used to treat tendinous or peritendinous inflammation, has been claimed to cause spontaneous Achilles tendon ruptures. However, the proof of the deleterious effects of peritendinous corticosteroid injections on human tendon properties are based solely on uncontrolled case studies; i.e., no well-controlled prospective clinical studies exist (Fredberg 1997). Some experimental studies have observed that cortisone inhibits the formation granulation tissue and delays the healing process of tendons (Balasubramanian and Chong 1971, Krahl and Langhoff 1971). On the other hand, several studies do not show adverse effects of corticosteroids on tendon tissue (Francis 1971, Randall 1978, McWorther 1991) Oxlund (1980) even observed increased tensile strength of the tendon with no change in collagen content after short-term local administration of cortisol around the peroneal tendons of rats. Intratendinous injections have, naturally, always been forbidden in clinical medicine since the pressure increase of such an injection alone may cause serious hypoxic-degenerative changes to the tendon tissue. Other peritendinous injection treatments that have been studied in human include glycosaminoglycan polysulphate (GAGPS) (Sundqvist et al. 1987) and hemodialysate (Pförringer et al. 1994). In conclusion, today it is generally thought that the judicious use of locally injected corticosteroids [i.e., limited number of injections (2 or 3), no intratendinous injections, no injection of chronic tendon disorders (tendinosis), no use of

substances with long lasting effects (such as triamcinolone), and dilution of the corticosteroid with local anesthetics before the injection] is likely to have minimal adverse effects on the target tendon (Leadbetter 1995, Fredberg 1997, Jozsa and Kannus 1997).

An association between increased mileage, interval training, running on sloping, hard or slippery roads, and Achilles tendon overuse injuries has been noted (James et al. 1978, Clement et al. 1984, Alfredson and Lorenzon 2000). “Too much training too soon” was stated by Brody (1987) to be a cause of Achilles tendon overuse injuries. Thus, periods of modified rest with alternative training methods such as swimming and bicycling have been recommended (Williams 1986, Brody 1987, Kvist 1991b, Jozsa and Kannus 1997). In addition, to correct the presumed biomechanical divergences, correction of excessive pronation (James et al. 1978, Clement et al. 1984, Hess et al. 1989, Kvist 1991a), correction of underpronation by using a heel lift on the lateral side (Komi et al. 1987), correction of forefoot or rearfoot varus (Clement et al. 1984, Subotnick and Sisney 1986) and heel lifts for relaxation of tight calf muscles (Clement et al. 1984) as well as proper footwear with good shock absorbing capacity and a sole structure that allows normal motion (Hess et al. 1989, Sandmeier and Renström 1997), have been included in treatment of the Achilles tendon complaints.

Stretching and strengthening of the triceps surae muscle and Achilles tendon have been advocated to preserve function of the triceps surae musculotendinous unit by restoring normal ankle joint mobility and decreasing the strain of the Achilles tendon with normal motion (Sandmeier and Renström 1997). Niesen-Vertommen et al. (1992) found eccentric training superior to concentric training in decreasing pain in chronic Achilles tendinopathy. In the prospective non-controlled follow-up study of Alfredson et al. (1998), promising preliminary results were obtained using an intensive eccentric muscle training regimen for chronic Achilles tendinosis. After the 12-week follow-up period, all 15 patients were back at their preinjury levels with full running activity, the pain during activity had decreased significantly, and the calf muscle strength on the injured side had increased significantly and did not differ significantly from that of the uninjured side. Recently, the authors stated in their review article that only one of the

original 15 patients has now been operated on for the chronic Achilles tendinosis during the 2-year follow-up (Alfredson and Lorenzon 2000).

In addition to stretching and strengthening program, physical therapy modalities, such as heat, ultrasound, electrical stimulation, and laser photostimulation, are commonly employed in the treatment of Achilles tendon injuries. Again, the scientific evidence on the effectiveness of these treatment modalities is sparse, and especially in regard to clinical evidence, somewhat controversial (Williams 1986, Rivenburgh 1992, Jozsa and Kannus 1997, Sandmeier and Renström 1997).

7.2. Surgical treatment

For the treatment of chronic Achilles tendinopathy, tendinosis, and retrocalcanear bursitis, surgery has been considered an acceptable choice among patients who fail to respond to conservative treatment (Kvist and Kvist 1980, Schepsis et al. 1987, Nelen et al. 1989, Kvist 1994, Lehto et al. 1994, Leppilahti et al. 1994, Schepsis et al. 1994). However, no prospective randomized studies comparing operative and conservative treatment of Achilles tendon overuse injuries have been published and most of our knowledge on treatment efficacy is based on clinical experience and descriptive studies (Table 4).

Recently, Tallon et al. (2001) reviewed studies that reported surgical outcomes of the chronic Achilles tendinopathy. In their review, methodology scores were generally low concerning the type of the study, subject selection process, and outcome measures, thus indicating methodological imperfection. A negative correlation was found between reported success rate and overall methodology scores, but the positive correlation between year of publication and overall methodology score suggests that the quality of studies is improving.

The causal relationship between the surgery and the healing of the tendon is still not understood (Jozsa and Kannus 1997, Sandmeier and Renström 1997). Although the results of non-controlled surgical studies in chronic Achilles tendon overuse injuries have been good, these results may not be due to surgical treatment alone as surgery is usually

combined with a postoperative period of immobilization, rest and a prolonged period of controlled rehabilitation (Stanish et al. 1985, Sandmeier and Renström 1997).

Leadbetter et al. (1992) has summarized the surgical goals for chronic tendon overuse injuries (Table 5). In Achilles tendon overuse injuries, various surgical techniques have been used. After the longitudinal division of the crural fascia, the paratenon is incised and any macroscopic adhesions are excised (Kvist and Kvist 1980, Nelen et al. 1989, Lehto et al. 1994, Leppilahti et al. 1994, Schepsis et al. 1994). In some studies, the adhesions were found mainly between the Achilles tendon and paratenon (Schepsis and Leach 1987, Nelen et al. 1989), while others reported that the paratenon was adhered mainly to the crural fascia, or even to the skin (Kvist and Kvist 1980, Rolf and Movin 1997). When an intratendinous lesion is seen in preoperative US or MRI examination and a nodule or thickening is palpable within the tendon, it is recommended that a longitudinal incision be made over the thickened area and the necrotic area or granulation tissue be excised (Williams 1986, Schepsis et al. 1987, Nelen 1989, Lehto et al. 1994, Leppilahti et al. 1994, Soma and Mandelbaum 1994, Alfredson et al. 1996, Rolf and Movin 1997, Jozsa and Kannus 1997, Alfredson and Lorenzon 2000). The use of side-to-side suture or the use of turned down tendon flap has been proposed to reinforce the tendon if there is an extensive debridement in the tendon (Ljungqvist 1968, Leach et al. 1981, Nelen et al. 1989, Leppilahti et al. 1994, Schepsis et al. 1994). Also, some authors have used open or percutaneous multiple longitudinal incisions of the tendon (Åström et al. 1996, Benazzo et al. 1997, Maffulli et al. 1997).

Table 5
Goals of operative treatment for tendon overuse injuries

1. To alter the tissue structure and restore its strength by including scar repair
2. To remove a nidus of offending aberrant tissue, e.g. chronic granulation tissue, a scar, a degenerated or necrotic tendon tissue, a hypertrophic tenosynovium or bursa, or a calcific deposit
3. To encourage revascularization of tendon tissue
4. To relieve extrinsic pressure, either bony or soft-tissue
5. To relieve tensile overload
6. To discover and repair gross interstitial tendon rupture
7. To replace or augment injured tendon structure

In patients with retrocalcaneal bursitis, or Haglund's syndrome, the posterior upper corner of the calcaneus and hypertrophic bursa is removed (Schepsis and Leach 1987, Lehto et al. 1994). In patients with anomalous soleus muscle, surgical treatment is recommended and consists of fasciotomy or excision of the anomalous muscle (Leppilahti et al. 1989, Brodie et al. 1996)

After surgery of a chronic Achilles tendon overuse injury, there is a extensive variation in descriptions of, and often sparse information on, the methods used for postoperative rehabilitation (Alfredson and Lorenzon 2000). Immobilization in a cast (Ljungqvist 1968, Schepsis and Leach 1987, Nelen et al. 1989, Åström and Rausing 1995, Alfredson et al. 1996, Morberg et al. 1997, Rolf and Movin 1997, Alfredson et al. 1998), in a walking boot (Saltzman and Tearse 1998), or in a walker splint (Soma and Mandelbaum 1994) for 2 to 8 weeks have been used. Others have proposed non-weight-bearing range-of-motion exercises (Kvist and Kvist 1980, Lehto et al. 1994, Leppilahti et al. 1994, Soma and Mandelbaum 1994, Schepsis et al. 1994, Maffulli et al. 1997). Range-of-motion and stretching exercises have been recommended by most authors (Schepsis and Leach 1987, Nelen et al. 1989, Alfredson et al. 1996, Morberg et al. 1997, Rolf and Movin 1997, Alfredson et al. 1998, Saltzman and Tearse 1998). A gradual return to sports when strength has been regained has been advised (Ljungqvist 1968, Leadbetter et al. 1992, Schepsis et al. 1994, Soma and Mandelbaum 1994, Åström et al. 1996, Morberg et al. 1997, Saltzman and Tearse 1998).

In most of the previous studies, surgery of Achilles tendon overuse injuries has given satisfactory results in 75 to 100% of patients. However, most of these works have been retrospective (Kvist and Kvist 1980, Nelen et al. 1989, Fernandez-Palazzi et al. 1990, Anderson et al. 1992, Leach et al. 1992, Lehto et al. 1994, Leppilahti et al. 1991, Leppilahti et al. 1994, Johnston et al. 1997, Rolf and Movin 1997, Maffulli et al. 1999) and only in few of them were the results based on objective evaluations, such as range of motion of the ankle (Schepsis and Leach 1987, Schepsis et al. 1994, Morberg et al. 1997).

Only two prospective studies on surgical treatment of the Achilles tendinopathy can be found (Alfredson et al. 1996, Maffulli et al. 1997). Alfredson et al. (1996) evaluated prospectively the effect of surgical treatment on isokinetic calf muscle strength in 13 patients with various types of Achilles tendon overuse injuries. They found that

after surgical treatment of the Achilles tendon overuse injury, six months of rehabilitation was not enough to return concentric and eccentric plantar flexion muscle strength to the same level as the non-injured side. In a study of Maffulli et al. (1997), the percutaneous longitudinal tenotomies showed acceptable results in 52 middle- and long-distance runners with unilateral Achilles tendinopathy (peritendinitis and/or intratendinous lesion). The patients were evaluated by isometric strength and endurance measurements and subjective evaluation (6 months and 18 months after the operation, respectively). The authors found that the presence of peritendinitis was a poor prognostic factor, since the patients with tendinopathy associated with peritendinitis were less satisfied, less strong and less resistant after the follow-up period when compared to patients with isolated tendinopathy (intratendinous pathology without peritendinous alterations at the examination).

Some studies have reported a relatively high complication rate after surgical treatment of Achilles tendon overuse injuries (Nelen et al. 1989, Leppilahti et al. 1991, Leppilahti et al. 1994, Rolf and Movin 1997). Unfortunately, the complications have often been reported in a rather general way only.

Kvist and Kvist (1980) reported only 2 superficial wound infection in their series of 201 cases of surgically treated Achilles tendon peritendinitis. Among the 15 patients with 20 surgically treated Achilles tendon overuse injuries, Leach et al. (1981) reported one complication: a neuroma of a small branch of the sural nerve which needed surgical removal. In his review article, Williams (1986) reported postoperative complications in 64 cases (14%) of 461 surgically treated Achilles tendon problems. The problems related to wound healing formed 89% of the complications. In 79 surgically treated Achilles tendon overuse injuries of 66 patients, Schepsis et al. (1987) described 4 postoperative complications (1 exuberrant scar formation, 1 skin slough, 1 heterotopic bone formation, and 1 extensive fibrotic scar reaction). Nelen et al. (1989) reported a complication rate of 4.7% in 170 surgically treated patients (6 cases of skin edge necrosis with prolonged wound healing, 2 of superficial wound infection, and 1 of thrombophlepitis). Anderson et al. (1992) found 6 complications in 48 patients treated surgically for chronic Achilles tendon overuse injury (3 keloid formation, 2 calf numbness, and 1 persistent inflammation at the Achilles insertion). In 275 surgically treated Achilles tendon overuse

injuries of 228 patients, Leppilahti et al. (1994) reported postoperative complications in 34 cases (12%), but, according to the authors, the complications did not influence the end results. Maffulli et al. (1997) found 5 complications in 48 patients (10%) treated surgically with percutaneous tenotomy (1 superficial infection and 4 subcutaneous hematomas). Morberg et al. (1997) stated that in their series of 64 chronic partial ruptures of Achilles tendon there were no intra-operative or postoperative complications. However, they also reported that one patient was reoperated on because of a hypertrophic and painful scar. Finally, among 58 surgically treated patients with achillodynia, Rolf and Movin (1997) observed postoperative complications in 8 cases (14%): two superficial infections, two deep infections, two deep vein thrombosis, one total rupture, and one hypertrophic scar.

AIMS OF THE STUDY

The aims of the study were:

1. to evaluate the value of US in the diagnosis of various Achilles tendon injuries and related disorders (I),

2. to examine the long-term outcome of patients treated conservatively for acute to subchronic Achilles tendinopathy (II),

3. to evaluate the short-term results of surgical treatment of chronic Achilles tendinopathy (III),

4. to analyze the complications after surgical treatment of Achilles tendon overuse injury (IV).

PATIENTS AND METHODS

1. Patients

The study consisted of the following groups of patients in studies I – IV:

Study I

Seventy-nine patients (80 surgically treated Achilles tendons) who underwent surgical intervention for various Achilles tendon disorders during the years 1990 - 1995 in the Tampere University Hospital, Tampere City Hospital, and Tampere Koskisairaala Hospital. There were 19 women and 60 men with a mean age of 42 years (range 11 - 88 years). Since it is commonly believed that a delay between US examination and surgery diminishes the accuracy of US diagnosis, we also examined this effect by dividing the patients into two subgroups according to the delay between US examination and surgery: 1) those examined less than 90 days before surgery (56 tendons) and 2) those examined more than 90 days before the procedure (24 tendons).

Study II

One hundred and seven patients (78 men, 29 women) who visited the Tampere Research Center of Sports Medicine during the period from 1985 through 1993 for acute to subchronic Achilles tendinopathy and met the initial inclusion criteria (Table 6), formed the basic population of the study. Eighty-three of the original 107 patients (78%) could be followed an average 8 ± 2 years after the initial contact. In addition, 10 patients answered the follow-up questionnaire but did not attend the re-examination (one patient died before re-examination, one emigrated, and eight declined to participate). The remaining fourteen patients could not been traced.

There were 61 men and 22 women with a mean age 32 ± 11 (SD) years. The most common symptoms-inducing activities were competitive running (18 patients, 22%), outdoor jogging (18 patients, 22%) and orienteering (17 patients, 20%). Fifty-one patients (61%) were competitive athletes and 30 patients (36%) recreational athletes, and 2 patients did not participate in sports. Onset of the symptoms was very fast (within 24

hours) in 25 patients, fast (within a few days) in 20 patients, and slow (longer than above) in 38 patients.

According to the delay between the onset of the symptoms of the Achilles tendinopathy and the initiation of the conservative treatment, the patients were divided into three subgroups: 1) acute, i.e. the conservative treatment initiated less than 14 days after the onset of the symptoms, 2) subacute, i.e. the conservative treatment initiated 14 to 42 days after onset of the symptoms, and 3) subchronic, i.e. the conservative treatment initiated 42 days to 6 months after onset of the symptoms. These subgroups were based solely on the duration and not necessarily on the severity of the symptoms.

Table 6
The initial criteria for acceptance into the 8-year follow-up study of acute to subchronic Achilles tendinopathy (Study II)

1. Unilateral acute to subchronic Achilles tendinopathy on basis of clinical examination*
2. No previous Achilles tendon disorders
3. Age 16 to 65 years
4. Initially decided to initiate conservative treatment strategy

* Acute to subchronic Achilles tendinopathy was defined as a condition with exertional pain and palpable tenderness in the Achilles tendon, the problems lasting less than 6 months. Tendon crepitation and diffuse swelling could accompany the symptoms, but patients with insertional complaints were excluded.

Study III

Fifty patients (36 men, 14 women) were treated surgically for Achilles tendinopathy at the Tampere University Hospital, Tampere and Hospital Tohtoritalo 41400, Turku, Finland, during the period from August 1995 through November 1998. Patients with disorders at the Achilles insertion (insertional tendinopathy) or previous surgical treatment of the index tendon were excluded. Forty-two of the original 50 patients (84%) participated in the 7 ± 0.7 (SD) month follow-up visit. Of those who dropped out during the follow-up, five patients could not find time to attend the follow-up examination; one patient was operated on 4 weeks after the initial operation due to quickly worsening Achilles tendon disorder on the contralateral side; one patient could

not attend due to low back pain and sciatica; and the remaining patient could not be traced.

Patients were divided into two subgroups according to their intra-operative diagnosis. In group A, intra-operative diagnosis was chronic Achilles tendinopathy with peritendinous adhesions (16 of the 42 patients, 38%) and in group B the intra-operative diagnosis was chronic Achilles tendinopathy with peritendinous adhesions and a localized intratendinous lesion (26 of the 42 patients, 62%). There were 29 men and 13 women. In group A, a mean age of the patients was 37 ± 12 (SD) years and in group B, 46 ± 14 (SD) years. The most common symptom-inducing activities were recreational outdoor jogging (16 patients, 38%), competitive running (4 patients, 10%), soccer (4 patients, 10%), and tennis (4 patients, 10%). Eleven patients (26%) were competitive athletes, 26 patients (62%) recreational athletes, and 5 patients (12%) did not participate sports.

In 10 patients, the contralateral Achilles tendon had been previously operated on for an Achilles tendon overuse injury. At baseline, 3 additional patients had exercise-induced Achilles pain at this contralateral side. For these reasons, the contralateral Achilles tendon could not be used as a control. Instead, the preoperative values of the index Achilles tendon were used as a baseline for follow-up observations.

In all patients, the diagnosis was based on a history of Achilles pain in exertion and on clinical findings (palpable tenderness, thickening, and, sometimes, palpable nodules at the Achilles tendon). In addition, to confirm the clinical diagnosis, preoperative ultrasound and/or MRI examinations were done in most subjects (preoperative US in 15 patients, MRI in 2 patients, both US and MRI in 18 patients, and clinical examination alone in 7 patients).

Study IV

Four hundred and thirty-two patients with a chronic Achilles tendon overuse injuries were treated surgically between April 1986 and December 1995 at the Department of Sports Medicine of the Deaconess Institute of Oulu (between April 1986 and December 1989), Department of Sports Medicine of the Deaconess Institute of Helsinki (between January 1990 and December 1991) and Hospital Tohtoritalo 41400 in

Turku (between January 1992 and December 1995). The average age of the patients was 31 years (men, 32 years; women, 28 years, range; 13 to 67 years). The duration of the Achilles tendon symptoms before the surgery varied from three months to several years.

In all patients, the diagnosis was based on patient's history of Achilles pain in exertion and on thorough clinical examination (palpable tenderness, thickening, and, sometimes, palpable nodules). In addition, preoperative US and radiographic examinations were used in the majority (65%) of patients to confirm the clinical diagnosis.

2. Conservative treatment

Study II

In each patient, the individualized nonoperative treatment strategy was initiated after the first clinical examination. The patient could receive more than one treatment, simultaneously or successively.

Modified rest (that is, rest of the injured site while allowing activity in the uninjured parts of the body) and gastrocnemius-soleus stretching was recommended for everyone. Local peritendinous steroid injections were given 1 to 3 times to 69 patients (83%), glycosaminoglycan polysulphate injection (GAGPS) to 26 patients (31%), and subcutaneous miniheparin to one patient (1%). Nonsteroidal anti-inflammatory medication (NSAID), with or without local anti-inflammatory gels, was used by 35 patients (42%). Thirty-five patients (42%) used standard-type heel lifts and 12 patients (14%) received custom-made orthotics. Physiotherapy was received by 12 patients (14%) and cryotherapy by 9 patients (11%).

The initial conservative treatment lasted from two weeks to three months. No extended treatment strategy and contacts were planned beyond this phase; i.e., in the case of recurrent aggravation of the symptoms of Achilles tendinopathy, the further strategy between conservative and surgical treatments was considered individually. The most important factors that determined initial or further treatment included duration and severity of the symptoms, type and level of the symptom-inducing activity,

biomechanical predisposing factors, and response of the symptoms to the first conservative treatment.

Study III

Initially, all patients had been advised to rest or clearly reduce their athletic activities. Additionally, 31 of the 42 patients (74%) had been treated with a small amount of corticosteroid, the steroid being injected 1 to 4 times around the Achilles tendon, and NSAID had been used by almost all of the patients. Mean length of the nonoperative treatment was 18 months (range 3 to 192 months). In all patients, the overuse symptoms were not relieved by preceding nonoperative treatment.

Study IV

Initially, all patients had been advised to rest or reduce the athletic activities. Additionally, 140 patients had been treated with a small amount of local corticosteroids (the steroids being injected [1-4 times] around the Achilles tendon or into the retrocalcaneal bursa) and 41 patients had been given peritendinous injections of GAGPS. Frequently, anti-inflammatory medication (about 95%), various forms of physiotherapy and heel supports had been also used (with or without the above noted injections), while heparin injections (10-12%), acupuncture (1%), laser treatment (1%), or immobilization (2%) had been used only occasionally. In all patients, the overuse symptoms were not relieved by preceding conservative treatment.

3. Surgical treatment

Study III

In all patients, the indication for surgical treatment was failure of conservative treatment; that is, the patient's inability to continue physical activities without pain, persistent swelling around the Achilles tendon, or both.

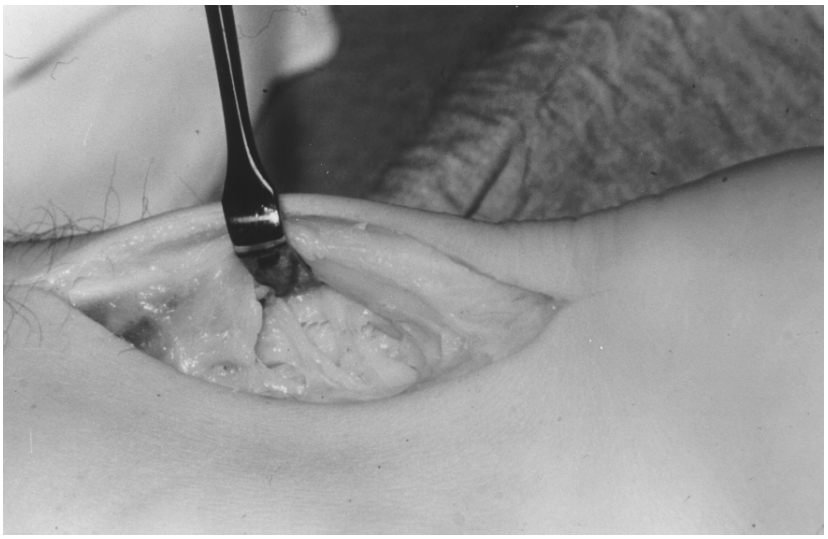
All patients were operated on as outpatients. Spinal anesthesia was used in 19 of the 42 patients (45%), local intravenous anesthesia in 19 patients (45%), and local

anesthesia in 4 patients (10%). During surgery, the patient was placed prone. A tourniquet was used only occasionally (in the cases of a large intratendinous lesion). A longitudinal incision was made to the lateral side of the Achilles tendon and small subcutaneous veins were coagulated with diathermy. Care was taken that the distal part of the small saphenous vein and the sural nerve were identified, freed by a blunt dissection, and retracted anteriorly.

The intra-operative diagnosis was chronic Achilles tendinopathy with peritendinous adhesions in 16 of the 42 patients (38%) (group A) and chronic Achilles tendinopathy with peritendinous adhesions and a localized intratendinous lesion in 26 of the 42 patients (62%) (group B).

In all 16 patients in the group A, the crural fascia was incised and the adhesions, especially those between the paratenon and the crural fascia, were carefully excised, leaving as many layers of the true Achilles paratenon as possible intact (Figure 7). In the 26 patients in the group B, an additional longitudinal incision of the tendon itself was performed and the intratendinous lesion was removed. When the removal of the lesion was extensive, the remaining tendon was reapproximated by side-to-side sutures.

Figure 7. The crural fascia has been incised and the adhesions around the thickened paratenon have been divided. The tight adhesions, especially between the paratenon and the crural fascia, were carefully excised, but as many layers of the true Achilles paratenon as possible were left intact. The Achilles tendon was freed from adhesions, but on the anterior aspect, there was a considerable amount of paratenon close to the Achilles tendon. In this patient, there was no intratendinous pathology at the ultrasound examination or at perioperative palpation (a nodule-like tissue hypertrophy) and, thus, longitudinal incision of the tendon was not performed.



Study IV

In all patients, the indication for surgical treatment was failure of conservative treatment: i.e., the patient's inability to continue sports without pain, persistent swelling around the Achilles tendon or its insertional area, or both.

All patients were operated on as outpatients. Local anesthesia was used in 76 patients and spinal or local intravenous anesthesia in 356 patients. In surgery, the patient was in a prone position and the tourniquet was used in the cases of a partial tendon rupture or insertional complaint of the Achilles tendon, and, occasionally, with other diagnoses as well. The routine incision was a longitudinal one to the lateral side of the Achilles tendon in order to identify and save the sural nerve and small saphenous vein during surgery. In insertional complaints, the skin incision was more distal and sometimes it continued transversely from the lateral side to the medial side (just below the Achilles insertion) to form an L-shape. The small subcutaneous veins were coagulated with diathermy but care was taken that the distal part of the small saphenous vein and the sural nerve were identified, freed by a blunt dissection, and retracted anteriorly.

The main surgical diagnosis was a chronic Achilles peritendinitis in 171 patients; retrocalcaneal bursitis, insertional tendinopathy (inflammation, degeneration, or both at the Achilles tendon insertion) or both, in 107 patients; a partial Achilles tendon rupture in 92 patients; Achilles tendinosis or tendinitis in 50 patients; an anomalous soleus muscle in 9 patients; and an Achilles tendon xanthoma in 3 patients. Of above noted 107 patients with insertional disorder, 20% had pure insertional tendinopathy and in 80% retrocalcaneal bursitis alone or in combination with insertional tendinopathy.

In all 171 cases with Achilles peritendinitis, the crural fascia was incised and the adhesions around the thickened paratenon were cleaned. The tight adhesions, especially between the paratenon and the crural fascia were carefully excised, but as many layers of the true Achilles paratenon as possible were left intact (Figure 7). In the 50 patients with Achilles tendinosis (i.e., an intratendinous degenerative lesion which was found at the ultrasound examination and/or at perioperative palpation as a nodule-like tissue

hypertrophy), a longitudinal incision of the tendon was performed and the degenerated focus was removed. In 92 the cases with a partial tendon rupture, the pathological tendon tissue was debrided. When the removal of the degenerative lesion or the debridement of the partial rupture was extensive, the remaining tendon was reapproximated by side-to-side sutures. In the nine cases of an anomalous soleus muscle, the fascia cruris was opened, the excessive and abnormally distally extending muscle mass excised, and, if needed, the tendon and the paratenon were freed from the adhesions.

In the 107 patients with the Achilles overuse injury in the insertional area (retrocalcaneal bursitis and / or insertion tendinopathy), the hypertrophic retrocalcaneal bursa, when present, was completely removed. In addition, the posterior upper corner of the calcaneus was excised and the bone edges were carefully smoothed with a rasp. In 12 cases, the insertional complaint was associated with a partial rupture of the Achilles tendon. The rupture was located in the anterior surface of the Achilles tendon at the level of the posterior upper corner of the calcaneus (most likely due to rubbing of the anterior part of the tendon against the posterior upper corner of the calcaneus).

4. Postoperative regimen

Ankle mobilization and partial weight-bearing with the aid of the crutches were gradually started immediately after surgery. In cases of partial Achilles tendon rupture or tendinosis (cases where the excision of the tendon tissue was extensive) in study IV, the limb was immobilized with a dorsal splint for two weeks with the ankle joint in slight plantar flexion. Thereafter the ankle was mobilized.

The stretching exercises of the Achilles tendon–gastrocnemius muscle complex were initiated, and full weight-bearing allowed, as soon as the patient was able to walk without limping, usually 1 to 2 weeks postoperatively. Light sports-specific training was allowed once there was no pain during walking and no limitation in the active range of motion of the ankle joint, usually 4 to 6 weeks after the operation. Full sports-specific training was allowed 6 to 12 weeks after the surgery.

5. Evaluation at follow-up

The follow-up methods were:

Study I

All 79 patients underwent preoperative US examination and subsequent surgery. One patient was operated twice with a preoperative US examination performed both times, thus the total number of US examinations was 80. The medical records of all 79 patients were analyzed retrospectively. Pre-operative US was compared with surgical findings. The diagnostic criteria for the US and operative findings are shown in Table 7.

The 80 US examinations of the Achilles tendons were performed by 22 radiologists. All US examinations were performed using a real-time linear array scanner with 5-10 MHz transducer (mainly 7.5 MHz). Direct contact scanning with commercially available stand-off gel pads was used in most of the examinations. The patients were examined in a standard position (prone with the foot hanging over the scanning table). In each patient, both longitudinal and transverse images were obtained. In most cases, examination of the Achilles tendon was bilateral for comparison. At surgery, the surgeon was fully aware of the results of the clinical examination and US imaging. The delay between the US examination and surgery ranged from < 1 day to 10 months depending on the chronicity of the Achilles tendon disorder.

Table 7
Diagnostic criteria for Achilles tendon injuries and related disorders (study I)

Pathologic finding *	**US findings**	**Surgical findings**
Complete rupture	Disorganized echogenicity and complete discontinuity of the fibrillary echo texture luciency	Complete disruption of the tendon
Partial rupture	Altered intratendinous structure, usually accompanied with hypoechoic focal intratendinous lesion and local increase in the sagittal diameter of the tendon	Macroscopic partial disruption of tendon fibers
Tendinosis	Focal or scattered, usually hypoechoic but sometimes hyperechoic lesion and an increase in the sagittal diameter of the Achilles tendon	Nodular thickening and glossy appearance of the Achilles tendon with an intratendinous softened and discolored area
Peritendinitis/tendinitis	Slightly altered intratendinous structure with inflammatory signs, poorly defined borders of the Achilles tendon with or without semicircular fluid accumulations, or a combination of the above	Hyperemic, thickened and fibrotic Achilles paratenon with adhesions to surrounding structures
Insertitis	Altered echogenicity and enlargement of the distal part of the Achilles tendon	Degeneration and inflammation in the tendon insertion to the calcaneus
Retrocalcaneal bursitis	Enlarged, hypoechoic retrocalcanear bursa or interrupted echo structure in the bursal area	Enlarged, scarred retrocalcaneal bursa adherent to the Achilles tendon, the bursa sometimes filled with fluid collection and fibrinous material

* A patient may have one or more of these findings

Studies II-III

In study II, the follow-up examination consisted of a questionnaire, clinical examination, performance tests, lower limb strength measurements, and US examination of both of the Achilles tendons. In every evaluation, the opposite (uninvolved) limb and its Achilles tendon served as controls.

In study III, each patients was examined at entry to the study (before the surgery) and at 7-month follow-up. The study protocol was the same on both occasions. In addition, all the patients were examined 2 to 3 weeks after surgery by the surgeon to evaluate wound healing and any early postoperative complications. In 10 patients, the contralateral Achilles tendon had been previously operated on for an Achilles tendon overuse injury. At baseline, 3 additional patients had exercise-induced Achilles pain in exertion at this contralateral side, too. For these reasons, the contralateral Achilles tendon was not used as a control. Instead, the preoperative values of the index Achilles tendon were used as the basis of the follow-up observations.

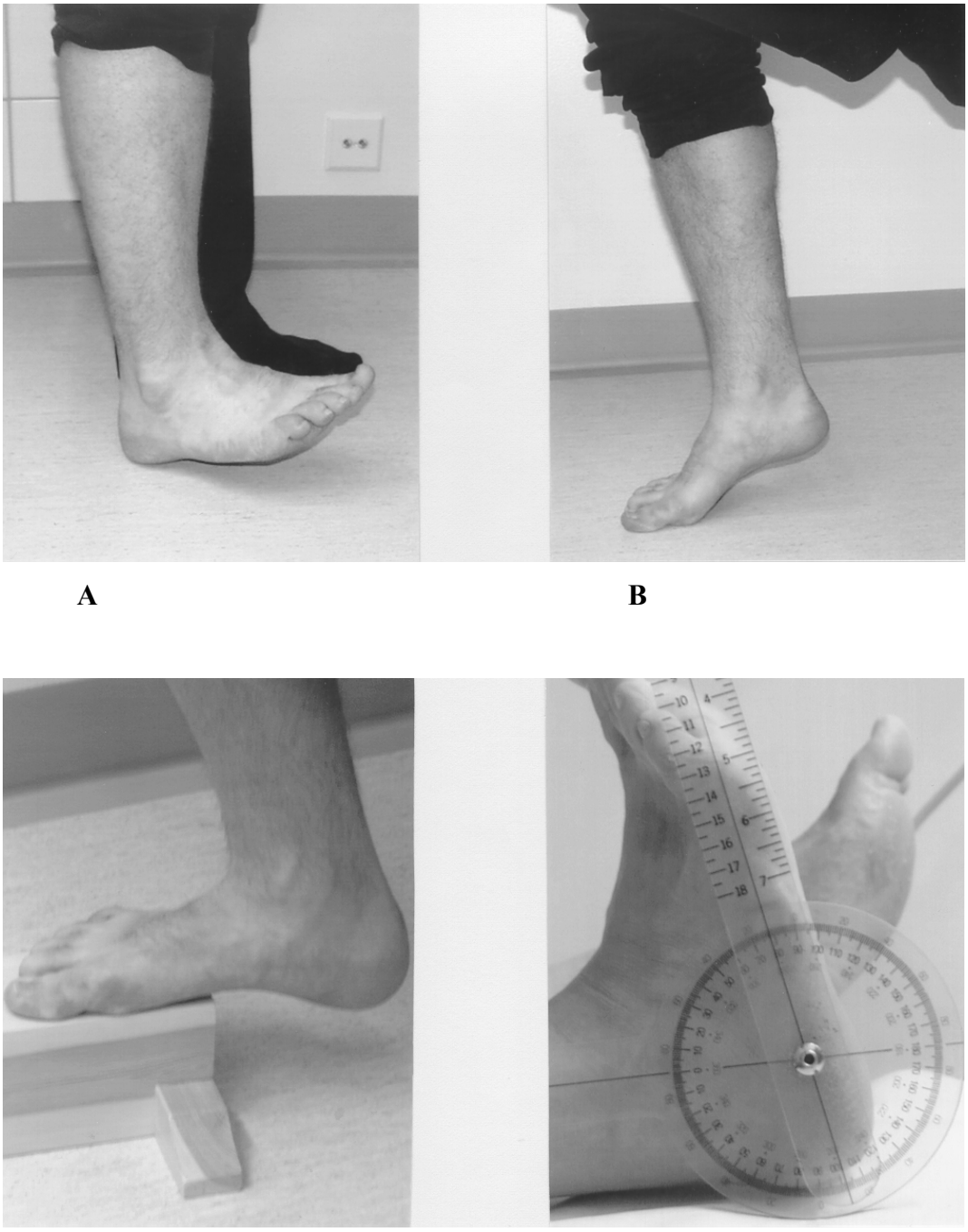
The patient's subjective opinion was asked by questionnaire in study II and by interview in study III. Subjective evaluation provided information on the onset of the symptoms of the Achilles tendon (II), subjective status (the present symptoms) of injured (II, III) as well as contralateral Achilles tendons (II), subsequent treatments (including surgical treatment) (II), ability to walk and run (walking and running was considered normal when there was no limping, no pain with light or moderate activity, and no stiffness limiting ankle range of motion) (II, III), and current physical activity (II, III). Also, possible postoperative complications were reevaluated at the end of the follow-up (III).

The performance of the lower limbs was determined by a standardized test protocol and scoring scale of Kaikkonen et al. (1994) (Table 8). The subjective evaluation was based on three "yes" or "no" questions (Table 8, questions I, II, and III), followed by evaluations of walking down stairs, rising on heel and toes, and a balance test (Table 8, tests IV–VII) (Figure 8). Finally, active range of motion of the ankle in dorsiflexion (knee extended) and stability of the ankle joint using the anterior drawer test were measured (Table 8, tests VIII – IX). The total test score was then calculated.

Table 8
A scoring scale for performance tests of the lower limbs in the 8-year follow-up study of patients with acute to subchronic Achilles tendinopathy [a]

I	Subjective assessment of the affected limb	
	No symptoms of any kind[b]	15
	Mild symptoms	10
	Moderate symptoms	5
	Severe symptoms	0
II	Can you walk normally?	
	Yes	15
	No	0
III	Can you run normally?	
	Yes	10
	No	0
IV	Climbing down stairs	
	Under 18 seconds	10
	18 to 20 seconds	5
	Over 20 seconds	0
V	Rising on heels	
	Over 40 times	10
	30 to 39 times	5
	Under 30 times	0
VI	Rising on toes	
	Over 40 times	10
	30 to 39 times	5
	Under 30 times	0
VII	Single-limbed stance	
	Over 55 seconds	10
	50 to 55 seconds	5
	Under 50 seconds	0
VIII	Laxity of the ankle joint (ADS)	
	Stable (≤5 mm)	10
	Moderate instability (6-10 mm)	5
	evere instability (>10 mm)	0
IX	Dorsiflexion range of motion	
	≥ 10°	10
	5° – 9°	5
	<5°	0

[a]Total: Excellent, 85-100; good, 70-80; fair, 55-65; poor, ≤50.
[b]Pain, swelling, stiffness, tenderness, or giving way during activity (mild, only 1 of these symptoms is present; moderate, 2 to 3 of these symptoms are present; severe, 4 or more of these symptoms are present).



A **B**

C **D**

Figure 8. In the performance test of the lower limbs, the one-legged rising on heels (**A**), the one- legged rising on toes (**B**), the one legged balance on a square beam (**C**), and the dorsiflexion of the ankle joint (**D**) were measured.

The clinical examination was carried out with special emphasis on palpable tenderness and nodules in the Achilles tendons and their insertional areas (II). Intensity and the exact site of the tenderness were recorded. The full range of motion (ROM) (III) of the ankle was measured using a goniometer (Biomet Inc., Warsaw, Indiana, U.S.A), and calf circumference (III) was measured with the measuring tape at the border of the upper and middle third of the fibula.

As a part of the above presented performance test, climbing up and down stairs (evaluated using two floors with 40 steps; height, 17 cm; depth, 30 cm), and the rising on toes test (subject was asked to rise on the toes with 1 leg as many times as possible at a pace of 60 times per minute to measure fatigue of the ankle plantar flexor muscles) was used in the clinical evaluation in study III.

In study II, the isometric extension strength of the lower limbs was measured separately on the involved and uninvolved side using an isometric leg press dynamometer (Tamtron Inc., Tampere, Finland). The knee and ankle angles were fixed at 90°. Three maximal efforts were allowed and the median value was recorded.

In study II, bilateral US examination of the Achilles tendons was performed at the Tampere University Hospital. All US examinations were performed using a real-time linear array scanner with 7.5 MHz transducer [Acuson Sequoia™ 512 Ultrasound System (transducer: 8L5 38 mm linear MultiHertz), Mountain View, CA 94039 USA]. Direct contact scanning with commercially available stand-off gel was used in every patient.

The patients were examined in the prone position with their feet hanging over the scanning table. Both longitudinal and transverse images were obtained. The findings of the US examination were classified into 4 different categories (no pathological alterations, mild abnormality, moderate abnormality, and severe abnormality) (see Table 9). In addition, the maximal sagittal diameter of the Achilles tendons was measured 2-3 cm above the posterior-superior corner of the calcaneus. This diameter was measured at precisely corresponding levels when both left and right Achilles tendons were measured.

Table 9
Ultrasonographic classification of Achilles tendon abnormality in the 8-year follow-up of patients with acute to subchronic Achilles tendinopathy (study II)

	Intratendinous lesion	**Peritendinous changes**	**Changes in retrocalcaneal bursa**	**Insertional changes**
No	Homogenous tendon structure. Parallel fiber bundles are clearly visible. No calcifications.	Clearly and sharp visible borders of the Achilles tendon. Normal echogenicity in the anterior border of the tendon.	Maximum diameter less than 10 mm and thickness less than 2 mm. Normal echo structure. Only slight fluid in the bursa. No calcification.	No calcification. Homogenous fiber structure in the insertional area.
Mild abnormality	Intratendinous hypoechoic lesion, length 5 mm or less, diameter 1 mm or less. No calcifications. Minor alterations in echostructure of the fibers.	Hyperechoic adhesions in anterior border of the tendon, length 10 mm or less. Slight alterations in peritendinous echostructure.	Maximum diameter more than 10 mm, or thickness more than 2 mm but less than 4 mm. No calcification, only slight alterations in the bursal area. No calcification.	Insertional calcification, length 10 mm or less and thickness than 2 mm. Homogenous fiber structure in the insertional area.
Moderate abnormality	Intratendinous hypoechoic lesion, length 5 to 15 mm and diameter less than 2 mm. Intratendinous calcification 5 mm or less in length.	Hyperechoic adhesions in the anterior border of the tendon, length more than 10 mm. Slight alterations in peri-tendinous echostructure.	Thickness more than 4 mm. Fluid accumulation in the bursa. Moderate alterations in the echo structure in the bursal area.	Insertional calcification, length more than 10 mm and thickness less than 2 mm. Slight alterations in the echo structure of tendon in the insertional area.
Severe abnormality	Intratendinous hypoechoic lesion, length more than 15 mm or diameter more than 2 mm. Intratendinous calcification more than 5 mm in length.	Hyperechoic adhesions in the anterior border of the tendon, length more than 10 mm and moderate to severe variety in peritendinous echostructure. Peritendinous calcification.	Thickness more than 4 mm. Severe fluid accumulation in the bursa. Severe alterations in the echo structure in the bursal area.	Insertional calcification, length more than 10 mm or thickness more than 2 mm. Moderate to severe variety in the echo structure of tendon in the insertional area.

Study IV

The follow-up time was a minimum of five months, clinical examinations performed at two weeks, one month, two months, and five months after the surgery. All minor and major complications were registered and treated. When a complication appeared, the patient was followed clinically for at least one year postoperatively (range 1 to 4 years).

6. Statistical analysis

In studies II and III, the data were analyzed by an IBM-compatible microcomputer using the 1997 version of the SPSS statistical software (SPSS Inc., Chicago, IL).

In study II, the results of the questionnaire (subjective evaluation) were analyzed by a chi-square test. In the remaining frequency variables, comparison of differences between the involved and uninvolved Achilles tendons and between the different subgroups (i.e.; between the patients in the acute, subacute, and subchronic groups) in the performance test, clinical evaluation, and ultrasonography was performed by weighted-least-squares method for repeated measurements. In continuous outcome variables (sagittal diameter of the Achilles tendon and muscle strength), one-way analysis of variance for independent groups was used to determine the side-to-side differences (between involved and uninvolved Achilles tendons) and differences between the subgroups. In each part of the analysis, an alpha level of less than 5% ($p<0.05$) was considered significant. The given significance levels refer to two-tailed tests. The results of muscle strength measurement and sagittal diameter of the Achilles tendon are given as mean ± standard deviation (SD).

In study III, the results of subjective assessment of the "symptoms of the Achilles tendon" and "ability to walk" and "run" were analyzed by the McNemar test but the statistical tests to find out the differences between the group A and group B could not be performed due to empty cells in the cross-tabs. In the remaining frequency variables ("recovery of physical activity" and "subjective assessment of the symptoms in the index Achilles tendon"), the comparison of differences between the subgroups was performed

by the chi-square test. Continuous variables (rising on toes, ROM of the ankle, the calf circumference, and climbing up and down stairs) were analyzed with non-parametric tests: Wilcoxon signed ranks test was used to determine the intragroup differences between the preoperative and postoperative tests, and Mann-Whitney's U-test to determine the differences in the preoperative-postoperative improvements between the group A and group B. Although the results of the performance test were classified into 4 different score categories, the test-to-test differences (determined by Wilcoxon signed ranks test) and differences between the two groups (determined by Mann-Whitney's U-test) were assessed using a continuous variable, the total performance test score. The results of the continuous variables are given as a mean ± standard deviation (SD) throughout the study, unless specified differently.

RESULTS

1. Suggest value of pre-operative ultrasonography in Achilles tendon injuries

Study I

Abnormal findings were observed in 76 of the 80 Achilles tendons in US examination and in 79 tendons at surgery. One patient was operated despite normal preoperative sonography and the surgical findings were also normal. Sixty patients had two or more sonographical findings and in 21 cases, two or more surgical diagnoses were given. Comparison between the surgical findings and US findings are given in Table 10.

Complete Achilles tendon ruptures were correctly found in 25 of the 26 cases (96%) by US. The remaining false-negative US case (delay 1 day) was sonographically regarded as a partial Achilles tendon rupture. There were no false-positive cases. Two patients were examined more than 90 days prior to the surgery, and in both of these cases the preoperative US examination revealed the correct diagnosis.

Partial rupture of the Achilles tendon was correctly identified in 8 of 11 cases (73%) by US. Two of the false-negative cases were sonographically considered Achilles tendon peritendinitis/tendinitis, and the remaining case normal. US gave a false-positive diagnosis of a partial Achilles tendon rupture in five tendons. Eight of the patients were operated on less than 90 days after the US examination and in one tendon the US gave false-negative diagnosis. In the two other false-negative cases, the US examinations were performed more than 90 days before surgery.

Intratendinous degenerative lesion or tendinosis could be correctly found in 3 of 7 Achilles tendons by US. Simultaneous peritendinitis/tendinitis was observed in each of the cases in surgery. In three of the four false-negative cases US finding was classified as peritendinitis/tendinitis, and one as a partial Achilles tendon rupture and peritendinitis/tendinitis. There were no false-positive cases. Two of the patients were operated on less than 90 days after the US examination and in one of these patients US revealed false-negative diagnosis. In three false-negative cases, the US examinations were performed more than 90 days before surgery.

Table 10
Comparison between the surgical and US findings in the Achilles tendon injuries and related disorders (study I)

Tendon condition diagnosed at surgery	Number of cases	Correct preoperative US diagnosis	False-negative on US	False-positive on US
Complete rupture	26	25	1	0
Partial rupture	11	8	3	5
Tendinosis	7	3	4	0
Peritendinitis/tendinitis	40	33	7	0
Insertitis	5	3	2	1
Retrocalcanear bursitis	8	6	2	0
Normal	1	1	0	3

Peritendinitis/tendinitis of the Achilles tendon were correctly found by US in 33 of the 40 tendons (83%). Four the false-negative cases was sonographically considered to be a partial rupture, 1 a retrocalcaneal bursitis, and in 2 cases there was no sonographical abnormality. There were no false-positive cases. Twenty-two patients were operated on 90 days or less after the US examination, of which US gave false-negative diagnosis in three cases. In the other four false-negative cases, the US examinations were performed more than 90 days before surgery.

Inflammatory changes in the Achilles tendon insertion, or Achilles insertitis, was suspected in 3 of the 5 surgically verified cases (60%) by US. One false-negative case was regarded as peritendinitis/tendinitis and calcaneus spur, and the other case a partial rupture of the Achilles tendon and Achilles peritendinitis/tendinitis. US gave a false-positive diagnosis of Achilles tendon insertitis in one case. Four Achilles tendon insertitis cases were examined less than 90 days prior to surgery and both of the false-negative US diagnoses were in this group.

Retrocalcaneal bursitis was correctly identified by US in 6 of 8 surgically verified patients (75%). One false-negative case was regarded as peritendinitis/tendinitis and the other as partial rupture and peritendinitis/tendinitis. There were no false-positive cases. Five of these patients were operated on less than 90 days after the US examination and in one tendon US provided a false-negative diagnosis. In the other false-negative case, US was performed more than 90 days before surgery.

In 4 surgically treated patients, the preoperative US examination did not show any pathological changes. Of these, the surgical findings indicated peritendinitis/tendinitis in two cases (delay 82 and 106 days) and a partial Achilles rupture in one case (delay 149 days). In one case, neither surgery nor US found pathological changes. In one patient, both the US examination and surgery showed calcaneal spur formation. In addition, a minor rupture of the soleus muscle was suspected on the basis of US in one case, which proved to be a rupture of the medial part of the gastrocnemius muscle in surgery.

2. Long-term course of nonoperatively treated acute to subchronic Achilles tendinopathy

Study II

Surgical treatment of the affected Achilles tendon had to be performed in 24 of the 83 patients (29%) during the 8-year follow-up period; 7 of the 24 patients (29%) were operated in the acute group, 6 of the 24 patients (25%) in the subacute group, and 11 of the 35 patients (31%) in the subchronic group. Seventeen of the 24 operations (71%) were focused on the pathologic structures around the tendon (release of the peritendinous adhesions), but in three patients the surgery additionally revealed an intratendinous lesion. In one patient, the Achilles tendon ruptured spontaneously in soccer three weeks after the onset of the symptoms of Achilles tendinopathy and the tendon was repaired. In the three remaining patients, the symptoms moved to the insertional area of the Achilles tendon by time and the surgery confirmed chronic retrocalcaneal bursitis. The surgically-treated patients recovered in 120 ± 30 (SD) days and the final outcome of these patients did not differ from those not needing surgery.

In the subjective evaluation, 49 of the 83 patients (59%) were asymptomatic after the 8-year follow-up period. Twenty-nine patients (35%) recognized mild exertional pain and four patients (5%) recognized considerable pain – but only during strenuous exertion. The remaining patient felt pain in the affected Achilles tendon even at rest but was still training daily. Physical activity had recovered to preinjury level in 70 of the 83 patients (84%). Four of 83 patients (5%) could not run normally and one patient could not walk normally due to Achilles tendon symptoms. Between the different subgroups no statistically significant differences were observed in the subjective evaluation (exertional pain, $p=0.46$; recovery of the physical activity, $p=0.65$).

In the performance test of the lower limbs, the uninvolved side was classified as excellent more frequently than involved side [45 of the 83 lower limbs (54%) vs. 35 of the 83 lower limbs (42%), $p=0.03$]. There were no statistically significant differences in the distribution of these test score categories between the different subgroups ($p=0.53$). The distribution of the patients according to the four categories of the total scores in the performance test are presented in Table 11.

Table 11
Distribution of the patients according to the performance test score categories in the 8-year follow-up study of acute to subchronic Achilles tendinopathy (study II)*

Score category	Acute group (N=24)		Subacute group (N=24)		Subchronic group (N=35)		Total (N=83)	
	Involved limb	Uninvolved limb	Involved limb	Uninvolved limb	Involved limb	Uninvolved limb	Involved limb	Uninvolved limb
Excellent (85-100)	11	16	11	12	13	17	35	45
Good (70-80)	10	7	11	10	19	15	40	32
Fair (55-65)	3	1	1	1	3	3	7	5
Poor (≤50)	-	-	1	1	-	-	1	1

* No significant group differences, although in the total group the uninvolved side was classified as excellent more frequently than the involved side (45 / 83 vs. 35 / 83, p=0.03) (the weighted-least-squares method for repeated measurements).

In the isometric extension strength test of the involved and uninvolved lower limbs (i.e., the maximum extension strength of the entire lower limb), statistically significant differences were observed neither between the involved and the uninvolved sides (p=0.86), nor between the different subgroups. In the acute group, the mean extension strength was 106 ± 22 kg in the involved lower limb and 109 ± 21 kg in the uninvolved lower limb; in the subacute group 103 ± 22 kg (involved) and 103 ± 23 kg (uninvolved); and in the subchronic group 103 ± 19 kg (involved) and 101 ± 19 kg (uninvolved).

In the clinical evaluation, tenderness as well as palpable nodules were found more frequently in the involved Achilles tendon than in the uninvolved side [tenderness, 35 of the 83 involved Achilles tendons (42%) vs. 24 of the 83 uninvolved Achilles tendons (29%); palpable nodules, 18 of the 83 involved tendons (22%) vs. 11 of the 83 uninvolved tendons (13%)], although the differences were not statistically significant (p=0.058 and p=0.11, respectively). In addition, no statistically significant differences were observed between the different subgroups.

The findings in the bilateral US examination of the Achilles tendons are shown in Table 12. US showed intratendinous abnormality more often in the involved Achilles tendon [29 of the 83 tendons (35%)] than uninvolved tendon [18 of the 83 tendons (22%)] (p=0.017). This difference was especially obvious among the more severe changes classified as “moderate” or “severe”. Peritendinous abnormalities were found in 60 of the 83 of the involved Achilles tendons (72%) and in 38 of the 83 tendons (46%) of the uninvolved tendons. This difference was statistically significant (p<0.001). In the insertional area, pathological US findings were less frequent than in the more proximal part of the Achilles tendon: changes in the retrocalcaneal bursa were found in 12 of the 83 Achilles tendons (14%) in the involved side as well as uninvolved side, and insertional changes were found in only 6 involved tendons (7%) and 1 uninvolved tendon (1%). These differences were not statistically significant. The subgroup differences of intratendinous, peritendinous or insertional US abnormalities were not statistically significant either.

Table 12
The results of the ultrasonographic examination in the 8-year follow-up study of acute to subchronic Achilles tendinopathy (study II)

Ultrasonographic finding	Acute group (N=24)		Subacute group (N=24)		Subchronic group (N=35)		Total (N=83)	
	Involved limb	Uninvolved limb	Involved limb	Uninvolved limb	Involved limb	Uninvolved limb	Involved limb	Uninvolved limb
Intratendinous lesion								
no	14	19	17	21	23	25	54	65
mild	7	4	1	3	8	7	16	14
moderate	1	1	6	-	4	2	11	3
severe	2	-	-	-	-	1	2	1
Peritendinous changes								
no	8	15	5	12	10	18	23	45
mild	9	6	11	7	12	8	32	21
moderate	6	2	6	5	11	9	23	16
severe	1	1	2	-	2	-	5	1
Changes in the retrocalcaneal bursa								
no	18	20	21	20	32	31	71	71
mild	5	3	3	3	3	2	11	8
moderate	1	1	-	1	-	2	1	4
severe	-	-	-	-	-	-	-	-
Insertional changes								
no	24	24	21	23	32	35	77	82
mild	-	-	1	-	3	-	4	-
moderate	-	-	2	-	-	-	2	-
severe	-	-	-	1	-	-	-	1
AP-diameter of the Achilles tendon* (mm)	7.0 (±1.8)	5.7 (±0.8)	6.5 (±1.3)	6.3 (±1.4)	6.4 (±1.3)	6.0 (±1.3)	6.6 (±1.5)	6.0 (±1.2)

* The maximal sagittal diameter of the Achilles tendon measured 2-3 cm above the posterior superior corner of the calcaneus (in the right and left Achilles tendons of the same patient, the measurement was always done exactly at the same level).

In the US examination, the involved-to-uninvolved side differences in the maximal sagittal diameter of the Achilles tendons were small: in all groups together, 6.6 mm vs. 6.0 mm; in the acute group, 7.0 mm vs. 5.7 mm; in the subacute group, 6.5 mm vs. 6.3 mm; and in the subchronic group, 6.4 mm vs. 6.0 mm. This side-to-side difference was statistically significantly larger in the acute group than in the subacute group (group difference 1.1 mm, p=0.013) and subchronic group (difference 0.9 mm, p=0.033).

In the initially uninvolved Achilles tendon, symptoms of overuse (exertional pain with or without swelling and stiffness) developed in 34 of the 83 patients (41%) during the follow-up period. These overuse symptoms was somewhat more common in the subchronic group [16 of the 35 patients (46%)] than in the acute [8 of the 24 patients (33%)] or subacute group [9 of the 24 patients (38%)], but the difference was not significant (p=0.46). In 5 of the 83 patients (6%), the initially uninvolved Achilles tendon was operated on during the follow-up period.

3. Short-term outcome after surgical treatment of Achilles tendinopathy

Study III

In the subjective evaluation, 12 of the 16 patients (77%) in group A (chronic Achilles tendinopathy with peritendinous adhesions) and 23 of the 26 patients (88%) in group B (chronic Achilles tendinopathy with peritendinous adhesions and a localized intratendinous lesion) had moderate to severe symptoms in the index Achilles tendon at the beginning of the study. After the 7-month follow-up period, the subjective assessment showed clear improvement as 15 of 16 patients (94%) in group A, and 20 of 26 patients (79%) in group B, were asymptomatic or had only mild symptoms in strenuous exercise (improvement in group A, p=0.001; in group B, p<0.001). There were no statistically significant differences between the patients in the groups A and B in the preoperative or postoperative subjective assessment of the injured Achilles tendon (preoperatively, p=0.38; postoperatively, p=0.32).

The physical activity recovered to preinjury level more often in group A than in group B [14 of the 16 patients (88%) vs. 14 of the 26 patients (54%), between-group

difference, p=0.025]. Subjective assessment of the ability to walk and run showed statistically significant improvement after the surgery of the Achilles tendon in both groups. Before surgery, only 10 of 16 patients (63%) in group A were able to walk normally and none of them were able to run normally. At 7-month follow-up, all 16 patients (100%) in group A could walk normally and 15 of these 16 patients (94%) could run normally (walking, p=0.031; running, p<0.001). In group B, only 14 of the 26 patients (54%) were able walk normally and 2 of 26 patients (8%) were able to run normally before the surgery, whereas at follow-up, 24 of these 26 patients (92%) could walk normally and 20 (77%) could run normally (walking, p=0.006; running, p<0.001).

In clinical tests, statistically significant improvement was seen in both groups in the climbing up and down stairs tests, and in the rising on toes test. There were no statistically significant differences between group A and group B in the improvements of these tests. Neither range of motion of the ankle nor calf circumference showed statistically significant intragroup changes during the follow-up period, or statistically significant differences between groups A and B.

In the performance test, the improvement of the median of the performance test score was significant in both groups (p<0.001 for both), without a significant between-groups difference in the improvement (Table 13). There were no statistically significant differences in the distribution of the preoperative test score between group A and group B (p=0.21). However, the postoperative test score was classified as “good” or “excellent” in all patients in the group A, whereas in group B the test score was classified as “good” or “excellent” in 19 of the 26 patients (73%) only. The distribution of the patients according to the four categories of the total scores in the performance test protocol are presented in the Table 13.

Table 13
Distribution of the patients according to the performance test score categories and the median (range) of the total score of the involved Achilles tendon in the 16 patients with Achilles tendinopathy with peritendinous adhesions (group A) and 26 patients with Achilles tendinopathy with peritendinous adhesions and intratendinous lesion (group B) (study III)

Score category of involved Achilles tendon	Group A (N=16)		Group B (N=26)	
	Before surgery	7-month follow-up	Before surgery	7-month follow-up
Excellent (85-100)	–	5	–	7
Good (70-80)	–	11	1	12
Fair (55-65)	6	–	8	1
Poor (≤50)	10	–	17	6
Median (range)[a]	50 (25 – 65)	80[b] (70 – 95)	48 (15 – 70)	75[b] (15 – 100)

[a]Maximum value = 100
[b]Wilcoxon signed ranks test for intragroup score change by time. In both groups, this change was significant ($p<0.001$), showing, however, no significant intergroup difference in the score improvement (Mann-Whitney's U-test).

Postoperative complications were observed in 8 of the 42 patients (19%): 4 superficial wound infections, 2 skin edge necrosis, and 2 fibrotic reactions or scar formations. These complications were found more often in patients in group B than in patients in group A [7 of 26 patients (27%) in group B vs. 1 of 16 patients (6%) in group A], although the difference was not statistically significant ($p=0.098$).

4. Complications after surgical treatment of chronic Achilles tendon overuse injuries

Study IV

Forty-six complications were observed in the 432 patients (11%) who were treated surgically due to the overuse injury of the Achilles tendon: 14 skin edge necrosis, 11 superficial wound infections, 5 seroma formations, 5 hematomas, 5 fibrotic reactions / scar formations, 4 sural nerve irritations, 1 new partial rupture, and 1 deep vein thrombosis (Table 14). Of these complications, 16 were classified as major and the remaining 30 as minor.

Fourteen patients with a complication were reoperated: 4 patients because of skin edge necrosis, 2 because of superficial wound infection, 2 because of seroma formation, 1 because of hematoma formation, 2 because of fibrotic reaction / scar formation around the Achilles tendon and paratenon, 2 because of sural nerve irritation, and 1 because of new partial rupture. The remaining 32 cases were treated conservatively.

The compromised wound healing (skin necrosis and superficial wound infection) was noticed in 13 (7%) of the 171 patients with chronic Achilles peritendinitis, in 10 (11%) of the 92 patients with partial tendon rupture, and in 2 (2%) of the 107 patients with retrocalcaneal bursitis and / or insertional tendinopathy. All 5 cases of postoperative seroma formation and 4 cases of sural nerve irritation appeared in patients operated on for chronic Achilles peritendinitis. The distribution of the complications by the surgical diagnoses are shown in Table 14.

Table 14
Distribution of the complications by the surgical diagnoses (study IV)

Diagnosis	Number of Patients	Complication							
		Skin necrosis	Superficial wound infection	Seroma formation	Hematoma	Fibrotic reaction / scar formation	Sural nerve irritation	New partial rupture	Deep vein thrombosis
Peritendinitis	171	8	5	5	1	3	4	-	1
Retrocalcanear bursitis, insertion tendinopathy, or both	107	1	1	-	2	1	-	-	-
Partial tendon rupture	92	5	5	-	1	1	-	1	-
Tendinosis, tendinitis	50	-	-	-	1	-	-	-	-
Anomalous soleus muscle	9	-	-	-	-	-	-	-	-
Tendon xanthoma	3	-	-	-	-	-	-	-	-
Total	432	14	11	5	5	5	4	1	1

DISCUSSION

1. Ultrasonography the diagnosis of Achilles tendon injuries

The use of ultrasonography in the imaging of tendon pathology has been recommended, especially in Achilles tendon disorders (Blei et al. 1986, Fornage 1986, Laine et al. 1987, Fornage and Rifkin 1988, Mathieson et al. 1988, Maffulli et al. 1989, Kainberger et al. 1990, Lehtinen et al. 1994). Some recommendations were based on a limited number of possible Achilles tendon diagnoses and a small number of patients. Moreover, in few reports the US diagnoses were verified by surgery.

On the basis of preoperative US of 30 patients, Lehtinen et al. (1994) found that US was a reliable method in the diagnosis of partial ruptures, however, underdiagnosing Achilles tendon peritendinitis and overdiagnosing tendinitis. Kälebo et al. (1992) examined the diagnostic value of ultrasonography with respect to surgery in partial ruptures of the Achilles tendon. In their comparison, the US examination had a sensitivity of 0.94, a specificity of 1.00 and an overall accuracy of 0.95. In the study of Åström et al. (1996), the preoperative US examination was compared with operative findings in 26 cases with chronic Achilles tendinopathy (4 partial ruptures and 22 degenerative lesions). In 20 of the 24 surgically verified cases, preoperative US examination was correct. Two tendons were macroscopically normal, but histological evaluation indicated tendon degeneration. US showed intratendinous abnormalities in one of these two cases. They concluded that US has great utility as a prognostic instrument.

In our retrospective study (study I), a relatively large number of patients were studied and the entire scale of various Achilles tendon injuries and disorders examined. Furthermore, every case was verified surgically so that accuracy of US could be evaluated. On the other hand, in a retrospective study design such as ours, it was not possible to blind the surgeon to the US results. In other words, the ultrasound report reviewed preoperatively by the surgeon might influence the recording of the surgical findings. This is unavoidable because positive ultrasound findings correlating with the clinical findings are used as an indication for surgery. In addition, no study can verify the US findings of those patients who, despite clinical symptoms and US findings, never

undergo surgical exploration. Thus, the prognostic value of these US findings remains unknown. The lack of histopathologic examination is a clear limitation in this study as the differentiation of partial rupture and tendinosis in surgery is difficult without histological reference. However, there may not be any point to distinguish these two entities since there has not been shown any differences in the treatment or prognosis of these complaints.

The experience of the radiologist has been supposed to influence the accuracy of US examination as a substantial learning curve exists in tendon sonography. Most of the previous studies have introduced results which have been based on US examinations performed by experienced US practitioners. In our study, the US examinations were performed by 22 radiologists. Thus, the study represents the general US experience in our city area. Despite this, US turned out to be a relatively good diagnostic tool in various Achilles tendon problems.

Recently, there has been progress in the understanding of Achilles tendon pathology that should influence the classification of disorders found at US examination and surgery (Kannus and Jozsa 1991, Åström et al. 1996, Kannus 1997). So far, classification and differentiation of the terms and findings such as tendinitis, peritendinitis, tendinopathy, and tendinosis, have not been familiar enough to many radiologists and previous textbooks of radiology have not drawn enough attention to the differential diagnosis of tendinitis and tendinosis, or partial rupture and tendinosis.

In study I, US was a rather reliable method in diagnosing complete Achilles tendon ruptures as only one false negative US diagnosis was found. However, the differential diagnosis of partial Achilles rupture and local degenerative lesion (tendinosis) was more difficult. The location of the lesion could be adequately determined by US. In our reanalysis of the US reports of the false-negative cases, step formation in the tendon surface, local increase in the diameter of the tendon, and a long intratendinous lesion were found to indicate a partial Achilles tendon rupture rather than tendinosis. This additional finding also emphasizes the role of careful interview of the patient for the differential diagnosis as it is generally believed that the sudden onset of the symptoms indicates the partial rupture.

US findings are believed to vary in different stages of Achilles peritendinitis/tendinitis and insertitis, and also according to previous activity level of the patient and the treatment received. Our study showed that positive US findings indicating Achilles peritendinitis or tendinitis are reliable, whereas a negative US finding is rather unreliable, particularly in patients with only slight adhesions between the paratenon sheaths. US was also accurate in diagnosing retrocalcaneal bursitis. US findings may, however, vary along with the degree of inflammation and fluid collection in the bursal area, and therefore we recommend that the interval between US and its interpretation with respect to treatment should not exceed 2-3 months.

2. Conservative treatment of Achilles tendinopathy

The long-term prognosis of patients with acute to subchronic Achilles tendinopathy is generally good and acceptable as was showed by our observational 8–year follow-up study (study II). Physical activity fully recovered in 70 of the 83 patients (83%), and at 8 years 78 patients (94%) were asymptomatic or had only mild pain in strenuous exercise. At the involved side, delay up to six months between the onset of the symptoms and initiation of conservative treatment did not had any remarkable effect on the long-term outcome.

Nevertheless, Achilles tendon overuse injury causes significant disability in some patients. Twenty-nine percent of subjects failed to respond to conservative treatment and underwent surgery. Also, even at 8-year follow-up, there was a clear side-to-side difference between the involved and the uninvolved sides in the performance test, clinical examination and ultrasonography. Furthermore, 33 of the 83 patients (41%) started to suffer from overuse symptoms (exertional pain with or without swelling and stiffness) at the initially uninvolved Achilles tendon, too.

Study II is the first prospective long-term follow-up of patients with acute to subchronic Achilles tendinopathy (using subjective, functional and clinical assessments as well as ultrasonographic examination as outcome criteria). However, it has two clear limitations that need consideration. First, since no consensus exists how to treat a patient

with Achilles tendinopathy, the conservative treatment initiated after the first examination was not uniform. In all patients, modified rest and gastrocnemius-soleus stretching was recommended and many of the patients (83%) received one to three local peritendinous corticosteroid injections. Second, at the initiation of the study, neither US nor MRI of the Achilles tendon were performed, and thus it is not known whether some of the peri- or intratendinous follow-up findings were present already initially. On the other hand, according to a recent prospective follow-up of patellar tendons of female basketball players (Khan et al.1997) occurrence of imaging abnormality at baseline predicted poorly the development of the symptoms of the jumper's knee. Since this discrepancy has been recognized in the authors' clinical practice for a long time, it is unlikely that baseline imaging studies would have changed the results of the current follow-up.

Kvist (1991a) found in his retrospective study, that 24% of the patients with Achilles tendinopathy and insertional pain needed surgical treatment. Leppilahti et al. (1991) reported in their retrospective study that 46% of the patients with overuse injuries of the Achilles tendon were treated surgically. In a more recent retrospective study of Johnston et al. (1997) an even greater proportion of the patients with chronic Achilles tendon disorder (20 of the 41 patients, 49%) underwent surgical treatment. The different proportions of patients needing surgical treatment in these retrospective studies are likely due to differences in the selection of the patients in the study, variability in the treatment strategies between the clinics, or difference in the duration of the follow-up period. In study II, 29 % of patients with initially acute to subchronic Achilles tendinopathy failed to improve with conservative treatment and these patients were operated on.

In study II, the final outcome of the surgically treated patients did not differ from those not operated on. However, no randomized treatment intervention was attempted and thus, the patients treated surgically may have already differed at baseline from those treated nonsurgically (the nonresponding cases are more likely to become included in the surgical group). Thus, in this study, comparison of patients with surgical vs. non-surgical treatment is not valid and therefore these data were not presented in detail.

Tendon degeneration, resulting in reduction of the tensile strength of the tendon, may predispose an Achilles tendon to spontaneous rupture (Jozsa and Kannus 1997), but only 4% to 33% of patients with complete Achilles tendon rupture report pre-existing

symptoms (Lea and Smith 1972, Bradley and Tibone 1990, Kannus and Jozsa 1991). The tendon ruptures have also been suspected to be associated with the use of local injections of corticosteroids, but the true effect of peritendinous injection on risk of tendon rupture is still unknown and therefore well-controlled clinical studies are needed (Leadbetter 1995, Fredberg 1997, Jozsa and Kannus 1997). In retrospective analysis of 298 patients with Achilles tendinopathy, Åström (1998) found that preoperative steroid injections predicted a partial rupture. However, patients with a partial rupture were physically more active and more often had an acute onset of symptoms than those who did not have a rupture, and, thus, were likely to be selected for steroid treatment because of severe pain.

In our study, one patient had suffered from symptoms of Achilles tendinopathy for two weeks, was examined with ultrasonography (in which no intratendinous abnormality was found) and received a peritendinous injection of corticosteroid and GAGPS. One week after the injection he sustained a complete Achilles tendon rupture in a soccer match. In interpreting this occurrence, we have to remember that the main reason for the rupture may not have been the cortisone itself but its anti-inflammatory effect (quick pain relief and consequently quick return to strenuous physical activity). Today it is believed that judicious use of locally injected corticosteroid – that is, limited number of injections (1 to 3), no intratendinous injection, no injection of chronic tendon disorders (tendinosis), no use of substances with long lasting effects such as triamcinolone, and dilution of the corticosteroid with local anesthetic before the injection – is likely to have minimal adverse effect on the target tendon (Kvist 1991b, Leadbetter 1995, Jozsa and Kannus 1997).

Although the long-term prognosis of patients with acute to subchronic Achilles tendinopathy seems acceptable, the involved Achilles tendons revealed tenderness and palpable nodules in 42% and 22 %, respectively, at 8-year follow-up. In the contralateral Achilles tendons, tenderness and palpable nodules were observed less frequently (in 29% and 13%, respectively). On the other hand, this tenderness in the Achilles tendon was usually mild; moderate or severe palpation tenderness was found in only 8 % of the involved and 5 % of the contralateral Achilles tendons. In the patellar tendon, poor correlation between mild tenderness and US evidence of tendon pathology is found (Cook et al. 2001). In addition, since the delay between the onset of the symptoms and

the initiation of the conservative treatment did not affect outcome, the clinical relevance of the palpable tenderness and nodules in the Achilles tendon remains questionable.

US examination has been reported to reliably visualize the indistinct borders of the tendon and thickening of the anterior border of the tendon in Achilles tendinopathy (Laine et al. 1987). In the Achilles tendon with tendinosis, US has been found to identify intratendinous hypoechoic lesions and altered tendon structure (Laine et al. 1987, Maffulli et al. 1987, Lehtinen et al. 1994). In study I, preoperative US findings concerning intratendinous degenerative lesions or peritendinous abnormality of the Achilles tendon proved reliable when compared to subsequent surgical findings. In study II, the pathologic US findings were rather common and the involved side was affected more frequently than the contralateral side. The delay between the onset of the symptoms and the initiation of the conservative treatment did notappear to influence the tendon's US appearance, although the side-to-side difference in the sagittal diameter of the tendon was larger in the acute group than subacute or subchronic groups. Abnormal US findings were especially common in peritendinous tissues; in 72% of the involved and in 46% of the contralateral Achilles tendons the paratenon was abnormal. The peritendinous changes were, however, usually mild or moderate only and often located in the anterior border of the distal Achilles tendon. Many of the patients with ultrasonographic peritendinous changes were asymptomatic or had only mild pain with strenuous exercise and these changes were common in the contralateral side, too.

Degeneration of the tendon tissue can develop without clinical symptoms in which case the tendon may only become symptomatic with heavy training (Puddu et al. 1976). In the study of Kannus and Jozsa (1991), pre-existing degenerative changes were demonstrated histologically in nearly all tendons with a spontaneous rupture. However, the exact role of the intratendinous lesions in the pathogenesis of the Achilles tendon overuse injuries, symptoms of the patient, and in particular, treatment of the patient is not known (Jozsa and Kannus 1997). Study II is one of the first (Gibbon et al. 1999) to show that asymptomatic Achilles tendons can contain rather large areas of abnormal US appearance. In study II, a few patients had mild intratendinous US changes of the Achilles tendon at the follow-up; however, without considerable clinical symptoms.

Almost all known intrinsic and extrinsic predisposing factors of Achilles tendon overuse injuries are frequently seen bilaterally. Thus, it is a problem to determine which structures or abnormal findings in the imaging or surgery of the Achilles tendon actually are responsible for pain and related symptoms. In study II, mild to moderate peritendinous and intratendinous changes were seen rather frequently in the contralateral Achilles tendon, too, but without considerable symptoms. Thus, these US changes could have been induced, at least partly, by long-standing physical activity and exertion alone.

Occasionally, Achilles tendinopathy has been found in combination with insertional complaint (Schepsis et al. 1994, Jozsa and Kannus 1997). In study II, in 3 of the 83 patients (4%) with initially non-insertional Achilles tendinopathy, the exertional pain also appeared in the insertional area and needed surgical treatment. In addition, US showed pathological changes in some patients' retrocalcaneal bursae (in 14% of the involved as well as contralateral tendons) and in the Achilles insertion (in 7% of the involved tendons and 1% of the contralateral tendons). As in the case with abnormal peritendinous and intratendinous US findings, the patients with changes in the insertional area were asymptomatic or had mild pain in strenuous exercise only. Nevertheless, we recommend that the insertional area should be carefully examined during clinical examination and imaging studies even in patients with non-insertional Achilles tendinopathy.

3. Surgical treatment of chronic Achilles tendinopathy

In the treatment of the chronic Achilles tendon overuse injuries, the goal is to return the patient to the desired level of physical activity without significant residual pain. In athletes, the recovery time should also be as short as possible.

Our prospective 7-month follow-up study (study III) showed that the short-term results after surgical treatment of chronic Achilles tendinopathy were satisfactory. Physical activity fully recovered in 28 of the 42 patients (67%), and 35 patients (83%) were asymptomatic or had only mild pain in strenuous exercise. In clinical tests, clear improvement was observed in the climbing up and down stairs and in the rising on toes

test. In addition, using the performance test protocol as the criterion, the surgical treatment of the Achilles tendinopathy seemed successful since at follow-up the total test score was excellent or good in 35 patients (83%) [preoperatively, the total test score was excellent or good in 1 patient (2%) only].

Although study III is the first prospective follow-up report of patients with surgery for Achilles tendinopathy, using subjective, clinical, and functional tests as outcome variables, it has two limitations. Firstly, although "recovery to the previous level of activity in the shortest possible time" is often emphasized in athletes, a longer follow-up is needed to determine the truly long-term outcome of the surgery. Secondly, the authors were unable to include in the study a group of nonoperatively treated controls, matched by age, gender, and physical activity. A randomized controlled trial would be needed to fulfill this demand.

In study III, the overall complication rate after surgical treatment of chronic Achilles tendinopathy was 19% and the delayed wound healing (skin edge necrosis and superficial wound infection) was the most common problem; the entire complication rate of skin problems was 14%. Postoperative complications were more frequent in patients operated on for Achilles tendinopathy with peritendinous adhesions and intratendinous lesion (group B) (27%) than in patients operated on for Achilles tendinopathy with peritendinous adhesions only (group A) (6%). One cause for the increased risk of postoperative complications after the operative treatment of the intratendinous lesion could be, as in study IV, extensive postoperative thickening of the Achilles tendon followed by abnormal skin stretching and impaired local circulation. Also, the more extensive surgery and subsequent tissue tugging may increase the risk of complications.

Surgical treatment of Achilles tendon overuse injuries has given satisfactory (70-95%) results in many previous studies. However, most of these works have been retrospective (Kvist and Kvist 1980, Nelen et al. 1989, Fernandez-Palazzi 1990, Leppilahti et al. 1991, Leach et al. 1992, Lehto et al. 1994, Leppilahti et al. 1994, Johnston et al. 1997, Rolf and Movin 1997, Maffulli and al. 1998) and only in few of these studies were the results based on objective evaluations, such as the range of motion of the ankle (Schepsis and Leach 1987, Schepsis et al. 1994, Morberg et al. 1997).

To our knowledge there are only two previous prospective studies on surgical treatment of the Achilles tendinopathy (Alfredson et al. 1996, Maffulli et al. 1997). Alfredson et al. (1996) studied prospectively the effect of surgical treatment on isokinetic calf muscle strength in 13 patients with various types of Achilles tendon overuse injuries. The subjective, clinical or functional test evaluations were not included in the study protocol. They found that after surgical treatment of the Achilles tendon overuse injury six months of rehabilitation was not enough to regain concentric and eccentric plantar flexion muscle strength, as compared with the uninjured side. However, an additional problem in their study design was that the surgery was followed by a relatively long (6 weeks) immobilization period with a plaster cast, although muscle tissue is known to be very sensitive to atrophy after short (1 week) periods of disuse, and its recovery to normal function and volume is generally known to be one of the most difficult challenges in sports medicine (Kannus et al. 1992).

Maffulli et al. (1997) evaluated the results of percutaneous longitudinal tenotomies on 52 middle- and long-distance runners with unilateral Achilles tendinopathy (peritendinitis and/or intratendinous lesion) on the basis of isometric strength and endurance measurements and subjective evaluation (6 months and 18 months after the operation, respectively). In that study, the presence of peritendinitis was a poor prognostic factor, since the patients with tendinopathy associated with peritendinitis were less satisfied, less strong and less resistant after the follow-up period when compared to patients with isolated tendinopathy (intratendinous pathology without peritendinous alterations at the US examination). Although the percutaneous longitudinal tenotomies showed acceptable results in that study, we feel that this type of surgery unnecessarily insults the integrity of the tendon at the unaffected regions, particularly in patients with tendinopathy without any intratendinous abnormality. In addition, in their surgical procedure (multiple percutaneous longitudinal tenotomy), there was no trimming of the peritendinous adhesions and thus, the peritendinous tissues were left adherent to the Achilles tendon and surrounding structures. Based on our surgical experience, all cases of Achilles tendinopathy with an intratendinous lesion show additional peritendinous adhesions and we recommend these adhesions be divided during the surgery.

In study III, the patients in the group A managed better than the patients in group B when evaluating the recovery of physical activity after surgery (88% vs. 54%). This trend of better recovery among patients with pure peritendinous adhesions (group A) was also found in the performance test of the lower limbs, although the group difference was not statistically significant. Although the surgery was more extensive and the patients somewhat older in the group B than group A, one reason for a worse outcome among patients with a co-existing intratendinous lesion might be the more serious pathology of Achilles tendinopathy. Although the exact role of the intratendinous changes in the etiology and pathogenesis of Achilles tendinopathy, related symptoms, and in particular, treatment and prognosis of the patients, is not known, we feel that preoperative imaging of the tendon structure with US or MRI might be beneficial when planning and timing surgical treatment for this condition. Also, the degree of tissue damage associated with removal of the intratendinous lesion at the surgery should be respected when planning the postoperative regimen and restarting sports-specific training.

In study III, clear improvements were observed also in the clinical tests (climbing up and down stairs and rising on toes) and in the performance test protocol of the lower limbs. An important factor for these improvements might be the relief of pain after the surgery. Our finding in improvement in the endurance of the calf muscles was in line with that of the previous study of percutaneous longitudinal tenotomy for Achilles tendinopathy (Maffulli et al. 1997), although in that study there still was a slight side-to-side difference between the injured and non-injured side 6 months postoperatively. Longer follow-ups are needed to see whether the above noted improvements in the function of the calf muscle – Achilles complex are long-lasting.

4. Complications after surgical treatment of chronic Achilles tendon overuse injuries

Surgical treatment of the chronic Achilles tendon overuse injuries is considered to provide pain reduction and return to preinjury levels of activity (Kvist and Kvist 1980, Leach et al. 1981, Nelen et al. 1989, Leppilahti et al. 1991, Schepsis et al. 1994, Morberg et al. 1997, Rolf and Movin 1997). However, some studies reported a relatively high complication rate (Nelen et al. 1989, Leppilahti et al. 1991, Leppilahti et al. 1994, Rolf and Movin 1997). Unfortunately the complications have often been reported in a rather general level only.

In study IV, using comprehensive criteria for documenting complications, an 11% overall complication rate was documented. Most of the complications (54%) involved compromised wound healing. For comparison, the complication rate for a surgical treatment of a complete Achilles tendon rupture has been well documented: in a review of literature, Cetti et al. (1993) observed that the overall complication rate among 4083 surgically treated complete Achilles tendon ruptures was 12%. The rate of major surgical complications was 4% and that of minor ones 8%, and half of the minor complications were superficial wound problems.

In the review article of Williams (1986), postoperative complications were reported in 64 cases (14%) of 461 surgically treated Achilles tendon disorders. Problems related to wound healing formed 89% of the complications. In 275 surgically treated Achilles tendon overuse injuries of 228 patients, Leppilahti et al. (1994) reported postoperative complications in 34 cases (12%), but, according to the authors, the complications did not influence the end results. Schepsis et al. (1994) described 4 postoperative complications (one exuberrant scar formation, one skin slough, one heterotopic bone formation, and one extensive fibrotic scar reaction) in 79 surgically treated Achilles tendon overuse injuries of 66 patients. In 58 surgically treated patients with achillodynia, Rolf and Movin (1997) observed postoperative complications in 8 cases (14 %): two superficial infections, two deep infections, two deep vein thrombosis, one total rupture and one hypertrophic scar. Nelen et al. (1989), in turn, described nine

postoperative complications (six skin edge necrosis with prolonged wound healing, two superficial wound infection and one thrombophlepitis) in 91 patients with 143 surgically treated Achilles tendon overuse injuries.

In the study of Kvist and Kvist (1980), only two minor complications (superficial wound infection) were reported among 201 cases of surgically treated Achilles tendon peritendinitis. Leach et al. (1981) reported one complication (a neuroma of a small branch of the sural nerve which needed surgical removal) among 15 patients with 20 surgically treated Achilles tendon overuse injuries. Morberg et al (1997) stated that in their series of 64 chronic partial ruptures of the Achilles tendon, there were no intra-operative or postoperative complications. However, they also reported that one patient was reoperated on because of a hypertrophic and painful scar.

In study IV, problems related to wound healing (skin necrosis and superficial wound infection) were the most common complications (54 % of all complications) after surgical treatment of the Achilles tendon overuse injury, the entire complication rate of skin problems being 6%. Delayed wound healing seems to appear more frequently in patients operated on for a partial Achilles tendon rupture. One cause for the increased risk of skin problems after operative treatment of partial Achilles tendon rupture could be extensive postoperative thickening of the Achilles tendon followed by abnormal skin stretching and impaired cutaneous circulation. Also, the more extensive surgery done and subsequent tissue tugging may increase the risk of these problems. A similar, relatively high, rate of skin problems has also been shown in patients operated on for complete Achilles tendon rupture. Similarly, in study III, the postoperative complications were more frequent in patients operated on for Achilles tendinopathy with peritendinous adhesions and intratendinous lesion (group B) (27%) than in patients operated on for Achilles tendinopathy with peritendinous adhesions only (group A) (6%).

Numerous factors related to patient and surgery can be associated to the prolonged wound healing and the risk of skin necrosis. In elderly patients, the wound healing capacity may be altered and a lack of subcutaneous fat tissue may decrease the vascularity of the skin in the region of the Achilles tendon. Repetitive corticosteroid injections or injections given just prior to surgery (less than 1 month) may decrease wound healing capacity. After surgery, delayed wound healing, perhaps as a result of

insufficient hemostasis, can be associated with the use of local anaesthesia, especially when combined with adrenalin, and also with the use of bloodless field tourniquet. Skin problems may also arise because of excessive mobilization of the skin in the surgical procedure, use of too thick suture material or too loose or tight postoperative bandage, and because of postoperative cast/plaster irritation. Since postoperative skin necrosis forms the great majority of all major complications in Achilles tendon surgery, all the above noted issues should be seriously considered to minimize this complication.

Adequate hemostasis is also essential to avoid the formation of an excessive hematoma, a complication, which increases the risk of deep infection and may require reoperation. Consequently, the use of drainage could be recommended hemostasis is inadequate during surgery. In study IV, excessive hematoma formation as a complication of the surgery was observed in five patients, although evacuation of the hematoma was needed in one patient only.

The paratenon functions as a gliding structure around the Achilles tendon. Thus, very careful trimming of adhesions, preserving as many layers of the paratenon as possible, especially the most inner part of the paratenon, the epitenon, could be recommended. This is also supported by our experience on the pathophysiology of the formation of seromas: excessive secretion of the serous fluid can be considered a reaction of the synovial cells of the inner layer of the paratenon to excessive excision of the paratenon during the surgery, usually combined with too early return to high activity level. It is typically not observed until three to four weeks after the surgery. In avoiding seroma formation, as many layers of the Achilles paratenon as possible should probably be left intact when the tendon and paratenon are freed from the adhesions. In the study IV, five cases of seroma formation were noticed after the Achilles tendon surgery. Three patients responded to early aspirations and corticosteroid injections, whereas reoperation (removing of postoperatively formed bursal-like tissue) was needed in two cases.

The causes of fibrotic reaction and scar formation as a complication of surgery of an Achilles tendon overuse injury are largely unknown. One possible reason could be an excessive inflammatory reaction around the tendon at the time of surgery. Fibrotic reaction and scar formation might be avoided by only performing surgery after the acute inflammatory phase of the Achilles tendon overuse injury is clearly over. On the other

hand, there may be recurrence of acute inflammation as a reaction to continuous mechanical stress in the chronic phase of the overuse injury, too. We observed fibrous reaction in 5 of 432 surgically treated patients. Reoperation was needed in two cases.

The sural nerve should be freed by blunt dissection and then retracted aside during the surgical treatment of Achilles tendon overuse injury. Sural nerve irritation with pain, numbness and insensitivity (or occasionally with hyperesthesia) may be caused by mechanical injury during the operation (i.e. too vigorous retraction, compression, or direct damage of the nerve or the nerve branches during surgery), or postoperatively, by cast or plaster irritation, or irritation due to extensive scar formation around the Achilles tendon and paratenon. In study IV, the postoperative sural nerve irritation was observed in 4 patients all of whom had been operated on for chronic Achilles peritendinitis.

Early mobilization and rapid return to full activity without significant residual pain is the main goal in surgical treatment of Achilles tendon overuse injuries, particularly in athletes. Postoperative complications may, however, seriously retard recovery and impair final outcome. Therefore, every decision to treat surgically a patient with an Achilles tendon overuse injury needs special experience and consideration. It is also imperative that the surgeon continuously reminds himself/herself about the possibility of postoperative complications and uses proper techniques to minimize this morbidity.

SUMMARY AND CONCLUSIONS

1. Study I assessed the value of US in the diagnosis of various Achilles tendon disorders by comparing pre-operative US with surgical findings in 79 patients with an Achilles tendon injury. US was accurate for diagnosing complete Achilles tendon ruptures and retrocalcaneal bursitis. Positive finding indicating Achilles peritendinitis or tendinitis are reliable, whereas a negative US finding is rather unreliable. US also seemed to be inadequate for differentiating a partial tendon rupture from a focal tendon degeneration, although, the occurrence and location of such a lesion could be adequately determined by US. Overall, US examination, using modern equipment with high-resolution probes, is generally accurate for locating Achilles tendon abnormality, estimating its severity, and determining most of the conditions in which the surgical treatment comes into question.

2. In study II, the long-term [8 ± 2 (SD) years] outcome of patients who were initially treated conservatively for acute-to-subchronic Achilles tendinopathy was examined. The follow-up analysis on 83 of 107 patients included a questionnaire, clinical examination, performance tests, muscle strength measurement, and US examination. Twenty-four of the 83 patients (29%) had to be operated on during the follow-up period. Seventy patients (84%) had full recovery of their activity level and after 8 years, 78 patients (94%) were asymptomatic or had only mild pain in strenuous physical activity. However, a clear side-to-side difference between the involved and the uninvolved sides was found in the performance test, clinical examination, and US examination. Also, in 34 patients (41%), overuse symptoms arose in the initially uninvolved Achilles tendon. On the involved side, delay of up to 6 months between the onset of the symptoms and initiation of conservative treatment did not prejudice long-term results.

   The results showed that the long-term prognosis of patients with acute-to-subchronic Achilles tendinopathy is favorable as determined by subjective and functional assessments. In clinical and ultrasonographic examinations, mild-to-moderate changes were found rather frequently in both the involved and initially

uninvolved Achilles tendons, but the occurrence of these change was not clearly related to patients' symptoms.

3. Study III assessed prospectively the short-term (7 months) results of surgical treatment of chronic Achilles tendinopathy and compared the subjective and functional outcome of patients with Achilles tendinopathy without a local intratendinous lesion with that of similar patients with such a lesion. Forty-two of the initial 50 patients were examined both at study entry (before surgery) and after the 7-month follow-up. The evaluation included an interview, subjective evaluation, clinical tests, and a performance test. At follow-up, 28 of 42 patients (67%) had full recovery of physical activity, and 35 patients (83%) were asymptomatic or had only mild pain with strenuous exercise. In clinical tests, significant improvements were noted in climbing up and down stairs and in the rising-on-toes test. Using the total performance test protocol as criterion, surgical treatment also provided successful results since at follow-up the total test score was excellent or good in 35 patients (83%), compared that preoperatively the total test score was excellent or good in one patient (2%) only. Patients with Achilles tendinopathy without local intratendinous lesion managed better than similar patients with such a lesion when compared by recovery of physical activity after surgery (88% vs. 54%), and by complication rate (6% vs. 27%).

   Overall, the results showed that surgical treatment of chronic Achilles tendinopathy gives good short-term results. A somewhat lower complication rate and trend to better recovery was observed in patients with pure peritendinous adhesions than in those with an additional intratendinous lesion.

4. In study IV, the complications after surgical treatment of Achilles tendon overuse injuries were analyzed in 432 consecutive patients. Clinical examination was performed 2 weeks, and 1, 2, and 5 months after the surgery. If a complication appeared, the patient was followed clinically for at least 1 year. There were 46 (11%) complications in the 432 patients who were treated surgically due to overuse injury of the Achilles tendon: 14 skin edge necrosis, 11 superficial wound infections, 5 seroma

formations, 5 hematomas, 5 fibrotic reactions / scar formations, 4 sural nerve irritations, 1 new partial rupture, and 1 deep vein thrombosis. Of these complications, 16 were classified as major and the remaining 30 as minor. Fourteen patients with a complication had reoperations: 4 patients because of skin edge necrosis, 2 because of superficial wound infection, 2 because of seroma formation, 1 because of hematoma formation, 2 because of fibrotic reaction / scar formation, 2 because of sural nerve irritation, and 1 because of new partial rupture. The remaining 32 cases were treated conservatively.

Overall, about every 10th patient with a surgery for a chronic Achilles tendon overuse injury suffered a postoperative complication that clearly delayed recovery. Finally, however, the majority of the complications healed and the patients returned to their preinjury level of activity. To reduce this morbidity, it is essential that the surgeon continuously reminds himself / herself about the possibility of postoperative complications and use proper surgical techniques to attempt to minimize their occurrence.

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