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REVIEW

Return to sport after surgical repair of the Achilles tendon

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Abstract

Achilles tendon rupture is among the most common sports injuries. In patients with high functional demands, surgical repair is preferred to facilitate early return to sporting function. This article reviews the literature and provides evidence-based guidance for return to sport after operative management of Achilles tendon rupture. A search was performed using PubMed, Embase and Cochrane Library for all studies reporting on return to sport after operative management of Achilles tendon rupture. The review included 24 studies reporting on 947 patients, and found that 65–100% of patients were able to return to sport between 3 and 13.4 months post-injury, with incidence of rupture recurrence 0–5.74%. These findings will help patients and healthcare professionals plan a recovery timeline, discuss athletic functionality post-recovery, and understand complications of repair and risk of tendon re-rupture.

Key words: Achilles tendon repair; Achilles tendon rupture; Return to play; Return to sport

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Introduction

The Achilles tendon is formed from the combination of the distal tendinous portions of the gastrocnemius and soleus muscles, and inserts into the distal-posterior aspect of the calcaneus (O'Brien, 2005). Despite being the thickest tendon in the body, with a high tensile strength, rupture of the Achilles tendon is among the most common and debilitating sports injuries. Although it varies between sports, the prevalence of Achilles tendon rupture is approximately 18 per 100 000 in the general population, with around 4500 patients seeking medical attention for this injury each year in the UK (Boyd et al, 2015; Uquillas et al, 2015). The incidence of Achilles tendon rupture is increasing because of the ageing population (Egger and Berkowitz, 2017). In both elite and recreational sport, injuries occur during training or competition, with the majority occurring in middle-aged males during running or jumping motions (Lemme et al, 2018).

Acute Achilles tendon rupture most often occurs in the midportion, 2–6 cm proximal to the calcaneal insertion point (Tarantino et al, 2020). Patients sometimes describe a popping sensation at the moment of rupture, as if they had been kicked on the back of the leg. It is usually possible to walk after rupture, but raising the heel off the floor on the affected side may no longer be possible after complete tendon disruption. Rupture is usually caused by either a single high-load impact through the ankle in a dorsiflexed position or, more commonly in sporting contexts, an acceleration–deceleration mechanism (Tarantino et al, 2020). Histology may indicate preceding degenerative changes in the tendon, such as increased vascularity, collagen disorganisation and hypercellularity, which reduce its tensile strength and thus increase the likelihood of rupture (Tarantino et al, 2020).

Diagnosis is typically made by clinical examinations via palpation for a gap in the tendon and the Simmonds–Thompson squeeze test. Plain film X-rays can be used to exclude fracture, while ultrasound scanning can differentiate between complete and partial Achilles tendon rupture. A magnetic resonance imaging scan of the ankle joint may be indicated in chronic injuries such as Achilles tendonitis (Baldwin et al, 2016). Achilles tendon rupture can either be managed conservatively or surgically. Despite many studies comparing the efficacy of each approach, it remains a contentious topic (Zhang et al, 2015; Ochen et al, 2019). A key metric for elite athletes after Achilles tendon rupture is the time taken to recover and return to training and competition for their respective sports, commonly referred to as 'return to sport'. Return to sport can be defined as the time taken from the start of

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an intervention, surgical or otherwise, for the player to regain sufficient functionality to partake in their sport once more. The terms 'return to sport', 'return to play', 'return to training' and 'return to competition' are used almost interchangeably between different articles; this article uses 'return to sport' as an umbrella term.

For recreational athletes, time taken to return to sport can be considered a proxy for return to baseline ankle functionality and repair satisfaction. Previously, surgical treatment was favoured for patients with high functional demands, because of the lower reported risk of re-rupture (Ochen et al, 2019). However, there is a paucity of evidence on how surgery for Achilles tendon rupture impacts the likelihood of, and time taken to, return to sport.

This article reviews the literature, provides evidence-based guidance for return to sport after operative management of Achilles tendon rupture and discusses factors that may impact the time taken.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Checklist was used for reporting the results (Page et al, 2021).

Outcome measures

The primary outcome measures were time taken to return to sport after acute Achilles tendon rupture and surgical repair, and percentage of patients returning to sport. Secondary outcome measures included percentage risk of complications, incidence of re-rupture and patient satisfaction.

Inclusion criteria

Randomised controlled trials, prospective and retrospective comparative studies, cohort, case-control studies, case series and case reports reporting time taken to return to sport after surgical Achilles tendon repair after acute rupture were included. Studies were not limited by year of publication. Recreational and elite athletes from all sporting backgrounds were included.

Exclusion criteria

Studies investigating return to sport after surgery for chronic Achilles tendinopathy and those from which raw data on return to sport could not be extracted were excluded. Published protocols, conference papers and unpublished papers were all excluded, as were studies not published in English. Articles discussing animal or laboratory studies, bilateral Achilles tendon ruptures and tendon re-rupture were also excluded.

Search methods

PubMed, Embase and Cochrane Library were searched in August 2021 using the search terms ((‘Achilles Tendon/Injuries’ [Mesh] OR ‘Achilles Tendon/Surgery’ [Mesh] OR ‘Achilles Tendon/Therapy’ [Mesh] OR ‘Achilles Tendon/Transplantation’ [Mesh] OR achilles rupture OR achilles repair)) AND ((‘Return to Sport’ OR ‘Return to Play’ OR ‘Sport’ OR ‘Athletes’)). Reference lists of previously published articles were also scanned.

Data collection

Title screening was initially performed, followed by abstract screening. Full texts were then assessed. Duplicates and studies not meeting the inclusion/exclusion criteria were removed at each step. Study selection was performed independently by two authors.

The following data were then recorded into a spreadsheet from the remaining studies: author, year of publication, study type, patient age, sex, sport, mechanism of injury, method of diagnosis, method of repair, rehabilitation regimen, postoperative patient satisfaction, patient-reported outcome measures, postoperative range of movement and strength, time taken to return to sport, proportion of athletes that returned to sport, complication rate and tendon re-rupture rate. Two authors independently extracted data.

Risk of bias was assessed using the ROBINS-I tool for observational studies and ROB-2 tool for randomised trials (Sterne et al, 2016, 2019). Two authors assessed each study independently and the final scores were reached, discussing and reaching a consensus on disagreements.

Results

Search results and description of studies

The preliminary search identified 815 studies for review; 152 abstracts were screened followed by 39 full texts, and 24 studies were deemed eligible for this review. No additional studies were identified from reference lists. The PRISMA flow diagram is shown in Figure 1.

Six of the studies included in this review were case reports or case series (Uchiyama et al, 2007; Byrne et al, 2017; Fanchini et al, 2018; Rungprai and Phisitkul, 2018; Hagen and Pandya, 2019; Morimoto et al, 2021), one was a case-control study (Sánchez et al, 2007), one was an observational cross-sectional study (Jallageas et al, 2013), four were prospective cohort studies (Kakiuchi, 1995; Jennings et al, 2004; Lansdaal et al, 2007; Saxena et al, 2021), ten were retrospective cohort studies (Gajhede-Knudsen et al, 2013; McCullough et al, 2014; Jack et al, 2017; Schipper et al, 2018; Grassi et al, 2020; 2022; Khalil et al, 2020; Siu et al, 2020; Chauhan et al, 2021; Tramer et al, 2021), one was a retrospective comparative study (Zayni, 2017) and one was a randomised controlled trial (Makulavičius et al, 2020).

Studies were published between 1995 and 2021, including 947 patients and covering basketball, soccer, American football, volleyball, racket sports, running, aerobics, bobsled, handball, rugby, Japanese fencing, martial arts, swimming and gymnastics. Eighteen studies included only elite athletes (Lansdaal et al, 2007; Sánchez et al, 2007; Gajhede-Knudsen et al, 2013; Jallageas et al, 2013; McCullough et al, 2014; Byrne et al, 2017; Jack et al, 2017; Fanchini et al, 2018; Rungprai and Phisitkul, 2018; Schipper et al, 2018; Hagen and Pandya, 2019; Grassi et al, 2020; 2022; Khalil et al, 2020; Siu et al, 2020; Chauhan et al, 2021; Morimoto et al, 2021; Tramer et al, 2021), and five included only non-elite athletes (Kakiuchi, 1995; Jennings et al, 2004; Zayni, 2017; Makulavičius et al, 2020; Saxena et al, 2021). The case series by Uchiyama et al (2007) included both elite and non-elite athletes. Many studies did not mention the methods of repair, and for those that did, surgical repair methods included both minimally invasive approaches or percutaneous and open repair. Appendix 1 outlines the complete study characteristics.

Return to sport

The mean time to return to sport ranged from 3 months (Morimoto et al, 2021) to 13.4 months (Schipper et al, 2018), and the proportion of athletes that return to sport ranged from 65% to 100%. The shortest time for return to sport (3 months) was a case report of a single

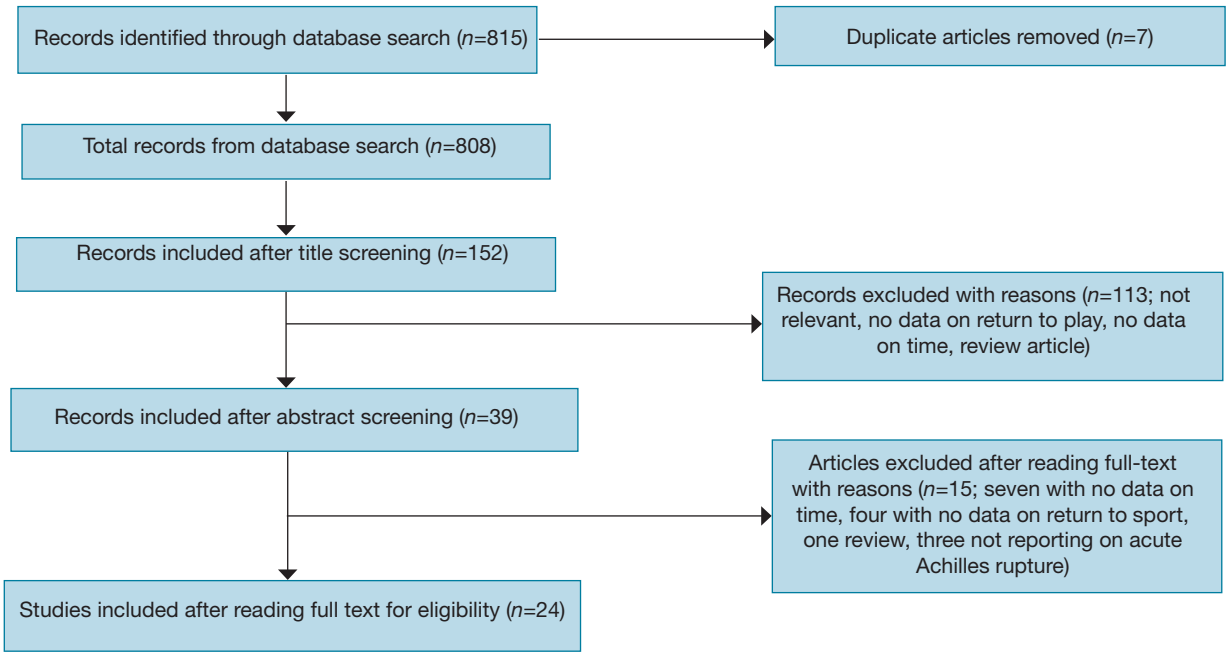

Figure 1. PRISMA flowchart detailing the results from the searches conducted across the databases of PubMed, Embase and Cochrane.

basketball player (Morimoto et al, 2021) who received an injection of freeze-dried platelet-derived factor concentrate 4 weeks post-surgery. No other studies used these injections. The patient had early rehabilitation and physiotherapy starting day 1 post-surgery. The longest time for return to sport (13.4 months) was in a retrospective cohort study of 12 American footballers (Schipper et al, 2018). Participants remained non-weight bearing for 4 weeks, then were put in a tall controlled ankle motion boot before transitioning to a regular shoe by 8–10 weeks.

Secondary outcome measures

Postoperative complications were reported in 16 studies including 594 patients (**Appendix 1**). Of 89 patients reporting complications (15%), the most common was sural nerve injury. Other complications included wound infections, wound dehiscence, keloid, suture reactions, sterile tendon necrosis and non-Achilles complications such as venous thromboembolism.

Re-rupture rates were reported in 16 studies, including 814 participants (**Appendix 1**). The incidence of re-rupture was 1%. The study reporting the highest re-rupture rate (5.74%) was an randomised controlled trial of 87 individuals divided into two groups. The first group underwent repair through an open 'crown' procedure, while the second group underwent percutaneous Bunnell-type repair. Time to return to sport was quicker for the first group (190.91 days vs 217.3 days, P=0.457) (Makulavičius et al, 2020).

Only two studies reported patient satisfaction. In a prospective cohort study by Lansdaal et al (2007), 92% were satisfied with their postoperative result, while the mean visual analogue scale was 9.85 in a randomised controlled trial by Makulavičius et al (2020).

Risk of bias

Risk of bias was assessed using ROBINS-I tool for observational studies and ROB-II tool for the randomised controlled trial. Overall risk of bias was deemed low in one study, moderate in 16 studies and serious in six studies. The randomised controlled trial by Makulavičius et al (2020) was felt to have 'some concerns' about bias. **Appendix 2** shows the full risk of bias assessment.

Discussion

Injuries to the Achilles tendon complex are among the most common injuries sustained during sporting activity and are associated with prolonged rehabilitation and highly variable rates of return to preinjury level of activity. In patients with high functional demands, there remains a preference to treat this injury surgically to facilitate early return to sporting function.

Risk factors for Achilles tendon rupture include intrinsic and extrinsic factors. Intrinsic factors relate to the anatomical characteristics of the athlete and the biomechanics of the sport. Subtalar hyperpronation, excessive rearfoot and forefoot varus, musculotendinous inflexibility and leg length discrepancies can all lead to imbalances in force distribution within the Achilles tendon, increasing the likelihood of rupture. Extrinsic factors include errors in training technique and excessive intensity (failure to allow sufficient time for tendon recovery). Fluoroquinolone antibiotics and corticosteroids have also been linked to delayed repair times for the Achilles tendon, increasing the likelihood of rupture (Hess, 2010).

Time for return to sport

The range of time taken to return to sport was 3–13.4 months (Schipper et al, 2018; Morimoto et al, 2021), which is a considerable variation. One explanation for this is the differing demographics of the study populations. Being a non-elite athlete seemed to decrease the time taken to return to sport. Five studies included non-elite athletes (Kakiuchi, 1995; Jennings et al, 2004; Zayni, 2017; Makulavičius et al, 2020; Saxena et al, 2021), with the remainder focusing on elite athletes. Of those five, the range for return to sport was 4–8.2 months, indicating a skew to the lower half of the overall range found.

The age of the athletes also impacted the time taken to return to sport. Khalil et al (2020), Siu et al (2020), Tramer et al (2021) and Schipper et al (2018) reported the longest times taken to return to sport: 10.1, 11.2, 12.5 and 13.4 months respectively. However, they all

included younger patients with a mean age close to 28 years old, which is on the younger end of the scale of the studies included in this review (the median age being 29.8 years). Studies reporting data from older athletes, such as Fanchini et al (2018), Jack et al (2017) and Jennings et al (2004), reported shorter return to sport times of 4, 5.1 and 4 months respectively, the reasons for which are difficult to determine. One explanation may be that older athletes function at a lower baseline of what is considered a return to sport, whereas younger athletes are more likely to be professionals who require much more rigorous recovery of their Achilles tendon to be fit enough to play once more, as they place much greater strain on their tendon than older athletes. Despite the vast range of time for return to sport, the authors conclude that, with currently available approaches to Achilles tendon repair, most athletes with acute rupture will return to sport within 1 year – only one study reported an average return to sport time of greater than 12 months (Schipper et al, 2018). For those that do return to sport, the rate of re-rupture is low – the highest reported rate being 5.74% (Makulavičius et al, 2020), with a number of studies reporting a 0% re-rupture rate (albeit with varying follow-up times) (**Appendix 1**).

Finally, there is a trend of return to sport for basketball athletes taking longer than for other sports; Khalil et al (2020); Siu et al (2020), Tramer et al (2021) and Chauhan et al (2021) report return to sport times of 10.1, 11.2, 12.5 and 10.4 months respectively. This is markedly higher than for athletes from other sporting backgrounds, indicating that there may be an underlying factor relating to the biomechanics of basketball that impedes recovery.

Rate of return to sport

Return to sport will be achieved by most athletes, with between 65 and 100% of the athletes assessed returning to their respective sports and multiple studies showing a 100% rate of return to sport (**Appendix 1**). The lowest rate of return to sport was in a prospective cohort study of 188 unspecified non-elite sports people – 103 received percutaneous repair while 85 had open repair and the combined return to sport rate was 65.5%. There was no difference in return to sport between the groups. Mean participant age was the highest of all included studies reporting return to sport rates (males 42.5 +/- 12.7 years, females 41.7 +/- 11.4 years). This may suggest that age is a significant factor in determining rate of return to sport after surgical Achilles tendon rupture.

Complications

Although rates of surgery-related complications (ie complications other than re-rupture) varied in terms of both reporting and occurrence, generally the rate of complications was low and the severity usually minor (wound infection, delayed healing, wound dehiscence). Five studies reported no further complications following surgery (McCullough et al, 2014; Byrne et al, 2017; Fanchini et al, 2018; Hagen and Pandya, 2019; Morimoto et al, 2021) and 11 studies reported one or more complications. Sural nerve injury was the most reported – the sural nerve crosses the lateral border of the Achilles tendon at a number of locations, making it especially vulnerable to damage during percutaneous repair (Fletcher, 2001). This is reflected in these studies: Lansdaal et al (2007), Makulavičius et al (2020) and Jallageas et al (2013) all reported sural nerve injuries specifically from methods of percutaneous repair. Sural nerve hypothesia or paraesthesia has a greater impact on the quality of life of professional athletes and, by extension, their satisfaction with surgical repair, as it may impede their future performance. Deep vein thrombosis is another major complication, reported in three cases of percutaneous repair and three of open repair (Jallageas et al, 2013; Makulavičius et al, 2020; Saxena et al, 2021). There was little indication of increased risk with either approach; having only six cases in 860 reported patients demonstrates a low overall risk of developing deep vein thrombosis.

There are limitations to the findings of this systematic review. A high proportion of studies have a high risk of bias, and the review includes multiple retrospective observational studies, case series and case reports. This review also did not control for the level of activity that the athlete returned to when they were deemed to have returned to sport. This is demonstrated in the differing descriptions of the endpoint of return to sport, discussing a return to play, a return to training, or a return to competition. Last, the review reports only on absolute return to sport and does not consider player performance following return to sport.

Comparison with non-surgical approaches

As mentioned, the comparative benefit of surgical and non-surgical approaches to Achilles tendon rupture is not clear. The conclusions of these articles vary between claims of one approach being superior or there being no difference. There is consensus that there is no statistically significant functional benefit for patients from surgical approaches (Keating and Will, 2011; Olsson et al, 2013; Reda et al, 2020). Few articles directly compared differences in time taken to return to sport – Keating and Will (2011) found no significant difference – surgical patients had a mean of 34 weeks, compared to 35 weeks for the non-surgical cohort. The main differentiator between surgical and non-surgical approaches is the re-rupture rate, with Keating and Will (2011), Olsson et al (2013), Cukelj et al (2015) and Reda et al (2020) reporting a lower re-rupture rate with surgical management. As such, despite there being no functional benefit to be gained, a surgical approach may still be the best option for athletes as it minimises the risk of future injury. Rehabilitation protocols have not been covered, but these could be a significant factor influencing the rate of return to sport.

Conclusions

Achilles tendon rupture is a potentially career-ending injury for sportspeople. This systematic review demonstrates that 65–100% of athletes can expect return to sport to be an eventuality, with the exact time taken to return to sport likely to depend on numerous factors around surgical approach and postoperative management, as well as the age at injury, sporting proficiency and the sport itself. Time to return to sport ranges from 3–13.4 months post-injury, and further work is required to assess the statistical significance of each factor. Reported rates of re-rupture are low (0–5.74%), providing reassurance about the reliability of repair. These findings will guide clinicians as they work with patients in planning for return to sport. The best approach to repair following Achilles tendon rupture is still unclear, but current surgical methods offer favourable absolute outcome data for both recreational and elite athletes. Future investigation of discrepancies in results for elite and non-elite athletes may help to clarify which factors (such as better nutrition, intensity of rehabilitation, quality of rehabilitation programme) contribute to the large range of return to sport times reported in this article.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

Key points

- The mean time to return to sport ranged from 3 months to 13.4 months.
- The percentage of athletes that made a return to sport ranged from 65% to 100%.
- Reasons behind these variations appear to include participant age, level of sporting activity (elite vs non-elite athletes) and surgical approach.
- Rates of re-rupture are low, providing reassurance in the reliability of repair.
- Similarly, complication rates are low, with the most reported complication being sural nerve injury.

References

Baldwin A, Hjelde N, Goumalatsou C, Myers G. Oxford handbook of clinical specialties. Oxford: Oxford University Press; 2016

Boyd RP, Dimock R, Solan MC, Porter E. Achilles tendon rupture: how to avoid missing the diagnosis. Br J Gen Pract. 2015;65(641):668–669. https://doi.org/10.3399/bjgp15X688069

Byrne PA, Hopper GP, Wilson WT, Mackay GM. Knotless repair of Achilles tendon rupture in an elite athlete: return to competition in 18 weeks. J Foot Ankle Surg. 2017;56(1):121–124. https://doi.org/10.1053/j.jfas.2016.07.007

Chauhan A, Stotts J, Ayeni OR, Khan M. Return to play, performance, and value of National Basketball Association players following Achilles tendon rupture. Phys Sportsmed. 2021;49(3):271–277. https://doi.org/10.1080/00913847.2021.1932634

Cukelj F, Bandalovic A, Knezevic J et al. Treatment of ruptured Achilles tendon: operative or non-operative procedure? Injury. 2015;46(Suppl 6):S137–S142. https://doi.org/10.1016/j.injury.2015.10.070

Egger AC, Berkowitz MJ. Achilles tendon injuries. Curr Rev Musculoskelet Med. 2017;10(1):72–80. https://doi.org/10.1007/s12178-017-9386-7

Fanchini M, Impellizzeri FM, Silbernagel KG et al. Return to competition after an Achilles tendon rupture using both on and off the field load monitoring as guidance: a case report of a top-level soccer player. Phys Ther Sport. 2018;29:70–78. https://doi.org/10.1016/j.ptsp.2017.04.008

Fletcher MDA. Sural nerve injury associated with neglected tendo Achilles ruptures. Br J Sports Med. 2001;35(2):131–132. https://doi.org/10.1136/bjsm.35.2.131

Gajhede-Knudsen M, Ekstrand J, Magnusson H, Maffulli N. Recurrence of Achilles tendon injuries in elite male football players is more common after early return to play: an 11-year follow-up of the UEFA Champions League injury study. Br J Sports Med. 2013;47(12):763–768. https://doi.org/10.1136/bjsports-2013-092271

Grassi A, Rossi G, D'Hooghe P et al. Eighty-two per cent of male professional football (soccer) players return to play at the previous level two seasons after Achilles tendon rupture treated with surgical repair. Br J Sports Med. 2020;54(8):480–486. https://doi.org/10.1136/bjsports-2019-100556

Grassi A, Caravelli S, Fuiano M et al. Epidemiology of Achilles tendon rupture in Italian first division football (soccer) players and their performance after return to play. Clin J Sport Med. 2022;32(1):e90–e95. https://doi.org/10.1097/JSM.0000000000000879

Hagen M, Pandya NK. Achilles tendon ruptures in young female basketball players: a case series. J Am Acad Orthop Surg Glob Res Rev. 2019;3(6):e016. https://doi.org/10.5435/JAAOSGlobal-D-19-00016

Hess GW. Achilles tendon rupture: a review of etiology, population, anatomy, risk factors, and injury prevention. Foot Ankle Spec. 2010;3(1):29–32. https://doi.org/10.1177/1938640009355191

Jack RA, Sochacki KR, Gardner SS et al. Performance and return to sport after Achilles tendon repair in national football League players. Foot Ankle Int. 2017;38(10):1092–1099. https://doi.org/10.1177/1071100717718131

Jallageas R, Bordes J, Daviet JC, Mabit C, Coste C. Evaluation of surgical treatment for ruptured Achilles tendon in 31 athletes. Orthop Traumatol Surg Res. 2013;99(5):577–584. https://doi.org/10.1016/j.otsr.2013.03.024

Jennings A, Sefton G, Newman R. Repair of acute rupture of the Achilles tendon: a new technique using polyester tape without external splintage. Ann R Coll Surg Engl. 2004;86(6):445–448. https://doi.org/10.1308/147870804957

Kakiuchi M. A combined open and percutaneous technique for repair of tendo Achillis. Comparison with open repair. J Bone Joint Surg Br. 1995;77(1):60–63. https://doi.org/10.1302/0301-620X.77B1.7822398

Keating JF, Will EM. Operative versus non-operative treatment of acute rupture of tendo Achillis: a prospective randomised evaluation of functional outcome. J Bone Joint Surg Br. 2011;93(8):1071–1078. https://doi.org/10.1302/0301-620X.93B8.25998

Khalil LS, Jildeh TR, Tramer JS et al. Effect of Achilles tendon rupture on player performance and longevity in National Basketball Association players. Orthop J Sports Med. 2020;8(11):232596712096604. https://doi.org/10.1177/2325967120966041

Lansdaal JR, Goslings JC, Reichart M et al. The results of 163 Achilles tendon ruptures treated by a minimally invasive surgical technique and functional aftertreatment. Injury. 2007;38(7):839–844. https://doi.org/10.1016/j.injury.2006.12.010

Lemme NJ, Li NY, Defroda SF, Kleiner J, Owens BD. Epidemiology of Achilles tendon ruptures in the United States: athletic and nonathletic injuries from 2012 to 2016. Orthop J Sports Med. 2018;6(11):2325967118808238. https://doi.org/10.1177/2325967118808238

Makulavičius A, Mazarevičius G, Klinga M et al. Outcomes of open 'crown' type v. percutaneous Bunnell type repair of acute Achilles tendon ruptures. Randomized control study. Foot Ankle Surg. 2020;26(5):580–584. https://doi.org/10.1016/j.fas.2019.07.011

McCullough KA, Shaw CM, Anderson RB. Mini-open repair of achilles rupture in the national football league. J Surg Orthop Adv. 2014;23(4):179–183

Morimoto S, Iseki T, Nakayama H et al. Return to the original sport at only 3 months after an Achilles tendon rupture by a combination of intra-tissue injection of freeze-dried platelet-derived factor concentrate and excessively early rehabilitation after operative treatment in a male basketball player: a case report. Regen Ther. 2021;18:112–116. https://doi.org/10.1016/j.reth.2021.05.002

O'Brien M. The anatomy of the Achilles tendon. Foot Ankle Clin. 2005;10(2):225–238. https://doi.org/10.1016/j.fcl.2005.01.011

Ochen Y, Beks RB, Van Heijl M et al. Operative treatment versus nonoperative treatment of Achilles tendon ruptures: systematic review and meta-analysis. BMJ. 2019;364:k5120. https://doi.org/10.1136/bmj.k5120

Olsson N, Silbernagel KG, Eriksson BI et al. Stable surgical repair with accelerated rehabilitation versus nonsurgical treatment for acute Achilles tendon ruptures. Am J Sports Med. 2013;41(12):2867–2876. https://doi.org/10.1177/0363546513503282

Page MJ, Mckenzie JE, Bossuyt PM et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. https://doi.org/10.1136/bmj.n71

Reda Y, Farouk A, Abdelmonem I, El Shazly OA. Surgical versus non-surgical treatment for acute Achilles' tendon rupture. A systematic review of literature and meta-analysis. Foot Ankle Surg. 2020;26(3):280–288. https://doi.org/10.1016/j.fas.2019.03.010

Rungprai C, Phisitkul P. Outcomes and complications following endoscopically assisted percutaneous Achilles tendon repair. Arthroscopy. 2018;34(4):1262–1269. https://doi.org/10.1016/j.arthro.2017.09.027

Sánchez M, Anitua E, Azofra J et al. Comparison of surgically repaired Achilles tendon tears using platelet-rich fibrin matrices. Am J Sports Med. 2007;35(2):245–251. https://doi.org/10.1177/0363546506294078

Saxena A, Maffulli N, Jin A et al. Acute Achilles tendon rupture repair in athletically active patients: results on 188 tendons. J Foot Ankle Surg. 2021;60(5):935–940. https://doi.org/10.1053/j.jfas.2021.01.009

Schipper ON, Anderson RB, Cohen BE. Outcomes after primary repair of insertional ruptures of the Achilles tendon. Foot Ankle Int. 2018;39(6):664–668. https://doi.org/10.1177/1071100718758257

Siu R, Ling SK, Fung N, Pak N, Yung PS. Prognosis of elite basketball players after an Achilles tendon rupture. Asia Pac J Sports Med Arthrosc Rehabil Technol. 2020;21:5–10. https://doi.org/10.1016/j.asmart.2020.03.002

Sterne JA, Hernán MA, Reeves BC et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016;355:i4919. https://doi.org/10.1136/bmj.i4919

Sterne JA, Savović J, Page MJ et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ. 2019;366:l4898. https://doi.org/10.1136/bmj.l4898

Tarantino D, Palermi S, Sirico F, Corrado B. Achilles tendon rupture: mechanisms of injury, principles of rehabilitation and return to play. J Funct Morphol Kinesiol. 2020;5(4):95. https://doi.org/10.3390/jfmk5040095

Tramer JS, Khalil LS, Buckley P et al. Effect of Achilles tendon rupture on player performance and longevity in Women's National Basketball Association players. Orthop J Sports Med. 2021;9(3):232596712198998. https://doi.org/10.1177/2325967121989982

Uchiyama E, Nomura A, Takeda Y, Hiranuma K, Iwaso H. A modified operation for Achilles tendon ruptures. Am J Sports Med. 2007;35(10):1739–1743. https://doi.org/10.1177/0363546507304492

Uquillas CA, Guss MS, Ryan DJ, Jazrawi LM, Strauss EJ. Everything Achilles: knowledge update and current concepts in management: AAOS exhibit selection. J Bone Joint Surg Am. 2015;97(14):1187–1195. https://doi.org/10.2106/JBJS.O.00002

Willits K, Amendola A, Bryant D et al. Operative versus nonoperative treatment of acute Achilles tendon ruptures: a multicenter randomized trial using accelerated functional rehabilitation. J Bone Joint Surg Am. 2010;92(17):2767–2775. https://doi.org/10.2106/JBJS.I.01401

Zayni R. Activity level recovery after acute Achilles tendon rupture surgically repaired: a series of 29 patients with a mean follow-up of 46 months. Muscle Ligaments Tendons J. 2017;7(1):69–77. https://doi.org/10.11138/mltj/2017.7.1.069

Zhang H, Tang H, He Q et al. Surgical versus conservative intervention for acute Achilles tendon rupture: a PRISMA-compliant systematic review of overlapping meta-analyses. Medicine (Baltimore). 2015;94(45):e1951. https://doi.org/10.1097/MD.0000000000001951

Appendix 1. Key findings from the articles included in this review

Reference	Type of study	Sample size	Sport	Method of repair	Rehabilitation	Mean time to return to sport (reported)	Percentage return to sport	Complications	Incidence of rerupture
Siu et al (2020)	Retrospective cohort study	12	Basketball	Unspecified	Unspecified	10.10 +/- 4.07 months	83.30%	Two non-Achilles complications	0%
Khalil et al (2020)	Retrospective cohort study	40	Basketball	Unspecified	Unspecified	11.23 +/- 4.07 months	85.20%	Unspecified	Unspecified
Jack et al (2017)	Retrospective cohort study	95	American football	Unspecified	Unspecified	339.8 +/- 84.8 days	72.40%	Unspecified	2%
Grassi et al (2020)	Retrospective cohort study	118	Soccer	Unspecified	Unspecified	199 +/- 53 days return to play, 274 +/- 114 days return to competition	96%	Unspecified	5%
Rungprai and Phisitkul (2018)	Retrospective case series	23	Unspecified	Endoscopically-assisted percutaneous repair	Non-weight bearing for 2 weeks, splint and sutures removed at 2 weeks and ankle mobilisation with walk boot (dorsiflexion limited to neutral and patients still non-weight bearing until 4 weeks)	5.7 months	78.20%	One superficial wound infection	0%
Byrne et al (2017)	Case report	1	Bobsled	Knotless technique with InternalBrace system, 11 days post injury	Early mobilisation with moon boot and crutches and aggressive physiotherapy	18 weeks	100%	No complications	0%
Schipper et al (2018)	Retrospective cohort study	12	American football, unspecified	11 Haglund's excision, one flexor hallucis transfer. Six suture anchor repair, six had transosseous bone tunnel repair	Non-weight bearing plantar-flexed splint for 2 weeks, then non-weight bearing in plantar-flexed boot/cast, transition to tall Cam boot with 2 cm heel lift at 4 weeks, transition to regular shoe by 8–10 weeks	13.4 months	100%	One wound dehiscence	0%

Appendix 1. Key findings from the articles included in this review (continued)

Reference	Type of study	Sample size	Sport	Method of repair	Rehabilitation	Mean time to return to sport (reported)	Percentage return to sport	Complications	Incidence of rerupture
Morimoto et al (2021)	Case report	1	Basketball	Modified side-locking loop suture technique with cross-stitch technique for peripheral suture. Injection of freeze-dried platelet-derived factor concentrate 4 weeks postoperative	Early rehabilitation and physiotherapy from day 1 postoperative	3 months	100%	No complications	0%
Saxena et al (2021)	Prospective cohort study	188	Unspecified	103 percutaneous repair, 85 open repair	Unspecified	8.2 +/- 2.9 months	65%	Two venous thromboemboli, 13 suture reactions, three infections, 11 wound complications, three surgical excisions of suture material	1.60%
Jennings et al (2004)	Prospective cohort study	22	Eight squash, four badminton, two running, two basketball, two aerobics, two football, ten unspecified	Polyester tape repair	Unspecified	122 days	No record	Three revision operations (two for infected wounds, one for scar release), one sural nerve injury	0%

Appendix 1. Key findings from the articles included in this review (continued)

Reference	Type of study	Sample size	Sport	Method of repair	Rehabilitation	Mean time to return to sport (reported)	Percentage return to sport	Complications	Incidence of rerupture
Grassi et al (2022)	Retrospective cohort study	11	Soccer	Unspecified	Unspecified	170 +/- 35 days return to play, 274 +/- 98 days return to competition	100%	Unspecified	Unspecified
Tramer et al (2021)	Retrospective cohort study	12	Basketball	Unspecified	Unspecified	12.5 +/- 3.3 months	83.30%	Unspecified	Unspecified
Jallageas et al (2013)	Observational cross-sectional study	31	Soccer, handball, rugby, basketball, volleyball	15 percutaneous repair, 16 open repair	Mean of 30 physiotherapy sessions	153 +/- 50 days	77.50%	Five local infections/delayed healing, three paraesthesia in sural nerve, three deep vein thromboses	0%
Zayni et al (2017)	Retrospective comparative study	29	Six badminton, three basketball, ten soccer, one tennis, two swimming, one gymnastics, six not recorded	16 percutaneous repair with tenolig implant, 13 open repair with end-to-end suturing using Krackow technique	Anterior splint maintaining plantar flexion for 21 days, full-weight bearing after 21 days	7.7 months	89.60%	Three wound infections, one sural nerve hypoesthesia, one wound healing delay, one scar adherence	Unspecified

Appendix 1. Key findings from the articles included in this review (continued)

Reference	Type of study	Sample size	Sport	Method of repair	Rehabilitation	Mean time to return to sport (reported)	Percentage return to sport	Complications	Incidence of rerupture
Uchiyama et al (2007)	Case series	21	11 basketball, three badminton, two American football, one soccer, one baseball, one Japanese fencing, one track/field, one kick volleyball	Modified technique with figure of 8 suture and single knot suture	Below-knee cast immobilisation for 1 week, then walking cast, ankle foot orthosis by 2 weeks	5 months	100%	Unspecified	2%
Fanchini et al (2018)	Case report	1	Soccer	Multiple single stitched re-absorbable sutures	Four phases: controlled mobilised, early rehabilitation, late rehabilitation, and return to play	119 days	100%	No complications	Unspecified
Lansdaal et al (2007)	Prospective cohort study	163	Unspecified	Minimally invasive approach	Non-weight bearing for 5 days then semi-rigid tape or soft cast, full-weight bearing after 2 weeks	167 days	76.60%	15 sural nerve injuries, three deep infections, one sterile tendon necrosis, one deep vein thrombosis, four reruptures	1.20%
Sanchez et al (2007)	Case-control study	12	Five soccer, four basketball, one volleyball, two racquet sports	Open repair, six with an additional injection of a preparation rich in growth factors, the other six with conventional open repair	Below-knee plaster cast in neutral ankle position for 2–3 weeks, then active rehabilitation protocol supervised by a physiotherapist	14 +/- 0.8 weeks preparation rich in growth factors group, 21 +/- 3 weeks control group	100%	One wound infection, one keloid scarring	Unspecified

Appendix 1. Key findings from the articles included in this review (continued)

Reference	Type of study	Sample size	Sport	Method of repair	Rehabilitation	Mean time to return to sport (reported)	Percentage return to sport	Complications	Incidence of rerupture
Hagen and Pandya (2019)	Case series	3	Basketball	Non-resorbable suture in running lock fashion on proximal and distal stumps of tendon	Accelerated rehabilitation protocol as described by Willits et al (2010)	6 months	100%	No complications	Unspecified
Kakiuchi (1995)	Prospective cohort study	22	11 kendo, one judo, one karate, two tennis, one badminton, two running, four unspecified	10 open repair, 12 combined open and percutaneous repair	Above knee cast for 1 week, below knee cast for 3 weeks, full-weight bearing after 6 weeks	21.6 weeks group 1, 25.2 weeks group 2	100%	One sural nerve injury	0%
Makulavičius et al (2020)	Randomised control trial	87	Unspecified	Group 1 open 'crown' procedure, group 2 percutaneous Bunnell type repair	Cast for 3 weeks, then walker boot, no formal physiotherapy	190.91 days group 1, 217.3 days group 2	75% group 1, 75.6% group 2	Two keloid scar, two wound dehiscence, three sural nerve damage, one deep vein thrombosis, five partial reruptures	5.74%
McCullough et al (2014)	Retrospective cohort study	9	American football	Minimally invasive approach. Percutaneous Achilles repair system under general anaesthetic	Non-weight bearing for 2 weeks, then removable splint or boot, full-weight bearing in boot with heel lifts at 4–5 weeks, regular shoe wearing at 8–10 weeks	273 days	100%	No complications	0%
Gajhede-Knudsen et al (2013)	Retrospective cohort study	9	Soccer	Unspecified	Unspecified	161 +/- 65 days	100%	Unspecified	0%
Chauhan et al (2021)	Retrospective cohort study	25	Basketball	Unspecified	Unspecified	311.0 +/- 100.9 days	80%	Unspecified	Unspecified

Appendix 2. Risk of bias assessment for the articles included in this review

Reference	Confounding	Participants	Intervention classification	Deviations from intended interventions	Missing data	Measurement of outcome	Selection of reported result	Overall
Siu et al (2020)	Low	Moderate	Low	Low	Low	Low	Low	Moderate
Khalil et al (2020)	Low	Moderate	Low	Low	Low	Low	Low	Moderate
Jack et al (2017	Low	Moderate	Low	Low	Low	Low	Low	Moderate
Grassi et al (2020)	Low	Moderate	Low	Low	Low	Low	Low	Moderate
Rungprai and Phisitkul (2018)	Low	Moderate	Low	Low	Low	Moderate	Low	Moderate
Bryne et al (2017)	Low	Low	Moderate	Low	Low	Serious	Low	Serious
Schipper et al (2018)	Low	Moderate	Low	Low	Low	Low	Low	Moderate
Morimoto et al (2021)	Serious	Low	Low	Low	Low	Moderate	Low	Serious
Saxena et al (2021)	Moderate	Moderate	Low	Low	Low	Moderate	Low	Moderate
Jennings et al (2004)	Moderate	Low	Low	Low	Low	Moderate	Low	Moderate
Grassi et al (2021)	Low	Moderate	Low	Low	Low	Low	Low	Moderate
Tramer et al (2021)	Low	Moderate	Low	Low	Low	Low	Low	Moderate
Jallageas et al (2013)	Low	Low	Low	Low	Low	Low	Low	Low
Zayni et al (2017)	Low	Moderate	Low	Low	Low	Moderate	Low	Moderate
Uchiyama et al (2007)	Low	Low	Low	Low	Low	Moderate	Low	Moderate
Fanchini et al (2018)	Low	Low	Low	Low	Low	Serious	Low	Serious
Lansdaal et al (2007)	Serious	Low	Low	Low	Low	Moderate	Low	Serious
Sanchez et al (2007)	Moderate	Moderate	Low	Low	Low	Moderate	Low	Serious
Hagen and Pandya (2019)	Serious	Low	Low	Low	Low	Moderate	Low	Serious
Kakiuchi (1995)	Moderate	Low	Low	Low	Low	Moderate	Low	Moderate
Makulavičius et al (2020)	Assessed with the Cochrane risk of bias assessment tool version 2 for randomised controlled trials		Deviations from intended interventions (effect of assignment on intervention): moderate	Deviations from intended interventions (effect of adhering to intervention): low	Low	Moderate	Low	Some concerns
McCullough et al (2014)	Moderate	Moderate	Low	Low	Low	Moderate	Low	Moderate
Gajhede-Knudsen et al (2013)	Low	Moderate	Low	Low	Low	Low	Low	Moderate
Chauhan et al (2021)	Moderate	Moderate	Low	Low	Low	Low	Low	Moderate