Patient characteristics and their impact on recovery after acute Achilles tendon rupture

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To Marcus

Abstract

The incidence of acute Achilles tendon rupture has increased in the Swedish population. The median age at injury onset is roughly 50 years, with a male-to-female ratio of approximately 4:1. Acute Achilles tendon rupture is managed surgically or non-surgically. Several randomised controlled trials (RCTs) have been conducted to compare patients who received one of the two treatment interventions. The results demonstrate no significant differences in self-reported or functional outcomes between these treatment modalities. Complications occur following both treatment regimens. Wound-related complications, such as infections or nerve damage, may follow surgical treatment, whereas re-ruptures are more common after non-surgical treatment. Notwithstanding the robust results of these RCTs, a unified approach to personalise patient treatment remains elusive. To support the development of individualised treatment plans, five studies have been performed to address this issue.

Studies I, II and III are based on patient-reported outcome measurements (PROMs). Patients who have sustained an acute Achilles tendon rupture were invited to complete the Achilles tendon Total Rupture Score (ATRS) and additional questions related to recovery, activity level and satisfaction after treatment. Study I investigated whether there were differences between men and women in self-reported outcomes. A total of 564 patients were included in the study, of which 129 (23%) were women. This study revealed that women self-reported significantly worse outcomes than men 1 to 6 years after injury.

Study II evaluated the extent to which patients refrained from physical activity due to fear of re-injury to their Achilles tendon. In this study, 550 patients were included, of which 308 (56%) reported fear of re-injury. These patients also reported poorer self-reported outcomes compared to those who did not report a fear of re-injury.

Study III aimed to establish the Patient Acceptable Symptom State (PASS) for the ATRS. The PASS is defined as patients' self-reported perception of their well-being. The study comprised 316 participants; their responses to the anchor question and ATRS yielded a PASS value of 75 points for the Swedish ATRS. Calculations were conducted employing the receiver operating characteristic (ROC) curve.

Study IV examined how the Achilles Tendon Resting Angle (ATRA)

correlated with ultrasound (US) measurements at 6 and 12 months after an acute Achilles tendon rupture. Moreover, the correlations between the ATRA and other clinical measurements were evaluated. The study included 60 patients. The results demonstrated a significant correlation between relative ATRA and tendon elongation and between relative ATRA and heel-rise height.

Study V investigated whether the distance between the tendon ends after an acute Achilles tendon rupture - as a criterion for treatment selection - could influence functional and self-reported outcomes. In the patient group where the tendon gap (measured by US) was < 5 mm, non-surgical treatment was employed. Conversely, patients were treated surgically if the tendon gap was ≥ 5 mm. A total of 128 patients were included in the study, with 87 (68%) treated surgically and 41 (32%) treated non-surgically. One patient in each treatment modality suffered from a re-rupture. The functional and self-reported outcomes showed no statistically significant differences between the two treatment groups.

In conclusion, this thesis shows that clinicians should be aware of the inferior outcome in female patients and patients who suffer from fear of re-injury following an acute Achilles tendon rupture. Moreover, establishing the PASS for the Swedish ATRS may facilitate improved clinical interpretation of ATRS scores. The correlation between ATRA and tendon elongation, evaluated with US, supports using ATRA to detect tendon elongation in the clinical setting. Furthermore, this thesis has contributed to our understanding of the tendon gap and its clinical relevance in selecting appropriate treatment following acute Achilles tendon rupture.

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Keywords: Acute Achilles tendon rupture, Sex-differences, Fear of re-injury, Recovery, ATRS, PASS, ATRA, Ultrasound, Treatment.

Sammanfattning på svenska

Förekomsten av akut hälseneruptur ökar i Sverige. Medianåldern för att drabbas av skadan är cirka 50 år och skadan är fyra gånger vanligare bland män än hos kvinnor. Behandlingen för akuta hälserupturer delas in i kirurgisk eller icke-kirurgisk. Flertal randomiserade studier har gjorts med syfte att utvärdera patienters återhämtning efter respektive behandling. Resultaten av dessa är att patienterna uppvisar likvärdiga resultat oavsett behandling. Komplikationer förekommer i båda behandlingsgrupperna. Sårkomplikationer, såsom infektion och nervskada kan efterfölja en kirurgisk behandling, medan förekomst av en ny ruptur i hälsenan är en befarad komplikation och vanligare efter icke-kirurgisk behandling. Trots att många välgjorda studier har genomförts så finns det fortfarande begränsade kliniska verktyg för att erbjuda en optimal behandling för den enskilda patienten. Med målet att komma närmare en behandlingsplan som är individuellt anpassad för varje patient så har nedanstående studier genomförts för att undersöka vilka patientkaraktäristika, som kan påverka återhämtningen.

Studie I, II och III är enkätstudier där patienter som drabbats av en akut hälseneruptur har svarat på frågeformuläret, Achilles tendon Total Rupture Score (ATRS) samt frågor relaterade till återhämtning, aktivitetsnivå och nöjdhet. I Studie I undersöktes om det förelåg någon skillnad i självrapporterad återhämtning mellan kvinnor och män. Femhundra-sextiofyra patienter deltog i studien, varav 129 kvinnor. Resultatet av denna studie var att kvinnor rapporterade en signifikant sämre återhämtning jämfört med män. Syftet med Studie II var att utforska i hur stor utsträckning patienter rapporterar att de avstår från fysisk aktivitet på grund av rädsla för att skada sin hälsena igen. Femhundra-femtio patienter inkluderades i denna studie, varav 308 patienter (56%) bejakade rädsla för ny hälseneskada, denna patientgrupp rapporterade även en signifikant sämre återhämtning jämfört med de som ej uppgav rädsla för ny hälseneskada.

Syftet med Studie III var att fastställa så kallat ”Patient Acceptable Symptom State” (PASS) för ATRS. PASS är ett mått för vilket patienter upplever sitt hälsotillstånd som acceptabelt.

Trehundra-sexton patienter inkluderades i studien genom svar på en så kallad ”ankar-fråga” samt ATRS. PASS för den svenska ATRS beräknades till 75 poäng. För att beräkna PASS i denna studie användes en Receiver Operating Characteristic (ROC) kurva.

I Studie IV undersöktes huruvida det kliniska instrumentet Achilles Tendon Resting Angle (ATRA) korrelerar med andra funktionella utfallsmått 6 och 12 månader efter hälseneruptur. Sextio patienter med en akut hälseneruptur inkluderades i studien. Resultatet av denna studie visade att det förelåg en signifikant korrelation mellan relativ ATRA och hälseneförlängning, mätt med ultraljudsundersökning och mellan relativ ATRA och tåhävningshöjd.

Studie V syftade till att undersöka om avståndet mellan senändarna vid en akut hälseneruptur - för selektion till kirurgisk respektive icke-kirurgisk behandling - påverkade funktionellt och självrapporterat utfall. Om avståndet mellan senändarna var < 5 mm erhöll patienterna icke-kirurgisk behandling och om avståndet var ≥ 5 mm opererades patienterna. Etthundra-tjugoåtta patienter inkluderades, varav 41 patienter erhöll icke-kirurgisk behandling och 87 patienter opererades. En patient i varje grupp drabbades av en ny hälseneruptur. Etthundra-tjugosex patienter utvärderades 6 och 12 månader efter skadan. Resultatet av de funktionella och självrapporterade utvärderingarna var att ingen signifikant skillnad förelåg mellan de båda behandlingsgrupperna.

Sammanfattningsvis så visar denna avhandling variabler som behöver beaktas vid en akut hälseneruptur, såsom kön och rädsla för ny skada på hälsenan, med anledning av att dessa påverkar den självskattade återhämtningen. Vidare så har ett PASS värde etablerats för att underlätta för den kliniska tolkningen av ATRS. Vetskapen om att ATRA korrelerar med senförlängning gör att det tillsammans med andra kliniska mått kan användas för att upptäcka senförlängning. Avhandlingen har även bidragit till ökad kunskap avseende betydelsen av avståndet mellan senändarna vid val av behandling för en akut hälseneruptur.

Nyckelord: Akut hälseneruptur, Könsskillnader, Rädsla för ny skada, Återhämtning, ATRS, PASS, ATRA, Ultraljud, Behandling

List of papers

This thesis is based on the following studies, referred to in the text by their Roman numerals.

I **Larsson E, Brorsson A, Carling M, Johansson C, Carmont MR, Nilsson Helander K**

Sex differences in patients' recovery following an acute Achilles tendon rupture - a large cohort study

BMC Musculoskelet Disord. 2022;23(1).
doi: 10.1186/s12891-022-05875-9

II **Larsson E, LeGreves A, Brorsson A, Eliasson P, Johansson C, Carmont MR, Nilsson Helander K**

Fear of reinjury after acute Achilles tendon rupture is related to poorer recovery and lower physical activity postinjury

J Exp Orthop. 2024;11(7).
doi: https://doi.org/10.1002/jeo2.70077

III **Larsson E, Brandt Knutsson S, Brorsson A, Johansson C, Nilsson Helander K**

Establishment of the Patient Acceptable Symptom State (PASS) for the Achilles Tendon Total Rupture Score in a Swedish Population

Orthop J Sports Med. 2024;12(7).
doi: 10.1177/23259671241253280

IV **Larsson E, Nilsson Helander K, Falkheden Henning L, Heiskanen M, Carmont MR, Grävare Silbernagel K, Brorsson A**

Achilles tendon resting angle is able to detect deficits after an Achilles tendon rupture, but it is not a surrogate for direct measurements of tendon elongation, function or symptoms

Knee Surg Sports Traumatol Arthrosc. 2022;30(12):4250-4257.
doi: 10.1007/s00167-022-07142-9

V **Larsson E, Brorsson A, Eliasson P, Szaro P, and Nilsson Helander K**

Using tendon gap as a decision-making tool provides comparable function regardless of surgical or non-surgical treatment for an acute Achilles tendon rupture

Manuscript

Additional papers by the author on the same topic

I Larsson E, Brorsson A, Carmont MR, Fahlström M, Zeisig E, Nilsson Helander K

A narrative review of Achilles tendon ruptures in racket sports

IJRSS. 2022;4(1):9-15.
doi: https://doi.org/10.30827/Digibug.76979

II Larsson E, Nilsson N, Walstern J, Brorsson A, Nilsson Helander K

Females present larger deficit in heel-rise height at 3 months following an Achilles tendon rupture compared with males

Knee Surg Sports Traumatol Arthrosc. 2024;32(10):2581–2588.
doi: https://doi.org/10.1002/ksa.12208

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Abbreviations

ATRA	Achilles Tendon Resting Angle
ATRS	Achilles tendon Total Rupture Score
AUC	Area Under the Curve
BMI	Body Mass Index
CMJ	Counter-Movement Jump
Drop CMJ	Drop Counter-Movement Jump
DVT	Deep Venous Thrombosis
GRS	Global Rating Scale
ICC	Intraclass Correlation Coefficient
ICD	Internal Classification of Diseases
LSI	Limb Symmetry Index
MCID	Minimal Clinically Important Difference
MCII	Minimal Clinically Important Improvement
PAS	Physical Activity Scale
PASS	Patient Acceptable Symptom State
PROMs	Patient-Reported Outcome Measures
ROC	Receiver Operating Characteristic
RCT	Randomised Control Trial
SU/M	Sahlgrenska University Hospital Mölndal
SD	Standard Deviation
IQR	Interquartile Range

Definitions in short

Absolute ATRA	Refers to the resting angle of the injured side
Relative ATRA	Refers to the differentiation of the resting angle of the non-injured side compared with the injured side
Effect size	The measure of the magnitude of the experimental effect (a higher effect size represents a higher relationship between two variables)
Limb Symmetry Index (LSI)	An index of side differences between the injured and uninjured limb expressed in per cent (injured limb/uninjured limb*100)
Reliability	The ability to measure the same variable in the same way on two separate occasions
Sensitivity	Refers to the ability of a test to correctly identify patients who truly have the outcome of interest (how well the test avoids false negatives)
Specificity	Represents the efficacy of a given test in identifying the absence of the condition being tested (how well the test avoids false positives)
Validity	The degree to which an instrument is capable of accurately measuring the intended variable

ELIN LARSSON

01

Patient characteristics and their impact on recovery after acute Achilles tendon rupture

Introduction

Chapter 1

During their lunch break, a middle-aged man plays a padel match with his colleagues. He is about to take a step back when he notices the slow pace of the ball coming towards him. To reach the ball, he pushes off quickly. He hears a snap, and the sensation of a punch to his lower leg makes him believe he has hit the wall with his heel. Regrettably, this is not the situation; his strongest tendon has ruptured.

In the past few decades, several randomised controlled trials (RCTs) and meta-analyses have been undertaken to explore which treatment regimen is optimal for an acute Achilles tendon rupture. Over the years, these studies have redefined the gold standard of treatment. Recent research has not demonstrated the superiority of one treatment approach over another regarding functional and patient-reported outcomes. However, surgical intervention is known to be related to an increased risk of wound-related complications, including infections, adhesions and nerve damage. On the other hand, non-surgical treatment has been linked to a higher frequency of re-ruptures.

It has been proposed that not only does the choice between using or refraining from the knife influence the outcome of an acute Achilles tendon rupture, but also factors, such as age, body mass index (BMI) and sex, are highly relevant. Moreover, psychological factors (e.g., fear of re-injury during the recovery phase) also appear to impact the outcome. However, these factors have received comparatively less research attention than treatment selection.

Given the differential functional outcomes and risks associated with each treatment, clinicians must exercise individualised judgment in selecting the optimal approach. However, achieving this end is challenging.

How should we treat the man who played padel? A man who considers himself at his peak and in good shape might want to start running again at some point in his life. Should we treat him in the same way as a 20-year-old female elite athlete? Should this not be the case, what is the rationale for an individualised assessment?

As clinicians, we need better tools to make a personalised treatment plan. Data suggest that, in addition to intrinsic factors, the gap between the tendon ends might be a prognostic indicator for the re-rupture rate and functional outcome. Might this factor contribute to the development of personalised treatments for acute Achilles tendon ruptures?

The Achilles tendon

The name of what we today call the Achilles tendon originates from the Iliad by the Greek poet Homer in the 9th century BC. According to the myth, the legendary warrior Achilles' invulnerability stemmed from his mother submerging him in the river Styx as an infant. Because his mother had to hold him while he was in the water (so he would not drown), one part of him remained vulnerable, namely his heel. Achilles' demise during the Trojan War resulted from a poisoned arrow striking his heel [33].

During the late 1600s, a professor of anatomy, Philip Verheyen, first used the term *tendo Achillis*. This was due to the confusion in the terminology of the Achilles heel and the tendo Achilles. *Tendo Achillis* was used instead of the term tendo Magnus, as Hippocrates earlier named it [64].

ANATOMY OF THE ACHILLES TENDON

The gastrocnemius muscle, with its medial and lateral heads, and the soleus muscle are often referred to as the triceps surae. The Achilles tendon serves as the attachment of the triceps surae to the calcaneal bone [36]. Gastrocnemius forms the proximal superficial part, which originates from the lateral and medial femur condyles, with the medial portion being longer than the lateral portion. The soleus is placed more distally and is deeply located; it has a wide origin from the posterior part of the proximal fibula and the tibia condyle [90] (Fig 1). The soleus muscle is flatter than the gastrocnemius, and together, they form the Achilles tendon. The proximal part of the tendon is flattened, while the distal part is rounded approximately 4 cm from the insertion [95]. The length of the tendon is between 11 and 26 cm, with an average length of 15 cm [7,36]. The tendon is widest in its proximal part (mean 6.8 cm), becoming progressively thinner in its midportion (mean 1.8 cm) and rounded and thicker towards its insertion [36]. The fibres of the Achilles tendon from the muscles to the insertion to the calcaneus are not strictly vertical but instead rotate up to 90° (Fig 1).

Tendons are responsible for transmitting force from muscles to bones, thereby enabling movement at a joint. The tendon fibres are composed primarily of collagen (65-80%), mostly type I and III, and contain elastin [58,97]. The tendon structure comprises the smallest units of collagen fibrils organised into collagen fibres. These fibres form primary, secondary and tertiary bundles, constituting the tendon structure [58,97].

The Achilles tendon diverges from the typical structure of other tendons, lacking a proper tendon sheath. In contrast, the tendon is encased in a

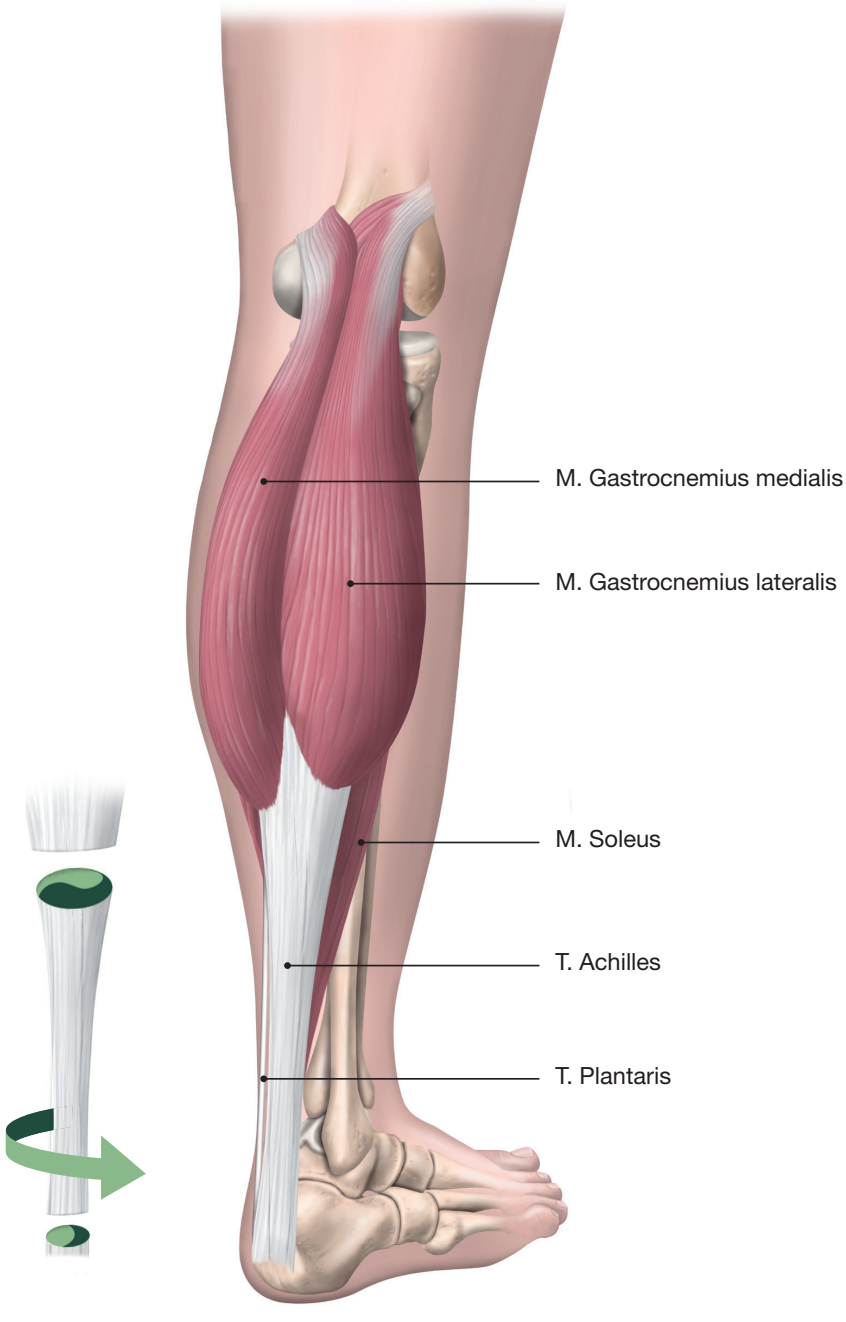

FIGURE 1. Illustration of the lower leg with the triceps surae, m plantaris and the Achilles tendon with its insertion to the calcaneus bone. The figure to the left illustrates how the Achilles tendon rotates from the proximal part to the distal insertion into the calcaneus.

paratenon, which is a layer of connective tissue containing blood vessels [116]. The blood supply to the Achilles tendon is derived primarily from two arteries: the posterior tibial and the peroneal arteries [26,133]. Blood from the arteries reaches the tendon through the paratenon, the musculotendinous junction and the osteotendinous insertion [2]. The middle third of the tendon, 2-6 cm from the insertion, exhibits a comparatively reduced efficiency of blood supply compared to the proximal and distal portions. Blood supply tends to decrease with age [26]. It is hypothesised that the limited vascularisation in the middle third portion of the tendon contributes to the high frequency of ruptures in this region. A study examining tendon microcirculation revealed a correlation between limited microcirculation and impaired healing and prolonged rehabilitation [108].

The sural nerve is located at the lateral margin of the Achilles tendon's midsection, with several anatomical variations documented in the literature [7]. Research indicates that the sural nerve, which is responsible for sensory perception in the lateral part of the foot, may become susceptible to iatrogenic damage during surgery on the Achilles tendon due to its anatomical location [98].

The plantaris tendon originates from the lateral condyle of the femur and its tendon passes medially in the gastrocnemius and soleus and inserts medially into the calcaneus or the Achilles tendon. The tendon assists the gastrocnemius in plantar flexion. The plantaris tendon is absent in approximately 6-8% of the population [128].

BIOMECHANICS

Tendon stress is calculated by dividing the applied force by the tendon cross-sectional area. This indicates that a larger cross-sectional area is capable of withstanding a greater force [81]. Tendon strain, defined as the percentage of tendon elongation, has been observed to occur within a range of 0-3% during walking [81]. A strain between 4 and 8% results in microscopic damage, whereas strains > 8% lead to a rupture of the tendon [96]. This relationship is illustrated in Fig 2 [82]. During cycling, the tendon experiences a force approximating body weight; however, this increases to 2-5 times body weight during walking and 9-12 times body weight during running [65].

TENDON HEALING

The healing of the Achilles tendon following an injury is typically divided into three stages as a response to the tendon injury: inflammation, proliferation and remodelling [29,118]. Within 24 hours after injury, the **inflammatory phase** starts and lasts about a week. This phase includes cell activation

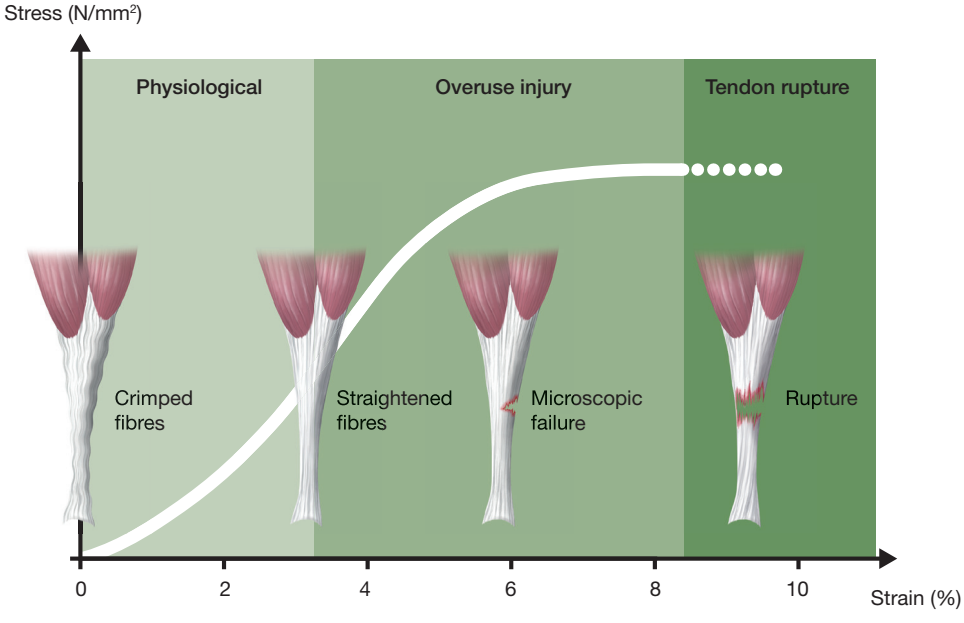

FIGURE 2. The illustration represents the tendon stress-strain curve, which describes the correlation between tendon stress and strain.

and migration from surrounding tissue towards the injury. This process is characterised by the formation of a fibrin clot to stabilise the injury site. A migration of neutrophils and macrophages is initiated. During this stage, proinflammatory cytokines, such as interleukins, tumour necrosing factors and vascular endothelial growth factors, are released [142]. Starting within one week, the **proliferation phase** initiates fibroblast and macrophage proliferation, thus beginning collagen synthesis. In contrast with their phagocytic role, macrophages have a significant function in growth factor release during this phase. During this phase, the matrix, primarily composed of collagen type III, is synthesised by tenocytes [29,142]. Finally, the **remodelling phase** takes place approximately four weeks post-injury. The collagen synthesis is now dominated by collagen type I. This phase leads to the reorganisation of the collagen network. The remodelling phase is divided into a consolidation stage and a maturation stage; during the consolidation stage, the tissue becomes more fibrous due to the higher proportion of collagen type I [52,142]. The maturation stage involves the gradual transformation of fibrous tissue into a scar-like tendon [118]. The remodelling phase continues up to at least 12 months [75].

Acute Achilles tendon rupture

The prevalent profile of an acute Achilles tendon rupture patient is a male aged between 40 and 50 years. Recreational sports activities are the most frequent cause of injuries, with racket sports exhibiting the highest incidence [48,71,74,111].

INCIDENCE

Men experience acute Achilles tendon rupture at a rate approximately four times higher than women [131]. Over the past decades, several epidemiological studies have reported a significantly increasing incidence of acute Achilles tendon ruptures [43,50,69,73,76,119,129,131]. During a 20-year period, between 1994 and 2013, the incidence of acute Achilles tendon ruptures increased from 27.0 to 31.2 ruptures/100,000 inhabitants/year in Denmark [43]. Numbers reported based on Finish data between 1997 and 2019 show an increase from 17.3 to 32.3 per 100,000 person-years [73]. The latest epidemiological study by Svedman et al. [131] investigated the national incidence of acute Achilles tendon ruptures in Sweden between 2002 and 2021. The study showed that the incidence increased by 45% from 28.8 to 41.7 per 100,000 person-years, with the greatest increment in the past 5 years (34.4 in 2017 to 41.7 in 2021). The increment for men ranged from 46.1 (2002) to 63.4 (2021) per 100,000 person-years, and the corresponding increment for women was from 12.1 to 19.1 per 100,000 person-years [131].

Studies indicate a bimodal age distribution of acute Achilles tendon rupture, with peaks in middle age and those over 60 years [136]. In the older age group with the second peak, the rupture is usually preceded by pain in the Achilles tendon and a lower amount of energy is required for the tendon to rupture in this age group [60,136].

However, not only is the incidence of acute Achilles tendon rupture increasing, but the patient's median age at the time of the injury is also increasing. Svedman et al. [131] reported an increase in median age at the time of the injury between 2001 and 2012 from 44 to 50 years. This trend has also been documented in Denmark and Finland [43,73].

The reason for the increased incidence and median age is unknown. However, theories suggest that participation in recreational sports increases with increasing age to a larger extent today compared to previous periods. Moreover, padel sport has been a subject of growing interest in Sweden. This sport has been hypothesised as a potential contributing factor to the rising incidence. Data from the Swedish Padel Federation indicate a substantial rise in the number of

unique padel court users between 2017 and 2021, increasing from 33,990 to 540,000 [1].

INJURY MECHANISM

Acute Achilles tendon ruptures are primarily associated with traumatic injuries that occur during sports or recreational activities [54]. These injuries result from a single impact with a high load, lacking any prior symptomatic warning [132]. The biomechanical mechanism underlying acute Achilles tendon rupture involves a concentric contraction of the gastrocnemius-soleus complex with a straightened knee, as commonly seen in the propulsive phase of racket sports. Moreover, an additional mechanism is the eccentric contraction of the gastrocnemius and soleus with ankle dorsiflexion (e.g., landing from a jump). Another potential mechanism is suddenly forced ankle dorsiflexion (e.g., stepping into a hole) [9] (Fig 3). An additional, less-documented injury mechanism involves ankle sprains [15,37]. Consideration should be given to Achilles tendon rupture in the differential diagnosis of acute lateral ankle sprains [37].

FIGURE 3. Three injury mechanisms leading to an acute Achilles tendon rupture.

ADDITIONAL PREDISPOSING FACTORS

Several factors have been identified as predisposing to acute Achilles tendon rupture. Corticosteroid injections near tendons, occasionally employed in tendinopathy treatment, along with quinolone antibiotics and cholesterol-lowering statins, have been recognised as potential risk factors for acute Achilles tendon rupture [23,32,55,77,140,143].

DIAGNOSIS

An acute Achilles tendon rupture diagnosis is typically established through clinical examinations and trauma reports [78]. The patient often describes the injury as a loud "pop" accompanied by acute lower leg pain, sometimes with the sensation of being hit on the heel [59]. However, the presence of weakness and distinct trauma is not always evident. Patients in older age groups may not provide the classic trauma report due to the lower amount of energy required for rupture. The classic tendon gap may be absent due to surrounding swelling [80]. This must be considered when examining the tendon to avoid missing a rupture. More than 20% of acute Achilles tendon ruptures are misdiagnosed or overlooked, resulting in inadequate initial treatment and subsequent chronic rupture [79,80].

The conventional examination for the diagnosis of an acute Achilles tendon rupture comprises palpation of the tendon, the calf squeeze test (Fig 4), (also known as Thompson's test) and the resting position test (Matles' test), (Fig 5). The Thompson's test is conducted with the patient in the prone position, with both feet positioned off the examination bench. The test involves applying a squeeze to the patient's calf muscles. A normal muscle response is plantar flexion; the absence of this response indicates the likely presence of tendon injury [135]. The Matles' test is also conducted with the patient in the prone position and involves observing the position of the feet with the knee in 90° flexion. An increased degree of dorsiflexion of the injured ankle indicates a ruptured tendon [83].

TREATMENT

Management of acute Achilles tendon rupture may involve either surgical or non-surgical approaches. Surgical treatment is either open, percutaneous or minimally invasive. An end-to-end adaptation characterises the open method, and various suture techniques have been described. A medial incision to avoid damage to the sural nerve is made over the rupture site to perform an end-to-end suture. Several suture techniques have been described, such as Kessler [62], Krackow [67], and Bunnell [21]. The percutaneous method aims to

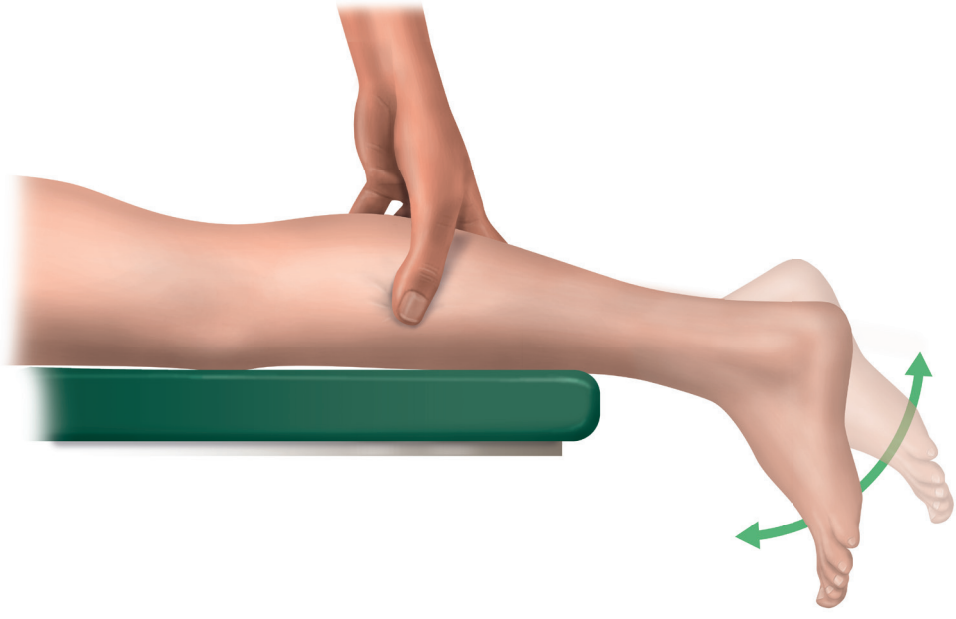

FIGURE 4. Thompson's test. The picture illustrates a negative test with a normal response, plantar flexion, of the foot during a squeeze to the calf.

prevent exposure of the ruptured site while preserving paratenon integrity during rupture repair [4]. Moreover, the minimally invasive treatment approach entails creating a small incision at the rupture site and making stab incisions proximal and distal to it to enable an adaptation [106]. After the surgical procedure, the patient receives a cast in the equinus position for two to three weeks, followed by a walker boot with wedges for six weeks. However, this postoperative regimen has several variations.

Non-surgical treatment of an acute Achilles tendon rupture involves using a cast and walker boot in the same regimen as post-operatively. Several factors influence the use of cast and walker boots, including immobilisation duration, boot type and wedge count. It is crucial during non-surgical treatment to ensure the correct dosage of load, adequate weight-bearing and structured physiotherapy treatment in parallel to active follow-ups to minimise complications, including re-rupture and extensive tendon elongation [38,39,127,139,151].

Surgical versus Non-surgical treatment

The first publication of a series of Achilles tendon ruptures was published in 1929 by Quenu et al., [109] who conducted a comparative analysis of surgical and non-surgical treatment modalities. The findings of that study indicated that no single treatment

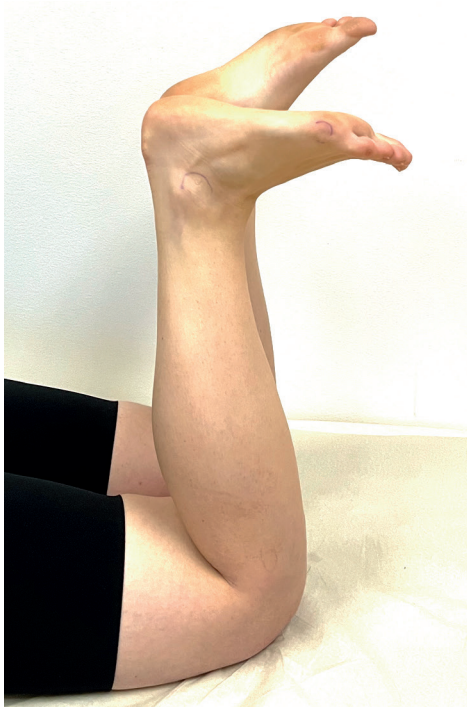

FIGURE 5. Matles' test. The picture illustrates that the left side has an increased dorsiflexion compared to the other side, equal to an Achilles tendon rupture.

protocol produced superior results. However, the authors expressed a preference for surgical treatment. Arner and Lindholm's 1950s findings [9] corroborated those of Quenu et al. [109], thus reinforcing surgery's standing as the preferred treatment. In 1993, Cetti et al. [27] conducted a prospective study to compare the outcome of surgical and non-surgical treatments. The authors found that surgical treatment reduced re-rupture frequency compared to non-surgical treatment. Moreover, the results demonstrated that the incidence of wound infection was higher in the surgical treatment group (3.6%). Regarding the return to a previous sport, a significantly higher rate was observed in patients undergoing surgical treatment ($p = 0.005$). In summary, these findings confirm the continued efficacy of gold standard surgical treatment.

Sahlgrenska University Hospital in Gothenburg, Sweden has a history of presenting several RCTs comparing surgical and non-surgical treatment [89,91,94,99].

This work was initiated by Nistor et al. [94] in 1981. The findings indicated no significant differences in major complications between the two treatment groups. Nevertheless, the non-surgical cohort exhibited an 8.3% re-rupture rate, in contrast to the 4.4% rate observed in the surgical cohort. Additionally, a higher incidence of wound complications (4.4%) was reported in the surgical group compared to none in the non-surgical group. Consequently, non-surgical treatment offered benefits, including reduced morbidity and a shorter hospital stay. The conclusion reached was that non-surgical treatment yielded more favourable outcomes than surgical treatment. This observation led to a local paradigm shift. In 2001, Möller et al. [89] reported that patients treated with a conservative regimen (8 weeks in a cast) suffered a higher risk of re-rupture (20.9%) than those who had undergone

surgical treatment (1.7%). Furthermore, the postoperative wound infection rate was 0.9%, a figure lower than that reported by Nistor et al. [94]. This resulted in a greater tendency among clinicians to recommend surgical treatment.

Nilsson-Helander et al. [91] (2010) and Olsson et al. [99] (2013) subsequently reported insignificant differences in functional and patient-reported outcomes between surgical and non-surgical groups. However, Nilsson-Helander et al. [91] reported a re-rupture rate of 12% in the non-surgically treated patients compared to 4% in the surgically treated group. Moreover, the surgically treated cohort exhibited a 4.1% complication rate due to wound infection. The corresponding results of Olsson et al. [99] for the re-rupture rate were 10% in the non-surgical group and 0% in the surgical group. Among patients undergoing surgical intervention, 12.2% experienced superficial wound infections.

The RCTs from 2010 and 2013 have established the non-surgical approach as the new standard of treatment during the past decade. However, substantial regional inconsistencies are present across Sweden. Svedman et al. [131] investigated the national treatment rate in Sweden for acute Achilles tendon rupture among surgically treated patients between 2002 and 2021. The authors observed a 47% decrease in surgical procedures (942 in 2002, compared to 495 in 2021). A similar trend has been observed in Finland [73]. Between 2017 and 2021, the proportion of surgically treated patients was approximately 14-15% in Sweden [131].

The most recent literature on treatment choice is a multicentre study performed in Norway (2022) by Myhrvold et al. [85]. This three-armed RCT included 554 patients with an acute Achilles tendon rupture, allocated to open repair, minimally invasive repair or non-surgical treatment. The results of this study demonstrated no significant differences in the primary outcome (patient-reported outcome) nor in functional outcome between the groups during a 12 month follow-up after injury. However, the re-rupture rate after non-surgical treatment was 6.2% compared to 0.6% in the open repair and 0.6% in the minimally invasive groups [85].

COMPLICATIONS

Complications associated with an acute Achilles tendon rupture can emerge due to the injury or manifest during the treatment. The most serious potential complications are re-rupture, deep venous thrombosis (DVT), sural nerve injury, infections, tendon lengthening and reduced calf muscle function.

Re-rupture

A re-rupture has traditionally been considered as the standard outcome in

terms of treatment failure. Re-ruptures occur in patients treated surgically and non-surgically; however, they appear to a greater extent in patients treated non-surgically. The reported frequency of re-rupture shows considerable variability, particularly among non-surgical patients (6.2-20.9%). For surgical patients, the frequency of re-rupture is 0-4% [70,85,89,91,99]. The highest incidence of 20.9% in non-surgically treated patients is reported in an RCT by Möller et al. [89] (2001). Patients receiving what was then termed "conservative" treatment were provided with a below-knee cast in the equinus position for four weeks. Following this, the cast was changed to a cast in a neutral position for four weeks, and weight-bearing was allowed after four weeks from the index injury. The lower limit of the re-rupture rate in patients managed non-surgically (6.2%) is derived from the findings of Myhrvold et al [85]. The non-surgical regimen in this study was two weeks of below-knee cast in equinus position followed by a walker boot for six weeks (weight-bearing as tolerated as soon as the cast was replaced). Studies have demonstrated that early weight-bearing and rehabilitation protocols allowing an early range of motion reduce re-rupture rates [63,127,139,151].

Deep venous thrombosis

Reported DVT incidence shows considerable variability, ranging from 0.4% to 48.5% [12,85,89,91,99,105]. It should be noted that the aforementioned article of Barfod et al., [12] which reported an incidence rate of 48.5%, employed a screening process in patients who suffered an acute Achilles tendon rupture. The screening involved the use of a colour Doppler ultrasound (US) to identify the presence of DVT at two and eight weeks following injury. Thrombosis prophylaxis was omitted for all study participants given the absence of any associated risk factors. A consensus on thrombosis prophylaxis has yet to be established [93]. Furthermore, intermittent pneumatic compression has been proposed as an option to prevent DVT during lower leg immobilisation [35].

Nerve injury

Surgical treatment of an acute Achilles tendon rupture poses a challenge due to the anatomic position of the sural nerve. A sural nerve injury results in sensory loss at the lateral aspect of the foot. In the open surgical technique, the skin incision is often intentionally placed slightly medial to the tendon to prevent injury to the sural nerve. However, despite this approach, nerve injuries are reported between 0.9% and 4.1% [85,89,91,99]. In contrast, minimally invasive and percutaneous techniques present a greater technical challenge in avoiding the sural nerve, thereby increasing the risk of nerve damage compared to the open surgical approach. The reported range of sural nerve damage associated with minimally invasive and percutaneous approaches is 5.2% to 7.3%, respectively [85,112].

Wound infections

Wound infections are mainly a complication related to surgical treatment. Minimally invasive and percutaneous techniques were developed to minimise the risk of infection in surgical wounds. Postoperative infections encompass a broad spectrum of severity, ranging from superficial, antibiotic-responsive infections to deep-seated infections causing significant tendon and potential skin damage. A deep infection may require several revision surgeries. In such cases a multidisciplinary approach involving not only the orthopaedic surgeon but also infection specialists and plastic surgeons may be necessary. The reported rate of infections after the open repair approach is reported between 1.1% and 12.2%; for the percutaneous approach, 0.6% to 1.1% and for the minimally invasive approach, 1.7% [85,99,146].

Tendon elongation

Tendon elongation is common after an acute Achilles tendon rupture, regardless of treatment [34]. Elongation is most likely to manifest early in treatment (within the first six weeks), with continued progression for at least six months after injury [39,57]. The length of the tendon has been observed to increase from 0.15 to 3.1 cm, as determined by different imaging methods [34]. The effect of early weight-bearing on tendon elongation has been a subject of discussion. Kangas et al. [57] performed an RCT to compare early motion after non-surgical treatment in a brace and non-surgical treatment with immobilisation in a below-knee cast for 6 weeks after an acute Achilles tendon rupture (n = 50). Full weight-bearing was allowed after three weeks in both groups. The authors documented tendon elongation in both cohorts; however, this difference was not statistically significant. At 60 weeks, the elongation was reported at a median of 2 mm (IQR -2.0-5.5) in the early mobilisation group and 5 mm (IQR 2.0-10.0) in the group not allowed early mobilisation. Moreover, in an RCT (n = 75) Eliasson et al. [39] investigated the impact of different rehabilitation protocols on tendon elongation. Patients who had undergone surgical treatment for an acute Achilles tendon rupture were randomised to one of three groups with different postoperative regimens following surgery:

- No weight-bearing until seven weeks
- No weight-bearing until seven weeks, but were allowed to perform non-weight-bearing movement of the ankle from week three
- Partial weight-bearing from the first postoperative day and full weight-bearing from week five. Allowed to perform non-weight-bearing movement of the ankle from week three

The results of this study indicated that the rehabilitation protocol did not significantly affect the risk of tendon elongation.

Different methods have been described for the direct measurement of tendon length (Table 1).

TABLE 1 Methods to measure tendon length

	Brief description	Reliability
Ultrasonographic measurement with anatomical markers **Barfod et al.** [14]	1- Prone position. 2- Identification of distal landmark (posterior superior calcaneus) with a probe in the sagittal plane. A needle projects the landmark between the skin and the probe, marked with a pen on the skin. 3- Identification of the proximal landmark (tip of the medial gastrocnemius head) with a probe in the sagittal plane. A needle and pen are used for the distal landmark. 4- The distance between the marks on the skin is measured with a tape.	Inter-rater reliability ICC: 0.97
Ultrasonographic measurement -Extended field of view **Silbernagel et al.** [124]	1- Prone position. 2- An extended field of view of the Achilles tendon is obtained using the probe along the Achilles tendon in the sagittal plane with continuous movement from the distal aspect of the calcaneus to the musculotendinous junction of the gastrocnemius (MTJ). 3- Length is measured between the marked calcaneal notch and the MTJ using ultrasonographic equipment.	Inter-rater reliability ICC: 0.997
Measurement on Magnetic resonance imaging **Barfod et al.** [14]	1- T1 weighted images are used. 2- Length is measured on the axial plane, from the distal part of the gastrocnemius medial head to the distal end of the Achilles tendon (tuber calcani).	Inter-rater reliability ICC: 0.98

Functional deficits

A strength deficit of up to 30% has been observed one year after an acute Achilles tendon rupture [99]. This deficit is noteworthy for its tendency to persist; an inquiry into the underlying reasons is warranted [18,47,101,120]. In a long-term follow-up study, Brorsson et al. [18] investigated the functional performance seven years after an acute Achilles tendon rupture. Their findings indicated no significant improvement in calf muscle function compared to the results obtained two years post-injury.

ULTRASOUND AND TENDON GAP

Recent studies have highlighted the value of imaging the Achilles tendon to determine the gap between the tendon ends for patients with an acute Achilles tendon rupture [66,110,144,147].

Kotnis et al. [66] studied patients who suffered an acute Achilles tendon rupture using US as a treatment selection tool. Patients were treated non-surgically if the tendon gap was < 5 mm and surgically if the tendon gap was ≥ 5 mm. The re-rupture rate was 3.5% in the non-surgically treated group and 1.5% in the surgically treated group [66].

Westin et al. [144] proposed that a greater distance between the ruptured ends of the Achilles tendon might predict re-rupture and a poorer clinical outcome in non-surgically treated patients. That study included patients with an acute Achilles tendon rupture, randomly allocated to either surgical or non-surgical intervention. All patients were examined by US for the Achilles tendon within 72 hours of the initial trauma. Patients in the non-surgical treatment group with a gap of > 5 mm between the tendon ends reported significantly poorer self-reported and functional outcomes than those in the surgical treatment group ($p = 0.004$ and $p = 0.048$). Moreover, three of the four patients in the non-surgical treatment group with a gap > 10 mm sustained a re-rupture.

The findings of Westin et al. [144] are consistent with those of Yassin et al. [147]. Yassin et al. [147] investigated the correlation between the tendon gap (observed using US) and ATRS in a non-surgically treated cohort. The results demonstrated a correlation between increased tendon gap and an inferior ATRS score. Moreover, a significant association was found between a tendon gap > 5 mm and a lower ATRS score (at a mean follow-up of 20 months) compared to patients with a gap < 5 mm (73 in patients with a tendon gap > 5 mm and 82 in patients with a tendon gap < 5 mm ($p = 0.031$)). The reported re-rupture rate in the total cohort was 1.5%.

Qureshi et al. [110] reported on a study of non-surgically managed patients (n=19) with acute Achilles tendon rupture. A US assessment was conducted to determine the tendon gap. The mean gap reported by the study patients was 4.8 mm (measured in the equinus position). In contrast to the previously referred studies, this cohort exhibited no re-ruptures and no correlation was observed between the tendon gap and ATRS scores.

REHABILITATION

Rehabilitation starts almost immediately after the selection of treatment. Regardless of treatment modality, patient rehabilitation constitutes the most

important task for the patinent (Fig 6). Literature reviews on surgical versus non-surgical treatment indicate that non-surgical treatment is comparable to surgical treatment when coupled with early, controlled motion [98,150].

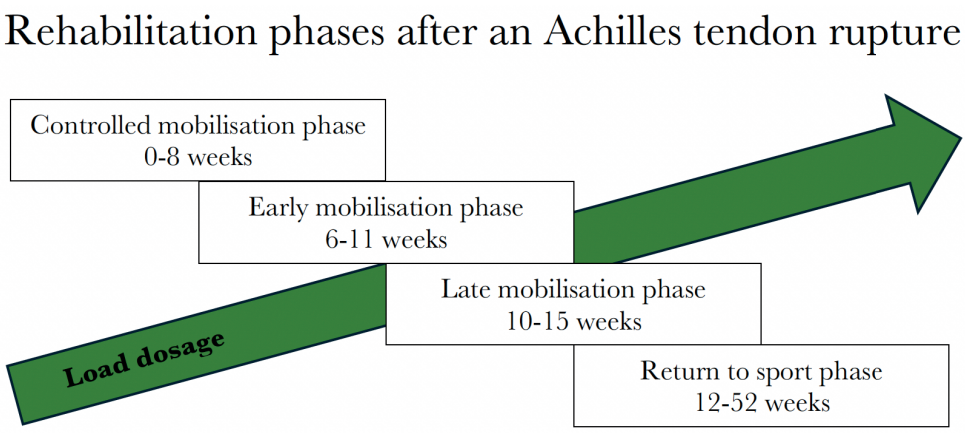

FIGURE 6. Rehabilitation phases [121].

Psychological aspects

A literature review indicates a paucity of studies examining the psychological well-being and perceived recovery of patients following an acute Achilles tendon rupture and the impact of these factors on the resumption of physical activity [53]. A study by Jónsdóttir et al. [53] found that that 50% of patients with an acute Achilles tendon rupture sometimes avoided physical activity due to fear of re-injury to their Achilles tendon. Patients experiencing fear of re-injury demonstrated a significantly greater difference in strength between their injured and un-injured legs compared to those without this fear. Moreover, a study by Olsson et al. [100] indicated that patients reporting kinesiophobia exhibited significantly poorer self-reported outcomes and reduced physical activity three months after an acute Achilles tendon rupture.

The aforementioned studies [53,100] collectively suggest that fear and kinesiophobia may have an impact on physical recovery post-acute Achilles tendon rupture. A review by Hsu et al. [49] supports these results. These authors observed that fear of re-injury can have a detrimental impact on the rehabilitation process, recovery and subsequent successful return to sport.

SEX DIFFERENCES IN RECOVERY

Because patients who suffer from an acute Achilles tendon rupture are more often of the male sex (ratio 4:1) [131], only 8-32% of the cohorts are women [70,85,89,91,99,117]. Consequently, the extant literature concerning functional and self-reported outcomes after acute Achilles tendon rupture in women is demonstrably limited. Nevertheless, recent studies indicate a critical need for further investigation into potential sex-differences in the treatment and outcomes of these injuries, given the significant impairment experienced by women [10,17,100,117,122].

Olsson et al. [100], investigated factors predicting single heel-rise performance 12 weeks post-acute Achilles tendon rupture in surgical and non-surgical treatment groups. The results indicated that male sex was one of the predictors of performing a single heel-rise, as only 2 of 12 women (17%) could perform a single leg heel-rise at 12 weeks compared to 39 of 69 (56%) men.

Silbernagel et al. [122] evaluated whether there is a difference in outcome between sexes following an acute Achilles tendon rupture. A total of 30 women and 152 men were included in the study. Men exhibited a significantly greater improvement in the heel-rise work test at 12 months post-injury than women, irrespective of treatment (i.e., surgical or non-surgical). Notably, at 6 and 12 months post-injury, female surgical patients exhibited significantly lower self-reported ATRS than their male counterparts.

Moreover, Saxena et al. [117] presented parameters for predicting the return to physical activity after surgically treated acute Achilles tendon rupture. Their findings revealed a significant difference between the sexes, with a longer delay noted among women participants. That study included 70 women and 149 men, and the return to activity was defined by three criteria: heel-rises, symmetry of the calf circumference and ankle range of motion. 11 women, but only 2 men, did not meet the criteria for return to activity and were thus classified as having a delayed return to activity.

Aujla et al. [10] evaluated patients treated (n = 236) for an acute Achilles tendon rupture at a mean of 24 months post-injury using ATRS. This study showed that women reported a significantly worse ATRS score than men (66 versus 76 points).

However, there are also examples of studies reporting opposing results. In a prospective cohort study of 110 patients treated surgically after an acute Achilles tendon rupture, Bostick et al. [17] showed that women had superior results for single-leg heel-rise at 6 and 12 month follow-ups. They also had better calf muscle endurance at 12 months compared to men.

Knowledge gap

Although the first article comparing surgical and non-surgical treatment was published almost a century ago, there is still a knowledge gap. There is a lack of knowledge, especially concerning the impact of sex, psychological factors (such as fear of re-injury), tendon elongation, patient-reported outcomes and the distance between the tendon ends.

Analysis of the reviewed studies reveals discrepancies in functional and self-reported outcomes between male and female participants. However, most of the studies indicate that women tend to demonstrate inferior functional outcomes and report worse self-reported outcomes following an acute Achilles tendon rupture. Still, these studies are mostly based on small cohorts with high risk of selection bias.

Studies exploring the impact of fear of re-injury on the recovery after an acute Achilles tendon rupture are limited. It has been suggested that psychological factors affect functional and self-reported outcomes, but further exploration is needed to substantiate this suggestion.

The ATRS is used to evaluate patients from a subjective perspective. The Swedish version of the ATRS is a valid and reliable instrument. However, no established cutoff point (e.g., a “PASS” score) exists to guide clinicians in interpreting total scores.

An indirect measure, ATRA, is useful to estimate the differences in the length of the Achilles tendon between the injured and non-injured sides. This measurement has been validated and shown to be reliable. However, further investigation is required to examine the correlation between ATRA and US.

In patients with acute Achilles tendon rupture the degree of tendon gap has been identified as a significant predictor of re-rupture risk and functional prognosis. Nevertheless, the potential use of this knowledge about the treatment choice remains unknown and needs further assessment.

ELIN LARSSON

02

Patient characteristics and their impact on recovery after acute Achilles tendon rupture

Aim

Chapter 2

The overall aim of this thesis was to examine the influence of various factors related to the outcome of patients with an acute Achilles tendon rupture. These factors include demographics (e.g., age, BMI and sex), as well as psychological responses (e.g., fear of re-injury). Additionally, this thesis sought to improve the clinical applicability of the US measurement of tendon gap in guiding treatment selection and follow-up assessments encompassing ATRA and ATRS, to track patient outcomes and detect any deviations from predicted results.

Study I
To investigate the differences in self-reported outcomes following an acute Achilles tendon rupture between women and men and between surgically and non-surgically treated patients.

Study II
To explore the impact of fear of re-injury to the Achilles tendon on return to physical activity. Moreover, to assess the correlation between fear of re-injury and self-reported outcome measures.

Study III
To establish a Patient Acceptable Symptom State (PASS) for the Swedish Achilles tendon Total Rupture Score (ATRS).

Study IV
To examine the relationship between Achilles Tendon Resting Angle (ATRA) and US measurements of the Achilles tendon length and functional and patient-reported outcomes.

Study V
To evaluate the use of acute US to determine the tendon gap between tendon ends to guide the treatment choice in patients with an acute Achilles tendon rupture.

ELIN LARSSON

03

Patient characteristics and their impact on recovery after acute Achilles tendon rupture

Patients and Methods Chapter 3

Overall, the studies included in this thesis can be divided into two broad categories: retrospective studies with a prospective follow-up using PROMs and prospective cohort studies with a follow-up comprising a combination of PROMs and clinical outcomes (Table 2).

TABLE 2. Overview of studies included in the thesis.

	I[1]	II[2]	III[3]	IV[4]	V[5]
Study design					
Retrospective cohort study with prospective follow-up	•	•	•		
Prospective cohort study with follow-up				•	•
PROMs[a]					
ATRS[b]	•	•	•	•	•
PAS[c]					•
Questions related to recovery	•	•			•
Questions related to the current activity level	•	•			
Questions related to fear of re-injury		•			•
Questions related to satisfaction with treatment	•	•			
Anchor question			•		
Clinical outcomes					
ATRA[d]				•	•
Calf Circumference					•
Tendon Length				•	•
Range of Motion of the ankle					•
Heel-Rise Work test				•	•
Drop Counter-Movement Jump				•	•
Counter-Movement Jump					•
Hopping					•
Strength Evaluation					•

[a] Patient-Reported Outcome Measures, [b] Achilles tendon Total Rupture Score, [c] Physical Activity Scale, [d] Achilles Tendon Resting Angle, [1] Sex differences in patients' recovery following an acute Achilles tendon rupture - a large cohort study, [2] Fear of re-injury after acute Achilles tendon rupture is related to poorer recovery and lower physical activity post-injury, [3] Establishment of the Patient Acceptable Symptom State (PASS) for the Achilles Tendon Total Rupture Score in a Swedish Population, [4] Achilles tendon resting angle is able to detect deficits after an Achilles tendon rupture, but it is not a surrogate for direct measurements of tendon elongation, function or symptoms, [5] Using tendon gap as a decision-making tool provides comparable function regardless of surgical or non-surgical treatment for an acute Achilles tendon rupture

Study population

Study I included all patients who responded to the follow-up questions after retrospective data collection from medical charts. Patients who responded to the question related to "fear of re-injury" were included in Study II. Patients who responded to the follow-up questions within 12-27 months following their initial injury were included in Study III. The patients included in Study IV were recruited before to the start of Studies I, II and III. Some of the patients (n=32) recruited from the physiotherapy clinics had visited the emergency department or the orthopaedic department related to their treatment and were therefore included in the retrospective study. There was a minor overlap between the inclusion period of Study V (August 2020 – February 2022) and Studies I-III (January 2015 – December 2020) n = 34. As illustrated in Fig 7, there is an overlap in the population across all studies. An overview of patient demographics across the five studies is presented in Table 3.

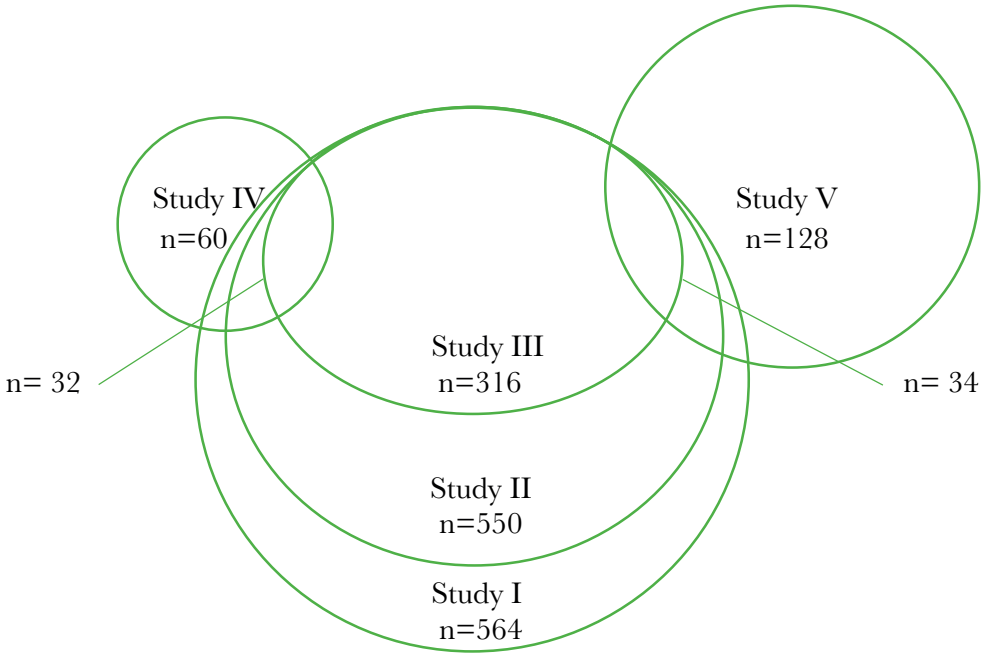

FIGURE 7. Overview of patients included in the different studies (not to scale)

TABLE 3. Demographics of patients included in the thesis

Variable	Study I n=564	Study II n=550	Study III n=316	Study IV n=60	Study V n=128
Age, mean (SD)	49 (15.2)	48 (14.9)	51 (15.4)	43 (9.0)	43 (11)
BMI, mean (SD)	26.2 (3.9)	26 (3.8)	26.2 (3.8)	25.7 (3.0)	27 (3.1)
Sex, women/men n (%)	129 (23%)/ 435 (77%)	125 (23%)/ 425 (77%)	73 (23%)/ 243 (77%)	13 (22%)/ 47 (78%)	25 (20%)/ 103 (80%)
Treatment, surgery/ non-surgery n (%)	158 (28%)/ 406 (72%)	155 (28%)/ 395 (72%)	99 (31%)/ 217 (69%)	21 (35%)/ 39 (65%)	87 (68%)/ 41 (32%)

Patient and data collection

Studies I, II and III, performed at the Sahlgrenska University Hospital/Mölndal (SU/M), Sweden, were designed as retrospective studies with a prospective follow-up component. Patients were enrolled between January 1st 2015, and December 31st, 2020 (Study III with a sub-cohort from July 1st 2018 – December 31st, 2020). Eligible patients were identified using the Internal Classification of Diseases (ICD) code for an acute Achilles tendon rupture (S86.0) or spontaneous flexor tendon rupture (M66.3). The reason for using M66.3 was to avoid missing any patients, even though this is an incorrect code for acute Achilles tendon rupture. Patients were excluded for insufficient medical record documentation, if they were deceased, or lack of a valid address.

Subsequently, the charts of the identified patients were reviewed manually. This was done to identify a cohort diagnosed with acute Achilles tendon rupture. Additionally, patient characteristics were extracted. These included age, sex, injury level, date of injury, date of treatment and treatment regimen. The injury was considered acute if the patient received treatment within 14 days of rupturing.

Study IV was a clinical study conducted between 2016 and 2020, involving patients with acute Achilles tendon rupture recruited from five Gothenburg physiotherapy clinics. Patients were included in the study if they were between 18 and 65 years old and had received treatment within 4 days of sustaining their injury. Participants were excluded if they had a neurological disease, a previous injury to the Achilles tendon (irrespective of side), or an inability to communicate verbally or in writing in Swedish.

Study V, which was also a clinical study, was conducted at the SU/M, Sweden.

Patients presenting with an acute Achilles tendon rupture at the emergency department were included between August 1st 2020 and February 12th 2022. The inclusion criteria specified an age range of 16 to 65 years, participants had to be diagnosed with a clinical examination with an acute Achilles tendon rupture located in the tendon midsubstance and have received treatment within 48 hours post-injury. Patients with a history of Achilles tendon injury (regardless of side), diabetes, immunosuppression, neuromuscular disease, or other lower extremity injuries affecting Achilles tendon, foot, or lower leg function were excluded. Additionally, participants unable to communicate verbally or in writing in Swedish, were excluded from the study.

Following enrolment into Study V, patients were discharged with a ventral cast that sustained the ankle in approximately 30° of plantar flexion and were administered low-molecular weight heparin for 10 days as thrombosis prophylaxis, administered to prevent thrombosis over the following 10 days. Patients were instructed to return to the hospital on a scheduled time for a US examination of the Achilles tendon to determine the gap between the ends of the ruptured tendon. If the gap ≥ 5 mm, patients were scheduled to undergo surgical treatment within a week. Patients were scheduled to receive non-surgical treatment if the gap was < 5 mm.

Tendon gap measurement

Patients included in Study V were booked at the radiological department on a predefined day of the week for a US examination of their Achilles tendon. A radiologist conducted the US examination using a Logiq 10 US machine manufactured by GE Healthcare Sweden AB. The probe that was used was a linear probe (6-15 MHz).

The patient was prone, with 10° flexion in the knee joint and a ventral cast secured to prevent ankle dorsiflexion (Fig 8). The Achilles tendon was evaluated starting from the musculotendinous junction to the insertion on the calcaneal tuberosity in all anatomical planes.

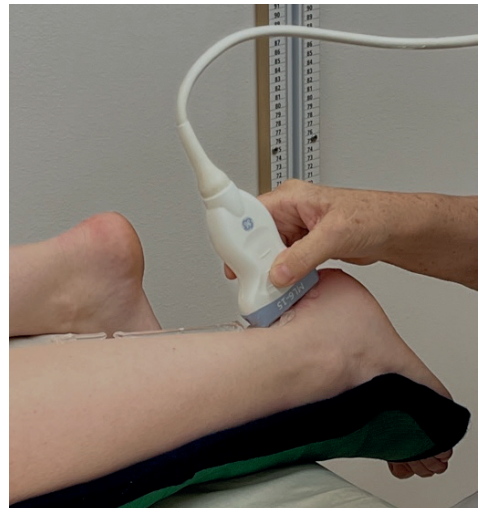

FIGURE 8. Picture illustrating the patient in the prone position during ultrasound measurement to determine the gap between tendon ends. The ventral cast is placed during the whole examination to maintain plantar flexion.

Gap morphology was assessed, followed by measuring the shortest distance between the tendon ends in the sagittal plane, considered the tendon gap. The tendon gap was documented using both video recordings and panoramic longitudinal views. The thickness of the tendon ends was measured at their midportions.

The gastrocnemius muscle, Achilles paratenon, deep calcaneal bursa and plantaris tendon were evaluated in accordance with clinical routine.

Surgical procedure

The surgical procedure was performed with the patient in the prone position, using one of three anaesthesia methods: general, regional or local. Tourniquets were employed for patients under general or regional anesthesia. The skin was incised longitudinally, medial to the Achilles tendon, at the rupture site, preserving the sural nerve.

In Study V the tendon was adapted using either the Nilsson Helander et al.'s [91] (Fig 9) or Olsson et al.'s [99] technique (Fig 9).

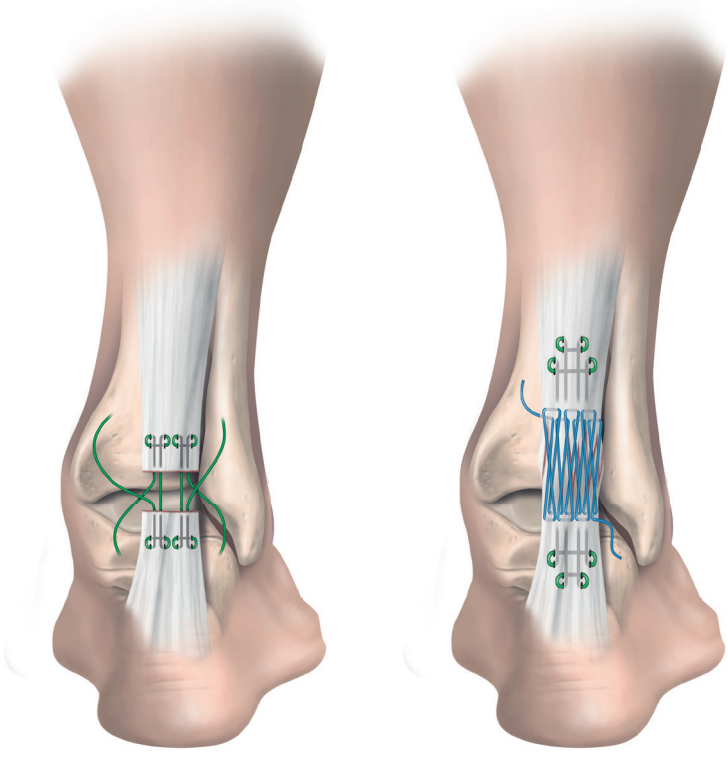

FIGURE 9. Two surgical methods are illustrated. To the left is the Nilsson Helander et al.'s method with a modified Kessler suture. To the right is the Olsson et al.'s method with a modified Kessler suture and a criss-cross reinforcement (Silfverskiöld).

Nilsson Helander et al.: An end-to-end suture was applied using the modified Kessler [62] technique with a polydioxanone (PDS), 1-0.

Olsson et al.: By using semi-absorbable sutures (No. 2 Orthocord) a modified Kessler [62] technique was used in an end-to-end suture. The locking mechanism should be positioned at a distance from the point of rupture. Furthermore, a modified criss-cross technique was applied using an absorbable suture (No. 0 Polysorb). The criss-cross technique has previously been described by Silfverskiöld et al. [126].

Post-surgery, patient immobilisation was achieved using a below-knee cast positioned at approximately 30° of plantarflexion. This cast was replaced with a walker boot two weeks later.

Immobilisation

All patients in this study followed the same immobilisation protocol, regardless of surgical intervention.

Upon diagnosis of the injury at the emergency department, all patients were provided with a below-knee cast in the equinus position (approximately 30° plantar flexion of the ankle). For those who underwent surgical treatment, a new below-knee cast was applied post-operatively for the subsequent two weeks (from the date of surgery). Patients who received non-surgical treatment wore their cast for two weeks from the date of their visit to the emergency department.

However, in Study V patients received a ventral cast in the equinus position until the US examination was performed. After this examination, patients received a below-knee cast (Fig 10).

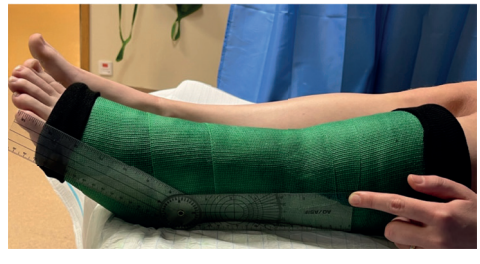

FIGURE 10. The picture depicts a below-knee cast, with the goniometer positioned to present the equinus position of the ankle.

FIGURE 11. A walker boot with wedges. Model: Aircast Standard.

After 2 weeks, the cast was replaced during an appointment at the orthopaedic department with a walker boot with wedges (Fig 11). A six-week period of

continuous walker boot use was prescribed for all patients; wedge removal was to be performed incrementally by a physiotherapist (Table 4).

TABLE 4. Rehabilitation protocol

Week	Treatment	Exercise
2-4	Walker boot with three wedges	Partial-/full weight-bearing with crutches Non-weight-bearing movement of the ankle 3-5 times/day
4-6	Walker boot with two wedges	Full weight-bearing with crutches outdoor Non-weight-bearing movement of the ankle 3-5 times/day
6-8	Walker boot with one wedge	Full weight-bearing, with focus on the gait pattern Non-weight-bearing movement of the ankle 3-5 times/day
8-12	Wean off the walker boot, and transition to footwear with a heel drop, used both indoors and outdoors	Active ankle excessive for range of motion (ROM) Sitting heel-rise Standing heel-rise (two-legged) One leg standing balance with shoes on flat surface Step restriction
12-16	Allowed to walk without shoes indoors	Balance exercises with shoes Gradually transition to excentric one-legged heel-rise
16-20		Two-legged jumps Gradually increase movement by starting with a gentle jog
20-		One-legged jumps Agility exercises

Rehabilitation

Regardless of the treatment regimen, all patients were seen by a physiotherapist and a physician at the 2-week follow-up, either following the initial injury or post-operatively. The physiotherapists provided instructions on walker boot usage and gave information about the initial exercises, weight-bearing and crutches. Patients were then referred to a physiotherapy clinic for continued rehabilitation (Table 4), with the gradual discontinuation of wedge support and, ultimately, the walker boot. Study V restricted the number of physiotherapists to whom patients were referred. These physiotherapists attended special training days on rehabilitation after acute Achilles tendon rupture.

Follow-ups

For Studies I, II and III, patients were contacted by regular mail between one to six years after injury. The participants received ATRS and additional questions

related to treatment satisfaction and recovery. All patients were contacted a second time by regular mail if they had not responded to the initial correspondence. The initial regular mails were distributed in October 2020 and December 2021.

Patients enrolled in Study IV underwent evaluations at 6 and 12 months after injury. These evaluations included ATRA, assessment of the length of the Achilles tendon using US, functional evaluations and PROMs.

Patients participating in Study V were referred to the orthopaedic department, designated "Hälsenemottagningen" (the Achilles tendon out-patient clinic), two weeks following treatment initiation or post-operatively to change the cast to a walker boot. The patients were evaluated 3, 6 and 12 months after injury. The evaluation included an US measurement of the tendon length, ATRA, calf circumference and functional assessment. Moreover, patients completed PROMs at these time intervals.

Outcome measures

PATIENT-REPORTED OUTCOME MEASURES

Patient-reported outcome measures (PROMs) are used to assess health-related quality of life, limitations, symptoms, experience of care and psychological factors [16]. PROMs can be general, regional or injury specific.

Achilles tendon Total Rupture Score
The ATRS is an injury-specific PROM developed in 2007 by Nilsson-Helander et al [92]. The ATRS is intended to enable a complete and consistent evaluation of related symptoms and recovery following an acute Achilles tendon rupture. The ATRS contains 10 questions, all referring to limitations or difficulties related to the injured Achilles tendon. Patients answer each question on a Likert scale ranging from 0 to 10, yielding a maximum score of 100 points. A lower score indicates greater limitations and more symptoms. The ATRS has been translated and culturally adapted into 15 languages, thereby demonstrating its usefulness in several contexts [6,8,11,20,25,31,42,61,86,102,104,130,137,141,148]. The questions were developed by an expert group of four orthopaedic surgeons and four physiotherapists. The ATRS's reliability has been assessed using test-retest methodology. A total of 43 patients completed ATRS twice within 2 weeks. The test-retest results were also used to calculate the effect size to measure the responsiveness of the ATRS. The test-retest's Intraclass Correlation Coefficient (ICC) value was reported as 0.98. The effect size for responsiveness was 0.87 – 2.21 [92].

Physical activity scale
The Physical Activity Scale (PAS) was

first described in 1968 by Saltin and Grimby et al. [115] and a modified version was published in 1986 by Grimby et al. [45]. The modified version, used in this thesis, is a scale ranging from one to six and is used for classification of activity level. One denotes to minimal physical activity, and six refers to strenuous physical activity undertaken multiple times per week. PAS has not been validated for patients following an acute Achilles tendon rupture but is used to complement existing PROMs.

Additional questions

The research group formulated four additional questions to complement existing PROMs. The initial proposal suggested their use for assessing treatment quality at the SU/M, Sweden. The questions are used in Studies I-III (for further details, see Table 2).

1. How would you describe your recovery after your Achilles tendon rupture as a percentage from 0-100? 0 stands for not recovered, and 100 for fully recovered.

2. How would you describe your recovery after your Achilles tendon rupture?

3. What is your current activity level now compared to before?

4. Do you ever refrain from activity for fear of re-injuring your Achilles tendon?

Question one was answered using a scale from 0 to 100 per cent. This is a global rating scale (GRS). GRS is an instrument with the advantage of clinical relevance and is easy for the patient to understand. The application of GRS is prevalent in both clinical and research settings [44,56].

Questions two and three were answered on a five-point Likert scale. Question four was a yes or no answer.

Anchor Question

1. How satisfied are you with the treatment of your Achilles tendon rupture?

Answers were given on a five-point Likert scale: 1= Completely satisfied, 2= Satisfied, 3= Neither satisfied nor dissatisfied, 4= Dissatisfied and 5= Completely dissatisfied. Responses 1 and 2 were classified as positive, and responses 3,4 and 5 as negative.

An anchor question was used to establish the PASS and was used in addition to the ATRS.

PATIENT ACCEPTABLE SYMPTOM STATE

PROMs are widely used research tools, offering invaluable insights into patient perspectives, including recovery and satisfaction. Response criteria for PASS

have been developed to ascertain the clinical relevance of a given score on a PROM. This concept was initially presented in 2005 by Tubach et al. [138]. The objective was to facilitate clinicians' and researchers' interpretation of PROM results. The definition of PASS is the value beyond which the patients consider themselves well [138].

Minimal Clinically Important Difference (MCID) and Minimal Clinically Important Improvement (MCII) are additional concepts that are used to interpret scoring from PROMs. MCID was described in 1989 by Jaeschke [51] and refers to the smallest change in a measurement that benefits the patient. MCII is defined as the minimal improvement that is considered relevant [138]. Multiple methods exist to calculate MCID and MCII, including anchor-based or distribution-based approaches. The distinction between these two methods is that the anchor-based method is based on an external factor (subjective or objective), whereas the distribution-based approach is based on statistical criteria [103].

FUNCTIONAL OUTCOMES

All functional outcomes during the follow-ups were conducted and compiled by one experienced physiotherapist. All tests were conducted on the injured and non-injured legs, starting with the uninjured. All patients wore standardised shoes (Bagheera Omega) that the test leader provided.

Achilles Tendon Resting Angle

In accordance with the established nomenclature, ATRA is defined as the angle between the long axis of the fibula and the head of the fifth metatarsal bone [22]. During the measurement of

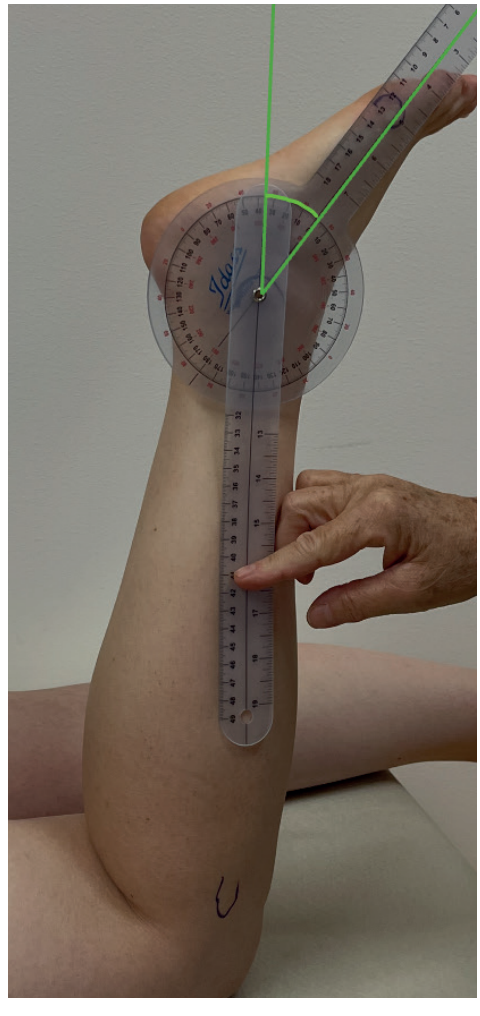

FIGURE 12. The picture shows the ATRA measure with the use of a goniometer.

ATRA, the patient is placed in a prone position on the examination bench. The knee is in 90° flexion, and a goniometer used to measure the angle (Fig 12).

The ATRA was first described in 2013 by Carmont et al. [24] and is currently used as an indirect measure of tendon elongation following an Achilles tendon rupture. During its development, the purpose was to achieve a measurement that was easy to perform, accessible and non-invasive. The ATRA measurement has been tested for reliability, with an ICC value of 0.91-0.92 [24].

Carmont et al. [22] proposed that the ATRA increases following an injury of the Achilles tendon and will subsequently be reduced post-surgery. Post-operatively the ATRA increases once more during rehabilitation [22]. ATRA has been demonstrated to correlate with functional outcome [22] and tendon elongation [149].

ATRA can be reported as either an absolute ATRA, representing the value of the injured side, or as a relative ATRA, which refers to the difference between the non-injured and injured sides. An increased dorsiflexion of the injured ankle results in a negative relative ATRA value, whereas an increased plantar flexion in the injured ankle results in a positive value when compared to the non-injured side [22].

Calf Circumference

Calf circumference measurements were obtained from the patient while prone, with feet extending beyond the examination table. The circumference was measured with a measuring tape at the thickest part of the calf [87].

Tendon Length

The absolute length of the tendon was measured using the extended field of view (LOGIQ™ P9, GE Healthcare Sweden AB) [113]. A wideband array linear probe (5.0-13.0 MHz) was applied. The B-mode at 10 MHz and a depth of 3 cm were used to record the images.

The patients were prone on the examination bench with both feet extending beyond the edge of the bench. The length was measured from the calcaneal notch to the gastrocnemius myotendinous junction (Fig 13). The ICC value for this measurement technique of tendon length has been reported to be 0.9 [124].

Range of Motion of the ankle

The patient is standing during the measurement with the instructions to maintain their balance with their hands on the wall. The foot on the side designated for measurement was positioned as far posterior as possible without knee flexion. The angle of dorsiflexion was quantified using an inclinometer (Fig 14). The test was then repeated but with the knee bent. The test has been reported to be reliable, with an ICC value of 0.88 [84].

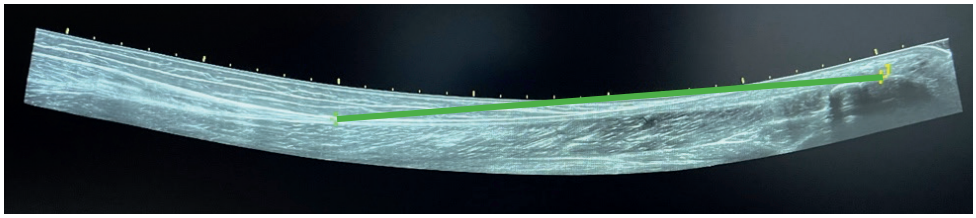

FIGURE 13. Tendon length was measured using an extended field of view (ultrasound). The green line represents the length from the calcaneal notch and the gastrocnemius myotendinous junction.

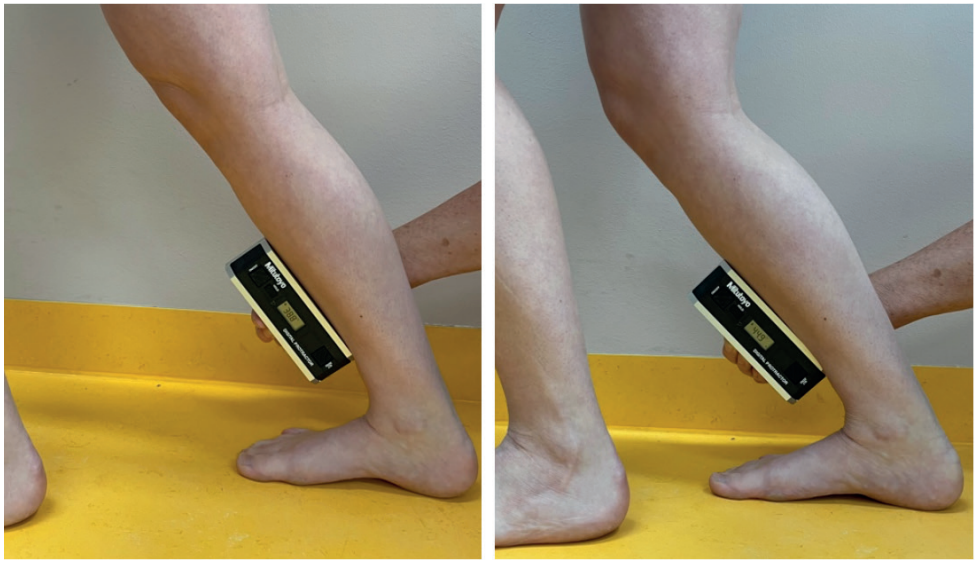

FIGURE 14. The picture on the left illustrates measurement conducted using an inclinometer with the knee straight, and the image on the right with the knee bent.

Heel-Rise Work Test

The heel-rise work test was performed with the patient standing on a 10°-incline board (Fig 15), performing maximum height on single-leg heel-rises in a predetermined tempo of 30 heel-rises per minute. A linear encoder was attached to the heel. The linear encoder was connected to the MuscleLab system (Ergotest Technology, Oslo, Norway). Total work was calculated using the number of heel-rises, the height of the heel-rise and the patient's weight. Total work was presented in Joules. The heel-rise work test was described by Silbernagel et al. [120] and is considered a reliable and valid method to evaluate patients with an acute Achilles tendon rupture with ICC values ranging from 0.78 to 0.84 [88].

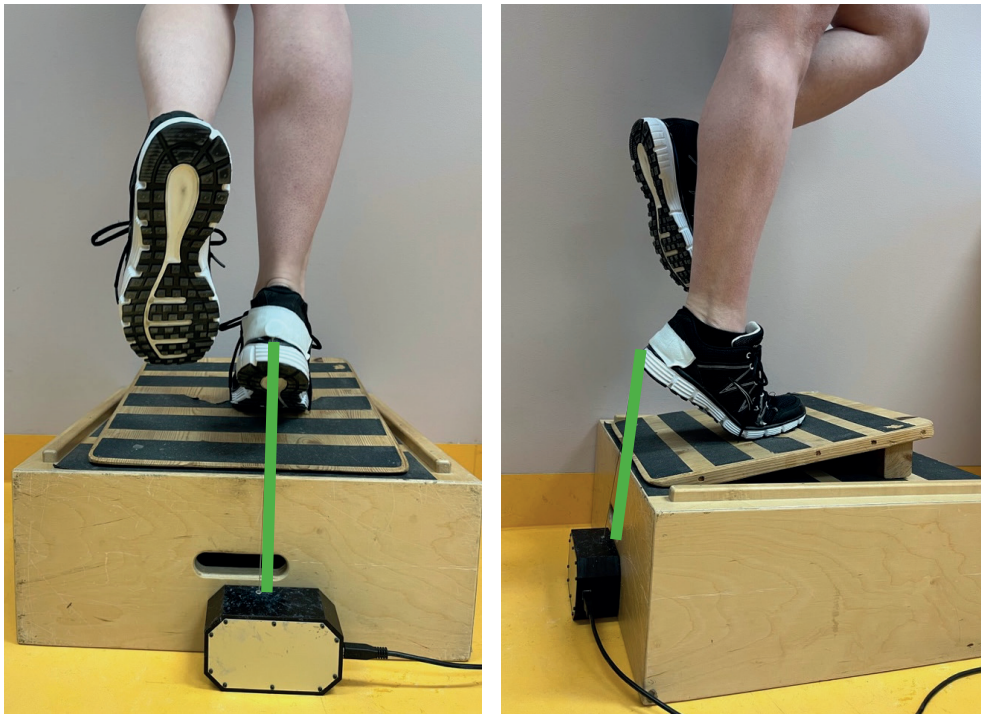

FIGURE 15. The pictures demonstrate the heel-rise work test. A linear encoder is attached to the heel during the test.

Counter-Movement Jump

The counter-movement jump (CMJ) was performed with the patient standing on one leg on a flat surface with their hands behind their back throughout the test. Next, the patient was instructed to perform a vertical jump to achieve maximum height. The test was conducted on at least three occasions, with the highest jump documented as the CMJ in centimetres (cm) [123].

Drop Counter-Movement Jump

The patient was positioned on a box with a height of 20 cm from the surface with their hands behind their back during the whole test. They were instructed to jump down from the box while standing on one leg and immediately perform a vertical jump to reach a maximum height. At least three jumps were performed on each leg, and the highest jump was documented as a drop CMJ in cm [91,99,123].

Hopping

The hopping test was carried out on a flat surface; the patient was instructed to execute rhythmic unilateral vertical

jumps, simulating jump rope motion. Approximately 25 jumps were performed on each leg [123]. The results of the test were presented as the mean height of 20 jumps and the quotient of flight time/contact time [123].

Strength Evaluation

The strength of the lower leg was evaluated using a weight-training machine. The patient was instructed to stand with the weight on their shoulders, with an initial load of 13 kilograms (kg) and a linear encoder attached to their heel. The patient was instructed to perform three repetitions of one-legged heel-rises as fast and powerfully as possible with the weights and rest for 15 seconds between every heel-rise. If feasible, a 10 kg weight increment was implemented after each set. The results of this test are presented in Watts [123].

Statistical analyses

For all studies included in this thesis, continuous, normally distributed variables were presented as means with standard deviations (SDs), and non-normally distributed variables were presented as medians with interquartile ranges (IQRs). Categorical variables were presented as frequencies and percentages. Analyses of normally distributed data were executed using parametric statistics, and for non-normally distributed data, non-parametric statistics were employed. The data distribution was considered normally or non-normally distributed through visual inspection of histograms and a Shapiro-Wilk test for normality. The level of significance was set at $p \leq 0.05$. The software packages used in the studies were JASP (Version 0.16.2), IBM SPSS Statistics (Version 28) and Stata statistical software (Release 17; StataCorp).

STUDY I

The differences between women and men participants were analysed using an independent t-test or a non-parametric Mann-Whitney U test. Categorical variables were analysed using Pearson's chi-square test. A multiple linear regression analysis was performed to examine the impact of sex when comparing ATRS between women and men. The regression model was adjusted for BMI, age and treatment. Model assumptions were verified and found to be satisfactory.

STUDY II

A Pearson's chi-square test was employed for categorical data analysis to assess differences in fear of re-injury between the two patient groups. The Mann-Whitney U test was used to compare the ATRS and recovery in percentage between the two groups.

STUDY III

A ROC curve analysis was conducted to determine the PASS for the ATRS. Using the ROC curve, the threshold for the ATRS that predicts a positive response to the anchor question was detected. The area under the curve (AUC) measures the probability that a randomly chosen positive outcome will be ranked higher than a randomly chosen negative outcome. The AUC ranges from 0.5 (no accuracy in predicting the outcome variable) to 1.0 (excellent accuracy in predicting the outcome variable) [40]. An AUC > 0.7 is considered as an acceptable level of discrimination, while an AUC > 0.8 is considered to be excellent [107]. The optimal cut-off score was identified according to the Youden index [114].

STUDY IV

For Study IV, sample size was determined by a power analysis based on a pilot study [125]. For a 95% probability of detecting a 1.5 cm difference in tendon length between 6 and 12 months, a sample size of 57 patients was needed (assuming a two-sided alpha level of 0.05).

The comparisons between the injured and non-injured limbs at 6 and 12 months after injury were calculated using a paired t-test.

The correlations between relative ATRA, heel-rise height, drop CMJ, ATRS and tendon length were estimated using Spearman's Rho correlation coefficient for non-normally distributed data and Pearson's correlation for normally distributed data. As an effect size, r^2, was calculated. The correlation coefficient determined the strength of the correlation. A correlation coefficient of > 0.8 was considered to indicate a very strong relationship, 0.6 – 0.8 was considered to indicate a moderately strong relationship, 0.5 – 0.3 was considered to indicate a fair relationship and < 0.3 was considered to indicate a poor relationship [28]. The level of significance was set at $p < 0.05$.

STUDY V

A sample size calculation was performed before the study based on the results of Nilsson Helander et al. [91]. For an 80% probability of detecting a 10% difference in the heel-rise work test between surgically and non-surgically treated patients, a sample size of 128 patients was needed (assuming a two-sided alpha level of 0.05).

Limb symmetry index (LSI) values were used to compare the extent of recovery of the injured limb versus the non-injured limb in the two treatment groups. The LSI was calculated as

follows: injured/non-injured * 100 and expressed as a percentage.

The statistical analyses between the two treatment groups regarding functional outcomes and patient-reported outcomes at 6 and 12 months were performed using the Mann-Whitney U test for non-normally distributed data and an independent t-test for normally distributed data. For categorical variables, the chi-square test was computed. No corrections were made for multiple tests.

Ethical considerations

All patients received informed consent before inclusion (Table 5).

The potential benefits of all five studies were considered to outweigh the possible risks to the patients. All five studies involve sensitive personal data regarding personal health. The data being unidentified reduces the risk of medical information being tracked back to an individual. The code key was secured and accessible only to the responsible researcher. The potential risks in Studies IV and V were that participants may experience discomfort in their calf muscles for a few days after performing the tests.

TABLE 5. Ethical approvals of the studies.

Study	Ethical board	Date of approval	D-nr
I, II, III	Swedish Ethical Review Authority	210630	2021-01779
IV	Regional Ethical Review Board, Gothenburg	151120	803-15
V	Swedish Ethical Review Authority	191105	2019-05457

ELIN LARSSON

04

Patient characteristics and their impact on recovery after acute Achilles tendon rupture

Results

Chapter 4

Study I

For Study I, 856 patients were identified as eligible for inclusion. A total of 564 patients (66%) responded to the ATRS and the additional questions, 129 (23%) were women. Multiple linear regression analysis was conducted with variables of sex, BMI, age and treatment included (Table 6). The results demonstrated that sex, age and BMI were significant variables influencing the total ATRS score. Men scored 7.8 points higher on the ATRS, whereas increased age and BMI were associated with lower ATRS.

TABLE 6. Multiple regression analysis of ATRS, including the variables of sex, age, BMI and treatment.

Variable	Regression coefficient	Standard error	95% CI	P-value
Sex (men)	7.8	2.27	3.3 to 12.3	**<0.001**
Age	-0.2	0.07	-0.3 to -0.1	**0.006**
BMI	-1.0	0.25	-1.5 to -0.5	**<0.001**
Treatment (non-surgical)	-1.1	2.13	-5.3 to 3.1	0.613

Women reported significantly lower ATRS scores, with a median of 79 (IQR 59-91), compared to men, who reported a median score of 84 (IQR 67-95) (**p = 0.004)**. A similar trend emerged in recovery rate responses (85% for women and 90% for men, **p = 0.005**).

Moreover, the results of the analyses about satisfaction with treatment and recovery were significantly worse for female participants compared to their male counterparts. However, the question about current activity did not demonstrate any significant differences between men and women.

Study II

Of the 856 patients eligible for Study II, 550 (125 women) answered the question related to fear of re-injury, which gave a response rate of 64%. Of the study participants, 308 (56%) reported activity avoidance due to fear of re-injury.

A comparison between the two treatment groups revealed that 59% of the patients in the non-surgically treated group refrained from activity, compared to 48% in the surgically treated group. This difference was significant (**p =**

0.024). A similar comparison between men and women demonstrated no significant differences (Fig 16).

Further analyses showed that patients who reported fear of re-injury also reported significantly inferior results on the ATRS and the questions on recovery, satisfaction with treatment and recovery, as well as current activity compared to before the injury. The ATRS median score was significantly lower (**p < 0.001**) among patients with confirmed fear of re-injury (76 points) compared to those without (91 points). This finding is illustrated in Fig 17. Moreover, regarding the reported recovery rate (percentage), the group reporting no fear of re-injury showed a 10-percentage-point superior recovery (90% versus 80%, **p < 0.001**).

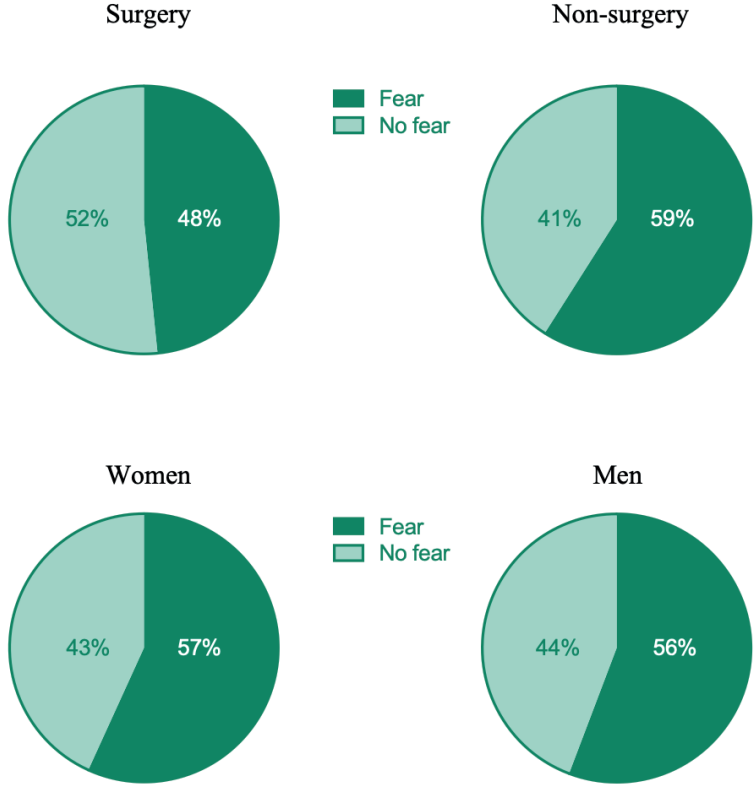

FIGURE 16. The upper circles demonstrate the distribution of patients' answers to questions regarding fear of re-injury in the surgical group (n = 155) and in the non-surgical group (n = 395). The lower circles demonstrate the patients' answers to the same question, although stratified by women (n =129) and men (n =435).

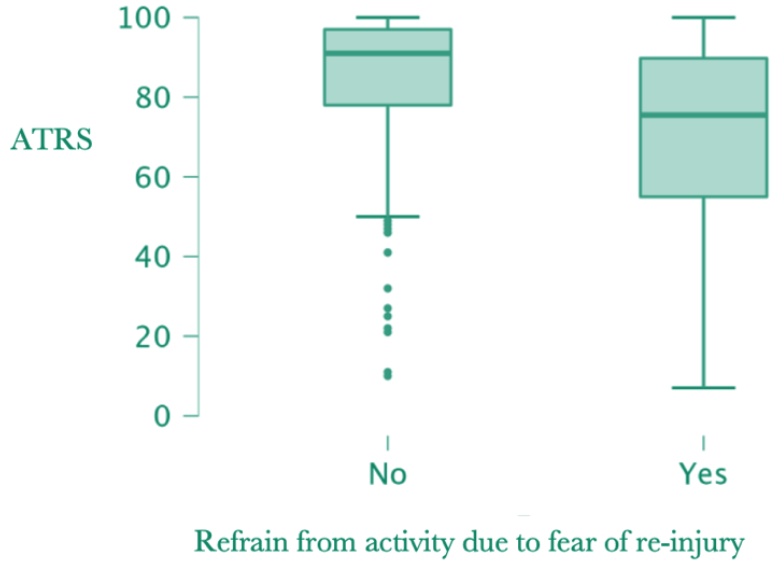

FIGURE 17. A box plot demonstrating the total ATRS in the group that confirmed the fear of re-injury and those who expressed no fear of re-injury.

A significant correlation between age groups and fear of re-injury was observed. The age groups were 16-29, 30-39, 40-49, 50-59, 60-69 and >70. Patients in the 30-39 and 40-49 age groups reported a higher degree of re-injury than other age groups. Patients >70 years of age reported the lowest degree of fear of re-injury **(p = 0.008)**.

Study III

Study III included 516 eligible patients; 316 (73 women) responded to both the ATRS and the anchor question (*"How satisfied are you with the treatment of your Achilles tendon rupture?"*) within 12-27 months after an acute Achilles tendon rupture.

The responses to the anchor question were provided on a five-point Likert scale (Fig 18). The answers were divided into "satisfied" and "not satisfied." The "satisfied" category included patients who reported being either "completely satisfied" or "somewhat satisfied". Patients who reported "neither satisfied nor dissatisfied," "somewhat dissatisfied" and "dissatisfied" were classified into the "not satisfied" category. The median ATRS of the total cohort was 80 (IQR 61-93). The median ATRS for satisfied patients was 86 (IQR 71-95), while the median of dissatisfied patients was 57 (IQR 36-69). The results of the ATRS in these categories are presented as box plots in Fig 19. A ROC analysis calculated the ATRS PASS cut-off value of 75 points. In the total cohort 210 patients (66%)

reached the PASS value and 179 (72%) who considered themselves satisfied reached PASS. The AUC was 0.85, which is regarded as excellent (Fig 20) [107].

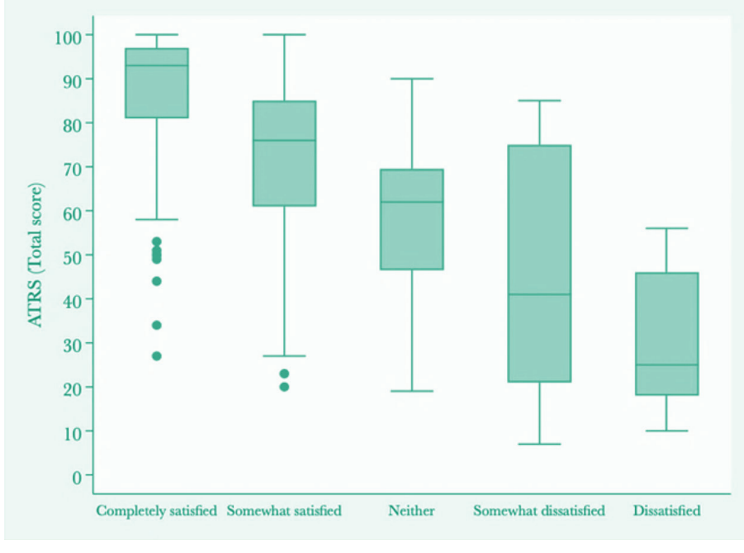

FIGURE 18. Box plots demonstrating the distribution of the total Achilles tendon Total Rupture Score (ATRS) according to five-point Likert scale responses for the anchor question.

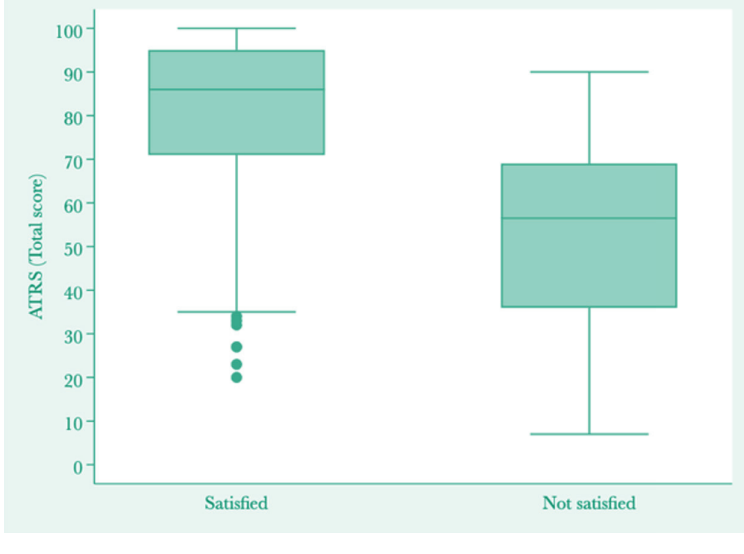

FIGURE 19. These box plots illustrate the distribution of the answers on satisfaction categorised into satisfied/non-satisfied and the Achilles tendon Total Rupture Score (ATRS).

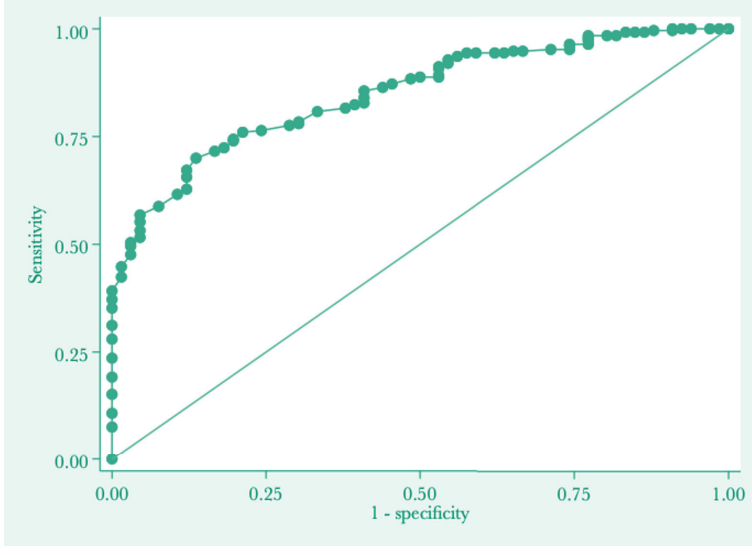

FIGURE 20. This diagram demonstrates the receiver operating characteristics (ROC) analysis of the Achilles tendon Total Rupture Score (ATRS) for Patient Acceptable Symptom State (PASS).

Study IV

Study IV comprised 66 patients. Of these 66 patients, 6 were excluded for various reasons. These 60 patients (13 women) were included in the final analyses.

At the 6 and 12 month follow-ups, significant differences were found in the performance of ATRA, tendon length, heel-rise height and drop CMJ on the injured side compared to the non-injured side (Table 7).

TABLE 7. Functional outcomes reported on the non-injured and injured leg at 6 and 12 months following an acute Achilles tendon rupture. The results are presented as mean (SD)

	6 months			12 months		
Variable	**Non-injured side**	**Injured side**	**P-value**	**Non-injured side**	**Injured side**	**P-value**
ATRA[1] (°)	47.1 (5.7)	52.9 (6.4)	**<0.001**	46.6 (6.2)	51.6 (5.6)	**<0.001**
Tendon length (cm)	21.4 (2.7)	23.4 (3.1)	**<0.001**	21.5 (2.2)	23.1 (2.9)	**<0.001**
Heel-rise height (cm)	14.0 (2.4)	10.1 (3.1)	**<0.001**	13.9 (2.1)	11.6 (2.1)	**<0.001**
Drop CMJ[2] (cm)	15.6 (4.8)	12.1 (4.6)	**<0.001**	15.8 (3.8)	13.1 (3.9)	**<0.001**

[1]Achilles tendon resting angle, [2]Drop Counter-movement jump

TABLE 8. Presentation of the correlation coefficient (r) and the statistical significance between relative ATRA and four variables; tendon elongation, deficits in heel-rise height, deficits in drop jump and ATRS.

Correlation	n	r	p value
Tendon elongation and relative ATRA[1]			
at 6 months	45	-0.083	0.588
at 12 months	51	-0.356	**0.010**
Deficits in heel-rise height and relative ATRA			
at 6 months	59	0.330	**0.011**
at 12 months	56	0.379	**0.004**
Deficits in drop jump and relative ATRA			
at 6 months	55	0.099	0.473
at 12 months	55	0.126	0.359
ATRS[2] and relative ATRA			
at 6 months	58	0.076	0.571
at 12 months	54	0.249	0.069

[1] Achilles Tendon Resting Angle, [2] Achilles tendon Total Rupture Score

The correlations were analysed between the relative ATRA and tendon elongation, heel-rise height, drop CMJ and ATRA (Table 8). The variables included in the correlation analysis are presented as "deficits", indicating the differences between the injured and uninjured sides. A significant negative correlation was demonstrated between relative ATRA and tendon elongation at 12 months (**p = 0.010**) (Fig 21). Moreover, a significant correlation was observed between the relative ATRA and deficits in heel-rise height 6 (**p = 0.011)** and 12 (**p = 0.004**) months after the index injury (Fig 22).

Study V

Study V included 128 (20% women) patients. A total of 87 patients demonstrated a tendon gap of ≥ 5 mm and underwent surgical treatment, while 41 patients demonstrated a tendon gap < 5 mm and underwent non-surgical treatment. One patient in each group suffered a re-rupture, resulting in a re-rupture rate of 1.1% in the surgically treated group and 2.4% in the non-surgically treated group. Accordingly, 126 patients were included in the functional and self-reported outcome analyses.

There were no significant differences in terms of ATRS in the non-surgically treated group compared with the surgically treated group at 6 and 12 months. No statistical significant differences were detected between treatment groups in the primary outcome (heel-rise work test) at 6 and 12 months post-injury. However, performance in the heel-rise work test at 12 months in the non-surgically treated group revealed a bimodal distribution with eight patients performing an LSI of < 50% (Fig 2 in the manuscript of Study V).

There were no significant differences in ATRS in the non-surgically treated group compared to the surgically treated group at 6 and 12 months.

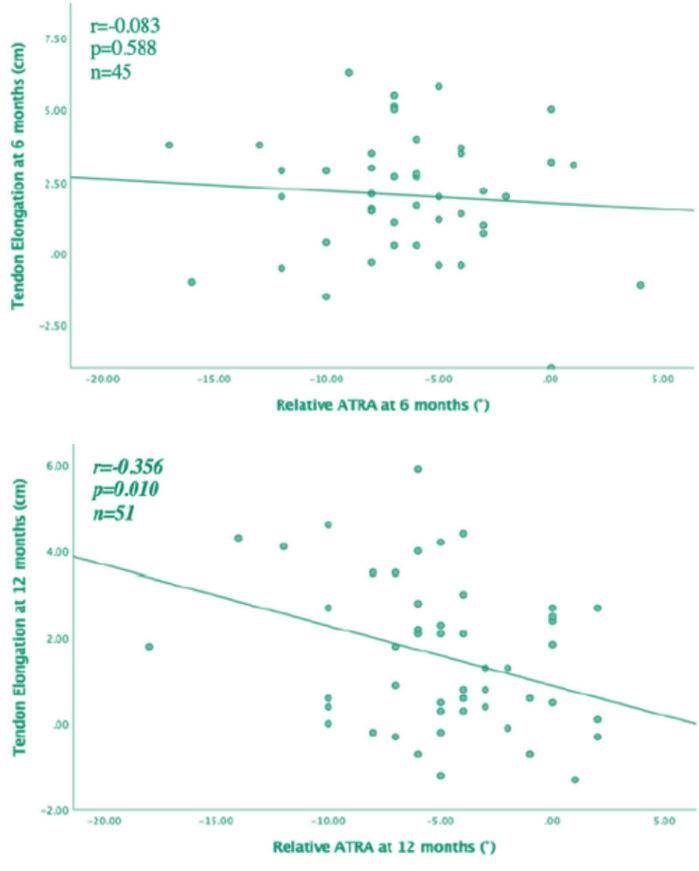

FIGURE 21. These diagrams demonstrate the correlation between tendon elongation and relative ATRA at 6 months (upper panel) and 12 months (lower panel). The line represents the regression model. Tendon elongation is defined as the difference between the injured and the non-injured leg. Relative ATRA is defined as the difference between a non-injured and injured leg (with increased dorsiflexion compared to the non-injured side, resulting in a negative value).

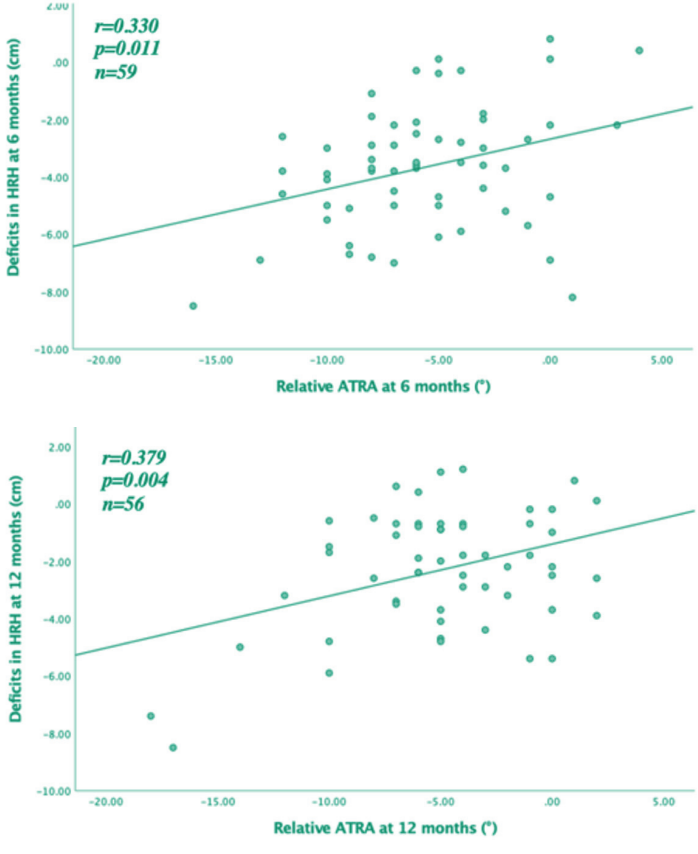

FIGURE 22. These diagrams demonstrate the correlation between deficits in heel-rise height and relative ATRA at 6 months (upper panel) and 12 months (lower panel). The line represents the regression model. The deficits in heel-rise height are defined as the difference between the injured and non-injured sides.

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Patient characteristics and their impact on recovery after acute Achilles tendon rupture

Discussion

Chapter 5

The ongoing debate regarding optimal acute Achilles tendon rupture management persists, albeit with a modified perspective. Most orthopaedic surgeons agree with the reasoning related to individualising the treatment choice. However, there are significant challenges in translating this into evidence-based individualised treatment plans for patients, at least on a group level.

The results of the studies included in this thesis suggest that there is a link between female sex and fear of re-injury, both correlated with inferior self-reported outcomes after an acute Achilles tendon rupture. These variables have previously been demonstrated to correlate with inferior outcomes; however, the studies in the present thesis are based on larger cohorts. The results underline the need for further studies to improve women's treatment. These results indicate that post-treatment duration may be more impactful than previously assumed, particularly from a psychological perspective.

Moreover, the ATRS has an established PASS value of 75 points. The present thesis demonstrates a PASS value exceeding that reported by Cramer et al. [30] for the Danish ATRS. However, there are various potential reasons for this discrepancy, such as cultural differences and different statistical methods. The PASS value for Swedish ATRS provides valuable information for clinicians interpreting the ATRS.

ATRA, combined with other functional tests, is a valuable instrument for identifying tendon elongation which is in line with previous studies [22,149] and underlines the usefulness of ATRA as a clinical tool.

We used US to assess the gap between the tendon ends to guide treatment decisions. The two treatment groups (surgical versus non-surgical) revealed no statistically significant differences in functional and self-reported outcomes. Furthermore, the re-rupture rate was relatively low in both groups. It could be speculated whether the selection based on the tendon gap may have contributed to this outcome. These findings, therefore, contribute to the knowledge and understanding of individualised treatment for acute Achilles tendon ruptures.

Differences in self-reported outcome between women and men

Previous studies indicate that women exhibit poorer self-reported outcomes and functional test performance

than men after acute Achilles tendon rupture [10,100,117,122]. However, the cohort sizes of these studies are small. The under-representation of women in the literature on Achilles tendon ruptures can be attributed to the 4:1 male-to-female incidence ratio. In Study I women reported 79 points on the ATRS versus 84 points by men (p = 0.004). This study included 564 patients, of which 127 (23%) were women.

These results are consistent with those of earlier studies [10,100,117,122]. For instance, Silbernagel et al. [122] observed a difference in median ATRS between surgically treated men and women (92 versus 82, p = 0.021) one year after an acute Achilles tendon rupture. These differences were not seen in the non-surgically treated group. Moreover, there was a difference in heel-rise height at 12 months following injury, with men performing better than women (p = 0.004). These results, concerning differences between men and women, align with Aujla et al., [10] who reported a median ATRS of 76 points for men and 66 points for women (p = 0.013) two years after injury. However, all patients in this study were treated non-surgically.

In contrast, Bostick et al. [17] reported superior functional outcomes in women compared to men following an acute Achilles tendon rupture in surgically treated patients.

Study I included only self-reported outcomes. Therefore, only a subjective picture of the recovery was given with this study design. However, a valid and reliable injury-specific PROM was used.

PROMs are extensively used in research, but it is essential to consider that several factors can influence these measurement results. The respondents may interpret the questions differently or provide responses influenced by their mood or personal bias. Alternatively, respondent scores may mirror what they believe is a desirable response for the physician/physiotherapist. However, the inherent subjectivity of the measurement provides a unique perspective, potentially revealing valuable insights unattainable through functional tests. Such examples are the fear of re-injury and pain.

The reason for the disparity in responses to the ATRS and supplemental questions between women and men regarding treatment and recovery satisfaction remains undetermined. However, several hypotheses merit consideration. One hypothesis is that the PROM's design, interpretation and additional questions may matter. Do men and women answer differently on PROMs? Do men overrate their ability, and do women underestimate theirs?

Should a disparity exist in the recovery of men and women after an acute Achilles tendon rupture, what accounts

for this difference? Are women more cautious following an injury to the Achilles tendon than men, leading to less training and worse function? Moreover, it has been suggested that oestrogen could have a negative effect on tendons. However, these studies are inconsistent [41,72].

The follow-up time in Study I, which ranged from one to six years, could have introduced bias. It may be assumed that patients who respond to the ATRS questionnaire after six years, in contrast to one year, have benefited from the extended rehabilitation. Accordingly, this longer rehabilitation period may result in a higher ATRS for these patients. Despite this finding, Olsson et al. [101] reported an absence of statistically significant differences in ATRS measurements at one and two years post-acute Achilles tendon rupture. A seven-year follow-up was conducted by Brorsson et al. [18]. This study evaluated the functional outcome of patients who had sustained an acute Achilles tendon rupture. Their findings indicated no improvement compared to the two-year follow-up.

Study I achieved a 66% response rate, indicating a significant number of non-respondent patients. It is crucial to acknowledge the influence of this substantial non-response rate on the interpretation of results. The analysis of the non-responders revealed a higher proportion of men (37%) than women (22%) ($p < 0.001$). Moreover, the non-responders were significantly younger, with a mean (SD) age of 43 years (13.7).

The impact of fear of re-injury on self-reported outcome

Studies investigating the role of fear of re-injury after an acute Achilles tendon rupture are scarce. However, similar studies are more common following ACL injuries. Fear of re-injury has been shown to impede resumption of physical activity and sports participation.

Jonsdottir et al. [53] investigated fear of re-injury following an acute Achilles tendon rupture. The authors noted that half of the patient population experienced a level of fear that inhibited physical activity. These results align with Study II, where 56% of the patients (n = 550) reported fear of re-injury after an acute Achilles tendon rupture.

Kvist et al. [68] studied patients who had suffered from an ACL injury. The study assessed the impact of re-injury fear on the return to pre-injury activity levels. Study results indicated a higher incidence of fear of re-injury among patients who had not returned to their pre-injury activity levels [68].

The reason for the large proportion of fear of re-injury following an acute Achilles tendon rupture remains inadequately studied and could not be elucidated in Study II. However, it is reasonable to assume that fear of

re-injury may lead to reduced exercise and rehabilitation training. These patients may be reluctant to participate in activities placing high demands on the Achilles tendon. This theory is also supported by the findings of Jónsdóttir et al. [53]. Alswat et al. [3] performed a study to investigate the fear of re-injury and its contributing factors in active individuals with a history of ACL injury. The study's results showed that fear of re-injury is affected by the frequency of sports participation, knee function and return to activity. Therefore, they recommended individualised strategies to encourage patients to perform sports and physical activities to overcome their fear and decrease the fear of re-injury.

Another perspective about fear of re-injury is that it may be an economic concern. Acute Achilles tendon ruptures commonly necessitate sick leave, the duration of which is occupation-dependent consequently incurring financial losses [145]. In a cost-effective analysis by Westin et al. [145] the mean sick leave was 17.8 days for surgically treated patients and 24.1 days for non-surgically treated patients. Patients who underwent non-surgical treatment experienced significantly longer sick leave. The potential career and economic consequences of time away from work following an acute Achilles tendon rupture may contribute to a fear of re-injury. The highest levels of fear of re-injury were observed in the age group 30-49 years, while the lowest levels were seen in the age group > 70 years. The assumption that economic factors may have an impact is supported by the observation that the age group demonstrating minimal fear is, on average, of retirement age, notwithstanding individual variations.

In Study II we found that a significantly larger proportion of non-surgically treated patients reported fear of re-injury than surgically treated patients (59% versus 48%, ($p = 0.024$)). One potential explanation for this discrepancy is that patients who have undergone surgery may have a stronger belief in tendon strength than those who have not undergone surgery.

PASS for ATRS

The PASS for the Danish ATRS has been reported in a study by Cramer et al. [30]. However, no such values have previously been available for the Swedish ATRS. Study III established a PASS threshold of 75 points for the Swedish ATRS; 66% of participants attained this score. In comparison, the Swedish PASS value was higher than the Danish PASS value for ATRS (57 points at 1 year) [30].

Study III employed ROC analysis to determine PASS. In contrast, Cramer et al. [30] employed a predictive modelling approach, arguing that this method provides a more precise estimate of PASS than ROC analysis. However, given the nature of the anchor questions, ROC analysis was deemed

more suitable. Cramer et al. [30] reported a four-point lower PASS value for their ROC analysis compared to predictive modelling, indicating a significant discrepancy between the studies.

Further comparisons of the cohorts revealed no differences in age or sex distribution as reported by Cramer et al. [30]. However, the Cramer et al. [30] cohort comprised an even greater proportion of non-surgically treated patients (92% at 1 year and 86% at 2 years) compared to the present study's cohort, which included 69% of non-surgically treated patients. Thus, previous studies have not observed significant differences between surgical and non-surgical treatment groups on self-reported outcomes [85,91,99]. However, it is important to acknowledge that cultural factors may have impacted the findings.

The decision to calculate the PASS score only once (unlike Cramer et al. [30] who calculated it at six months, one year and two years) was based on research indicating no significant differences in ATRS between one and two years post-acute Achilles tendon rupture. This approach allowed us to base the PASS analysis on a larger cohort by including patients 12 to 27 months after injury.

The median ATRS in the present study cohort was 80, which aligns with Myhrvold et al.'s [85] results who reported a mean ATRS score of 77 points for non-surgical treatment and 78 points for open repair at 1 year. Given the ATRS's frequent use as a post-acute Achilles tendon rupture outcome measure, numerous studies provide comparative data for Study III's median ATRS value. For example, Nilsson-Helander et al. [91] reported a median ATRS score of 88 points at a 12 month follow-up for surgically treated patients and 86 for non-surgically treated patients. Olsson et al. [99] reported a median ATRS of 90 points at 12 months for the non-surgical group and 89 for the surgical group. The observation that the median ATRS in this study is similar to those reported in other studies provides a methodological strength that contributes to the PASS calculation.

Separate PASS calculations should be carried out on unique translations of ATRS. The PASS value of 75 is only applicable to the Swedish ATRS. Moreover, the study's response rate was only 61%, which should be considered when drawing conclusions. The drop-out rate of 39% may have influenced the results; however, the precise direction is impossible to ascertain.

ATRA and tendon elongation

The correlation between the ATRA and tendon elongation has previously been investigated. Zellers et al. [149] found a moderate negative correlation between tendon elongation and relative ATRA 12 months after an acute Achilles tendon rupture. This finding aligns with Study IV's results, however, Zellers et al.

[149] used an inclinometer instead of a goniometer, potentially compromising the comparability of results. The correlation analysis in Study IV demonstrated a significant negative correlation (r = -0.356) between relative ATRA and tendon elongation at 12 months (p = 0.010).

Moreover, significant positive correlations (r = 0.330 and r = 0.379) were found between relative ATRA and heel-rise height deficits at 6 and 12 months. This result concurs with Carmont et al.'s [22] study, which presented a correlation between absolute ATRA and the LSI of heel-rise height at 12 months. However, we did not use the absolute ATRA or the LSI value; instead, the deficit between injured and uninjured limbs was expressed in degrees and cm.

In the present study tendon length was measured using the extended field of view, a technique previously established as a valid and reliable method [124]. Furthermore, this technique allows for retrospective analysis of measurements, a marked advantage over methods employing needle-marked anatomical landmarks [14]. Brouwer et al. [19] compared the reliability between the extended field of view and the measurement using anatomical markers. The ICC values for all measurements were excellent (0.85-0.96), with anatomical landmarks displaying greater reliability than the extended field of view [19].

The patients included in Study IV did not adhere to a standardised rehabilitation protocol, which may be relevant when discussing the study's results. However, all follow-up measurements were performed by one experienced physiotherapist, which constitutes a methodological strength. The functional follow-up measurements are reliable and validated for evaluation after Achilles tendon injuries [123].

In Study IV the elongation values in the injured tendon observed at the 6 and 12 follow-ups align with previous studies [39,57]. Kangas et al. [57] showed that tendon elongation occurs regardless of treatment regimen and that the elongation occurs during the first months after injury. Eliasson et al. [39] presented results demonstrating elongation up to six months after injury in surgically treated patients.

Ultrasound and tendon gap as treatment selection

The use of US to examine the characteristics of the rupture in patients with an acute Achilles tendon rupture has been a topic of interest since the 1980s. Thermann et al. [134] presented a study more than 35 years ago to compare surgical and non-surgical treatments for acute Achilles tendon ruptures. Patients underwent US and MRI to determine the tendon gap between the tendon ends. The findings indicate no differences in functional outcomes in patients treated

non-surgically with < 5 mm tendon gap compared to those who underwent surgical treatment [134]. Later, in 2011, Amlang et al. [5] conducted a prospective study to classify the characteristics of the rupture site in patients presenting with acute Achilles tendon rupture to individualise treatment selection. Kotnis et al. [66] studied patients (n = 125) with an acute Achilles tendon rupture using US as a treatment selection tool. Non-surgical treatment was applied if patients had a tendon gap of < 5 mm. Patients were treated surgically when a gap was ≥ 5 mm between the tendon ends. The primary outcome of this study was the re-rupture rate. Re-ruptures occurred in 3.4% (two patients) of the non-surgically treated group and 1.5% (one patient) of the surgically treated group [66]. Using US, Westin et al. [144] investigated the tendon gap in patients with acute Achilles tendon rupture. Patients were randomised to either surgical or non-surgical treatment. Patients in the non-surgically treatment group with a gap of > 5 mm between the tendon ends reported significantly poorer self-reported (p = 0.004) and functional (p = 0.048) outcomes than those in the surgically treatment group. Moreover, three of the four patients in the non-surgical group with a gap > 10 mm sustained a re-rupture [144].

The results of Study V show no significant differences in functional and self-reported outcomes between the selected treatment groups with a cut-off value of 5 mm. Moreover, the re-rupture rate of Study V was one patient (2.4%) in the non-surgical group and one patient (1.1%) in the surgical group.

A re-rupture rate of 2.4% for non-surgically treated patients following an acute Achilles tendon rupture is in the lower range of previously described re-rupture rates [9,27,70,85,89,91,94,99,110]. However, a few prospective cohort studies have reported a re-rupture rate of 0%. Arner and Lindholm et al., [9] for instance, reported a 0% re-rupture rate in a study of 92 patients, including 6 treated non-operatively. Qureshi et al. [110] also presented a re-rupture rate of 0% (n=26). All patients in the Qureshi et al.[110] study were treated non-surgically, and the total cohort had a mean gap of 4.8 mm between the tendon ends when the foot was placed in the equinus position.

More recently published data support the theory of a larger tendon gap resulting in inferior function and self-reported outcomes and higher re-rupture rates for non-surgically treated patients [144,147]. The choice of treatment based on the tendon gap may have resulted in a low re-rupture rate, but this needs to be investigated further.

Moreover, the results of Study V revealed that 68% of the patients had a tendon gap of 5 mm. The high number of patients with a tendon gap of 5 mm is notable, especially when considering

that surgical treatment for an acute Achilles tendon rupture is decreasing (approximately 14-15% of patients are treated surgically in Sweden today) [131]. Study I revealed no significant difference in ATRS scores between treatment groups, possibly due to the low surgical treatment rate (28%) reflecting typical clinical practice. This observation prompts a consideration of the optimality of the 5 mm cut-off value. Given that Study I showed an ATRS of 82 points, despite only 28% of the sample undergoing surgical treatment, the appropriateness of this threshold requires further evaluation. What is the optimal cut-off value to minimise re-rupture risk while limiting non-essential surgical interventions? Still, the 5 mm cut-off value is supported by the research of Westin et al. [144] and Kotnis et al. [66].

An important discussion point is the interpretation of the US measurements. The initial plan was to limit the number of radiologists. The constraints of daily clinical practice, however, rendered this infeasible. This resulted in multiple radiologists performing the measurements. Despite the competence of the radiologists at the hospital, the large number may have affected the accuracy of the measurement. Additionally, this study has highlighted challenges associated with US measurements. Therefore, a validation study is currently being conducted to address these concerns.

Swennergren Hansen et al. [46] attempted to develop an individualised treatment algorithm for patients with an acute Achilles tendon rupture. This algorithm incorporates an US measurement technique, performed using a needle to identify the anatomical landmarks [14]. Patients are recommended to receive non-surgical treatment if the tendon ends overlap and the degree of tendon elongation does not exceed 7%. Barfod et al. [13] presented an ongoing RCT with results from 60 patients. No significant reduction in tendon elongation or calf muscle hypotrophy was demonstrated in patients who received treatment according to the algorithm compared to randomisation to surgical or non-surgical treatment. Publication of data on re-rupture rates and functional outcomes is forthcoming.

Limitations

Recall bias may have influenced the results in Studies I, II and III, given that the ATRS and the additional questions were answered by patients one to six years after the index injury. As time passes, there is a risk of recall bias, whereby patients may find it difficult to remember their physical activity before the injury. This recall bias could lead to difficulty when comparing these pre-morbid levels to those observed after injury. Furthermore, patient adaptation to their condition and recalibration of

expectations six years post-injury may influence reported outcomes.

Choosing between an ROC analysis or predictive modelling to establish PASS is not straightforward. However, whether the ROC constitutes a limitation is open to discussion.

For Study IV, a bias may have been introduced due to the non-randomised inclusion of patients. The patient cohort was derived from a restricted number of physiotherapy clinics, potentially limiting the generalisability of the findings. To enhance the sample's representativeness, including patients from a more diverse range of settings, such as the emergency department (which covers all patients from Gothenburg, Sweden), or a multicentre study would be beneficial.

US measurements are highly user dependent. A limitation of Study V is the large number of radiologists, which could have influenced the results. The decision against randomisation was evidence-based, citing a previous study indicating a significantly higher re-rupture rate in the non-surgically treated group when the tendon gap exceeded 10 mm. Furthermore, patients with > 5 mm tendon gap in the non-surgically treated group had significantly impaired functionality [144]. The non-randomised study design resulted in different cohort sizes, which might also affect the interpretation of the results.

Clinical implications

Studying the impact of sex and fear on outcomes after acute Achilles tendon rupture is crucial for treatment optimisation. This could also serve as a critical component in the personalisation of treatment. Although this thesis does not explain why women report worse self-reported outcomes, it does corroborate the existence of this disparity. Moreover, it encourages physicians and physiotherapists to be more attentive to female patients during rehabilitation and follow-up appointments. Because over 50% of patients report a fear of re-injury, and these patients generally demonstrate significantly worse treatment satisfaction outcomes, early assessment of fear and functional follow-up is crucial to identify such individuals. Identifying these patients would allow physicians and physiotherapists to guide rehabilitation programmes toward more relevant and challenging activities.

Clinicians may find the ATRS PASS value helpful during follow-up to identify patients who fail to achieve the expected value and thus may need further support or alternative treatment strategies. Completing the ATRS prior to the clinical visit enables clinicians and physiotherapists to review the patient's progress efficiently.

Identifying tendon elongation is crucial, as it is associated with inferior outcomes. The correlation between

ATRA and tendon elongation furnishes clinicians with additional evidence supporting the use of this measurement. It is a readily available tool that only requires a goniometer. However, it is recommended to use this assessment tool in conjunction with additional assessment instruments, including US and heel-rise height measurements. The use of ATRA in clinical practice may facilitate the detection of tendon elongation, which would facilitate timely intervention.

Using US to help create individualised treatment plans is very valuable for the physician's decision-making but even more important for the patient. However, user dependence needs to be emphasised. Further investigation is required to elucidate the impact of the tendon gap on recovery.

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Conclusion

Chapter 6

- Women, compared to men, report significantly inferior self-reported outcomes one to six years following an acute Achilles tendon rupture.
- Over 50% of patients report fear of re-injury after an acute Achilles tendon rupture. Patients who report fear of re-injury have significantly worse self-reported outcomes.
- The PASS value for the Swedish ATRS 12-27 months after an acute Achilles tendon rupture is 75 points.
- ATRA, combined with other clinical measurements, such as US and heel-rise height, is a valuable tool for indirectly identifying tendon elongation.
- Using US as a selection tool for treatment choice presented no differences in functional or self-reported outcomes. Additionally, the re-rupture rate was low.

To conclude, what is the appropriate management strategy for the male patient described earlier in the Introduction? Recall that this patient sustained an acute Achilles tendon rupture while playing padel. The results of this thesis suggest that the size of the tendon gap may be a relevant factor in treatment selection.

Further in the recovery process, the results imply that awareness of female sex could be important. However, because this patient is of male sex, this is less important in this case. Moreover, in the context of rehabilitation, the eventual fear of re-injury needs to be addressed to develop rehabilitation strategies to optimise recovery. The use of ATRS and ATRA during follow-up may expedite the early identification of potential complications, thereby enabling prompt intervention and management.

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Future perspectives

Chapter 7

Given the rising incidence of Achilles tendon ruptures, an individualised treatment plan that encompasses the appropriate treatment modality and rehabilitation protocol is becoming increasingly necessary. The results of this thesis suggest the importance of considering sex and fear of re-injury as influential factors in recovery. Further research is required to clarify the causative factors underlying discrepancies in self-reported outcomes between men and women following an acute Achilles tendon rupture. A qualitative study may be the most effective next step, offering a more nuanced exploration of key factors.

To identify additional predictors a high-quality national register comprising all acute Achilles tendon ruptures would provide valuable information and increase the generalisability of study results. Such a register could serve as a quality control mechanism for patients with this injury, thereby promoting equitable health care access countrywide. This would also allow for a more comprehensive evaluation of surgical procedures and the impact of varying suture materials and suture techniques.

Further studies are needed to provide an optimal treatment plan for each patient while minimising the risk of re-rupture and surgical complications to achieve the best functional and self-reported outcome. The importance of tendon gap and its measurement accuracy in establishing the distance between tendon ends requires further research. Percutaneous and minimally invasive surgical techniques are more frequently used internationally than in Sweden. An analysis of percutaneous versus open surgical techniques for patients exhibiting a 5 mm tendon gap is warranted to assess potential reductions in wound-related complications.

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Chapter 8

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09

Patient characteristics and their impact on recovery after acute Achilles tendon rupture

Sahlgrenska Universitetssjukhuset ORTOPEDI

Deltagande i studien:

”Incidens, patientrapporterat utfall och konsekvenser av komplikationer samt könsskillnader efter behandling av såväl akuta som kroniska hälsenebristningar på SU/Mölndal under tidsperioden 1:a januari 2015-31:a december 2020.”

Personlig kod:

_____

Jag är:

☐ Kvinna ☐ Man ☐ Icke-binär

Längd i cm:

_____

Vikt i kg:

_____

Ålder:

_____

☐ Din E-mejladress:

_____

☐ Jag har ingen E-mejladress

ALLA frågor nedan syftar på eventuella besvär och omständigheter gällande din behandling av din **skadade** hälsena. Välj det svarsalternativ som stämmer bäst överens och svara kortfattat på följande frågor.

Jag har skadat:

- ☐ Höger hälsena
- ☐ Vänster hälsena
- ☐ Både höger och vänster, men senast var det

Jag erhöll följande behandling för min skadade hälsena:

- ☐ Operation
- ☐ Ej operation

Hur nöjd är du med resultatet av din behandling?

☐ Helt nöjd ☐ Ganska nöjd ☐ Varken nöjd eller missnöjd ☐ Ganska missnöjd ☐ Missnöjd

I hur stor utsträckning är du återhämtad efter din hälseneskada?

☐ Helt och hållet ☐ I stor utsträckning ☐ Varken stor eller liten utsträckning ☐ I liten utsträckning ☐ Inte alls

Hur återhämtad efter din hälseneskada upplever du att du är uttryckt i procent om 100% motsvarar fullt återhämtad och 0% motsvarar inte alls återhämtad

Svar:

Hur fysiskt aktiv är du just nu jämfört med innan du skadade din hälsena?

☐ Mycket mindre aktiv ☐ Något mindre aktiv ☐ Lika aktiv ☐ Något mer aktiv ☐ Mycket mer aktiv

Avstår du någon gång från en aktivitet på grund av rädsla för att skada din hälsena igen?

- ☐ Ja
- ☐ Nej

Om du skulle drabbas av en ny hälsenebristning, vilken behandling skulle du helst erhålla?

- ☐ Operation
- ☐ Ej operation

Upplever du att du fick vara delaktig i att välja behandlingsmetod (operation eller gips/ortos utan operation)?

☐ Ja

☐ Nej

Fick du någon komplikation i samband med din behandling?

☐ Ja

☐ Nej

Vilken eller vilka komplikationer fick du i samband med din behandling? Du kan markera mer än ett alternativ.

☐ Blodpropp

☐ Sårproblem

☐ Infektion

☐ Nedsatt styrka

☐ Annat:

_____

_____

Var erhöll du din sjukgymnastik/fysioterapi?

Svar:

Har du haft någon annan skada eller sjukdom som har hindrat dig att delta i fysisk aktivitet efter din hälseneskada?

☐ Ja

☐ Nej

Har du varit sjukskriven för din hälseneskada?

☐ Ja

☐ Nej

Hur länge var du sjukskriven? Svara i antalet veckor (mellan 0-28 veckor eller > 28 veckor)
Svar:

Hur fysiskt krävande anser du att ditt arbete är?

- ☐ Lätt fysiskt arbete (kontorsarbete)
- ☐ Måttligt fysiskt arbete
- ☐ Tungt fysiskt arbete

Hur lång tid tog det innan du kunde återgå till ditt arbete? Svara i antalet veckor (mellan 0-28 veckor eller > 28 veckor)

Svar:

Hur lång tid tog det innan du kunde återgå till tidigare fysisk aktivitet?

- ☐ <7 månader
- ☐ 7-12 månader
- ☐ > 12 månader
- ☐ Har inte kunnat återgå

Lundberglaboratoriet för Ortopedisk Forskning

ATRS

(Achilles tendon Total Rupture Score)

Alla frågor avser hur du upplever eventuella besvär på grund av din skadade hälsena

Markera med ett kryss i den ruta som bäst motsvarar din uppfattning!

1. Är du begränsad av minskad kraft i vaden/hälsenan/foten?

mycket begränsad											inte alls begränsad	Poäng
	0	1	2	3	4	5	6	7	8	9	10	

2. Är du begränsad av att du blir trött i vaden/hälsenan/foten?

mycket begränsad											inte alls begränsad	Poäng
	0	1	2	3	4	5	6	7	8	9	10	

3. Är du begränsad av stelhet i vaden/hälsenan/foten?

mycket begränsad											inte alls begränsad	Poäng
	0	1	2	3	4	5	6	7	8	9	10	

4. Är du begränsad av smärta i vaden/hälsenan/foten?

mycket begränsad											inte alls begränsad	Poäng
	0	1	2	3	4	5	6	7	8	9	10	

5. Är du begränsad i ditt dagliga liv?

mycket begränsad											inte alls begränsad	Poäng
	0	1	2	3	4	5	6	7	8	9	10	

Achilles Tendon Rupture Score (ATRS)
Version 6, Katarina Nilsson-Helander 2006-03-07

Lundberglaboratoriet för Ortopedisk Forskning

Alla frågor avser hur du upplever eventuella besvär på grund av din skadade hälsena

Markera med ett kryss i den ruta som bäst motsvarar din uppfattning!

6. Är du begränsad när du går på ojämnt underlag?

mycket begränsad											**inte alls begränsad**	Poäng
	0	1	2	3	4	5	6	7	8	9	10	

7. Är du begränsad när du går raskt uppför en trappa/backe?

mycket begränsad											**inte alls begränsad**	Poäng
	0	1	2	3	4	5	6	7	8	9	10	

8. Är du begränsad vid aktiviteter som innebär att springa?

mycket begränsad											**inte alls begränsad**	Poäng
	0	1	2	3	4	5	6	7	8	9	10	

9. Är du begränsad vid aktiviteter som innebär att hoppa?

mycket begränsad											**inte alls begränsad**	Poäng
	0	1	2	3	4	5	6	7	8	9	10	

10. Är du begränsad att utföra hårt fysiskt arbete?

mycket begränsad											**inte alls begränsad**	Poäng
	0	1	2	3	4	5	6	7	8	9	10	

Achilles Tendon Rupture Score (ATRS)
Version 6, Katarina Nilsson-Helander 2006-03-07

Sundberglaboratoriet för Ortopedisk Forskning
Laboratoriet för muskelfunktion och rörelseanalys

Ringa in det alternativ som bäst överensstämmer med din nivå innan du skadade dig.

Fysisk aktivitetsnivå **INNAN SKADA**

Ta hänsyn till vad du arbetar med, samt din fritid, motion och idrott

1 **Knappast någon fysisk aktivitet alls.**

2 **Mest stillasittande, ibland promenad, lättare trädgårdsarbete, eller liknande.**

3 **Lättare fysisk ansträngning omkring 2-4 timmar per vecka, t.ex. promenader, cykling, dans, ordinärt trädgårdsarbete, eller liknande.**

4 **Mer ansträngande motion 1-2 timmar per vecka t.ex. tennis, simning, löpning, motionsgymnastik, cykling (spinning), dans, fotboll, innebandy, tyngre trädgårdsarbete, byggarbete, eller liknande**
***ELLER* lättare fysisk aktivitet (enligt nivå 3) mer än 4 timmar per vecka**

5 **Mer ansträngande motion minst 3 timmar per vecka t.ex. tennis, simning, löpning, motionsgymnastik, cykling (spinning), dans, fotboll, innebandy, tyngre trädgårdsarbete, byggarbete, eller liknande**

6 **Hård träning regelbundet och flera gånger i veckan, där den fysiska ansträngningen är stor**

Ringa in det alternativ som bäst överensstämmer med din nivå just nu.

Fysisk aktivitetsnivå **JUST NU**

Ta hänsyn till vad du arbetar med, samt din fritid, motion och idrott

1 **Knappast någon fysisk aktivitet alls.**

2 **Mest stillasittande, ibland promenad, lättare trädgårdsarbete, eller liknande.**

3 **Lättare fysisk ansträngning omkring 2-4 timmar per vecka, t.ex. promenader, cykling, dans, ordinärt trädgårdsarbete, eller liknande.**

4 **Mer ansträngande motion 1-2 timmar per vecka t.ex. tennis, simning, löpning, motionsgymnastik, cykling (spinning), dans, fotboll, innebandy, tyngre trädgårdsarbete, byggarbete, eller liknande**
***ELLER* lättare fysisk aktivitet (enligt nivå 3) mer än 4 timmar per vecka**

5 **Mer ansträngande motion minst 3 timmar per vecka t.ex. tennis, simning, löpning, motionsgymnastik, cykling (spinning), dans, fotboll, innebandy, tyngre trädgårdsarbete, byggarbete, eller liknande**

6 **Hård träning regelbundet och flera gånger i veckan, där den fysiska ansträngningen är stor**

ELIN LARSSON

10

Patient characteristics and their impact on recovery after acute Achilles tendon rupture

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Chapter 10

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