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Achilles tendon rupture: etiology, diagnosis, prevention, repair, complications and their relation to future sports performance in the athletic population

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Abstract**Summary:**

The Achilles tendon is the most powerful and longest in our body. 20% of all serious tendon ruptures involve the Achilles tendon (AT). An AT rupture can be a career-ending injury. Proven risk factors predisposing and preventing tendon rupture are presented, as well as epidemiological data on the incidence of this disease in the population. In addition, it illustrates currently used diagnostic methods and presents the benefits they bring. Achilles tendon ruptures have a detrimental impact on athletic performance, and the most appropriate treatment method and return-to-play recommendations remain controversial. Recent studies show that operative intervention improves strength and functional results and is more effective compared to non-operative treatment combined with rehabilitation. Currently, according to the latest research, surgical intervention should be used, especially in athletes and very physically active people, because it shortens the time to return to full fitness and allows for better sports achievements in the future. However, you should remember about the complications that may result from such treatment. Nevertheless, the benefits of surgery outweigh the possible losses, especially to the athletic population. The purpose of this study is to comprehensively review the relationship between surgical repair of a ruptured AT and future athletic performance in an athlete population. The available research shows the effectiveness, side effects, complications, and benefits of surgical correction of a ruptured tendon in the athlete population, as well as the quality of performance they are able to achieve after recovery.

Materials and methods:

Materials used in this study were found in the PubMed database, using the following keywords: Achilles tendon”, Achilles tendon rupture”, Return to play”, Athletes injury”, Athletic population”.

Key words: Achilles tendon, Achilles tendon rupture, Return to play, Athletes injury, Athletic population

Introduction:

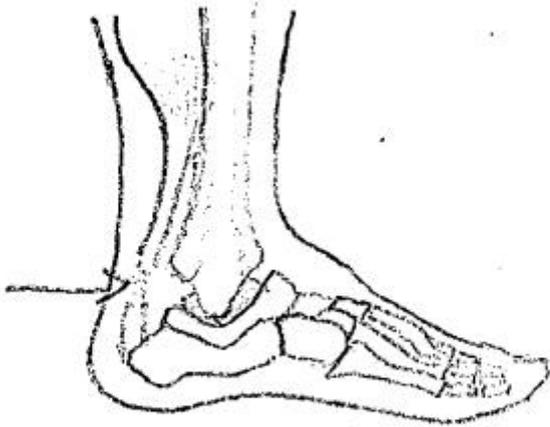
Currently, AT is one of the most common injuries at the lower limb level [1] and 1/5 of cases of tendon rupture [2]. Achilles tendon ruptures (ARTs) are one of the maximum not unusual places for tendon accidents to plague athletes [3]. The estimated incidence of this condition ranges from 11 to 37 per 100,000 inhabitants [4,5]. It is assessed that approximately one million athletes suffer from this injury each year [6].

Anatomy:

The Achilles tendon is the most powerful and widest in our body. It is the conjoined tendon of the gastrocnemius and the soleus muscles and may have a small contribution from the plantaris. On the back of the calf, near the superficial area, you can locate the Achilles tendon. Through the Achilles tendon, they are the main plantar flexors of the ankle [7,8]. The Achilles tendon, which is about 15 cm long, travels distally and twists approximately 90° internally. The fibers of the gluteus that were initially frontal insert laterally, while the fibers of the gluteus that were initially backward insert on the medial face of the Achilles tendon. Blood vessels entering the tendon are safeguarded by the Kager's fat pad situated prior to the Achilles tendon [9]. The posterior tibial artery supplies the proximal and distal sections of the tendon, while the middle part is supplied by the peroneal artery [10]. The middle part has relatively poor blood supply and is most susceptible to degeneration and rupture [11]. Instead of a tendon sheath, the Achilles tendon is composed of a highly vascularized paratenon [4].

Achilles Tendon Rupture

The most common place of tendon rupture - The middle part



Epidemiology:

20% of all major tendon ruptures involve the Achilles tendon [2]. The estimated incidence ranges between 11 and 37 per 100,000 inhabitants [5,12]. When running, jumping, hopping, and skiing, the Achilles tendon is under the most severe loads in the body, with tensile loads up to 10 times body weight [13,14]. Achilles injuries occur annually in 7% to 9% of top-class runners [14], and basketball, volleyball, and squash players [6,15]. According to reports, the incidence rates among athletes fall within 7-18 for runners, 9 for dancers, 5 for gymnasts, 2 for tennis players, and less than 1 for American football players. About 1 million athletes experience Achilles disorders every year [16]. The increase in the incidence of Achilles tendon rupture [3,17] is a result of the aging population, obesity prevalence, and increased participation in sports [18]. Currently, it is one of the most common injuries at the lower limb level. The increase in the incidence of this disease is related to the promotion of physical activity among people. It is widespread among professional athletes and people practicing sports recreationally. According to research, this disease most often occurs in the third and fifth decade of life, more often in men [1], and the risk is 2 to 12 times higher [19]. The majority of ailments in younger individuals are caused by high-energy injuries. However, low-energy injuries like ruptures in chronic Achilles tendinopathy or spontaneous rupture of a degenerated tendon are the primary causes at the age of about the fifth decade and beyond [20].

Etiology:

Forced, sudden plantar flexion of the foot, injuries, degenerative conditions, and long-term tendinopathies are commonly implicated in the disease [21]. Currently, known risk factors for Achilles tendon rupture include poor pre-exercise performance, excessive exercise, previous Achilles tendinopathy, drugs: fluoroquinolone antibiotics, long-term use of corticosteroids oral bisphosphonates, statins, aromatase inhibitors, anabolic steroids, and genetic factors [22,23,24]. The risk is elevated for chronic illnesses like diabetes, hyperparathyroidism, thyroid dysfunction, chronic renal failure, lupus, rheumatoid arthritis, and collagen deficiency. Infections may also contribute to the rupture of the Achilles tendon. The risk of Achilles tendon rupture may be increased by the presence of different kinds of foot abnormalities due to frequent injuries to the musculo-tendinous apparatus of the foot. We include them Cavus foot, Tibia vara, limited ability to perform ankle dorsiflexion, varus alignment with functional hyper pronation, and insufficient gastric-soleus flexibility and strength [25].

Achilles Tendon Rupture

Direct causes

- Injury caused by:
 - poor pre-exercise performance
 - excessive exercise

Indirect causes

- Degenerative conditions
- Long-term tendinopathies
 - Caused by:
 - Drugs (fluoroquinolone antibiotics, long-term use of corticosteroids oral bisphosphonates, statins, aromatase inhibitors, anabolic steroids)
 - Genetic factors
 - Chronic illness (rheumatoid arthritis, diabetes, thyroid dysfunction, hyperparathyroidism, chronic renal failure, lupus, collagen deficiency)

[21,22,23,24]

Diagnosis:

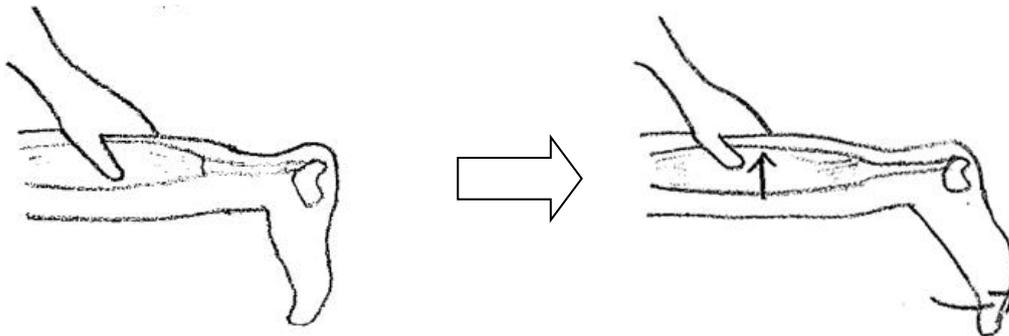
In order to make a diagnosis of Achilles tendon rupture, the most important thing is to take a thorough history and conduct a conscientious physical examination [26]. In most cases, patients are in their third or fifth decade of life [18]. They are characterized by a sudden loss of the ability to walk and sharp, throbbing pain when trying to jump or run. The common symptoms include difficulty walking without or with weight and limping. In addition, numerous patients have reported that when dorsiflexing their ankles, they hear a pop in the back of the lower limb or feel a kick at the ankle's back [26]. The Thompson test is the most common and straightforward clinical test that happens during a physical exam. The procedure is done while the patient is on their stomach and their lower limb is bent straight at the knee joint, pressing on their calf muscle. Suppose the Achilles tendon ruptures, plantar flexion of the foot is not present or very limited [27]. Intact extrinsic foot flexors can cause plantar

flexion to produce a false-negative Thompson test result, which is why approximately 25 acute ruptures are initially neglected [26]. To establish the diagnosis of acute Achilles tendon rupture, it is necessary to perform two or more of the following physical examination tests as per the clinical practice guidelines of the American Academy of Orthopedic Surgeons: a positive Thompson test, presence of a palpable defect, increased passive ankle dorsiflexion with gentle manipulation and decreased plantar flexion strength [28].

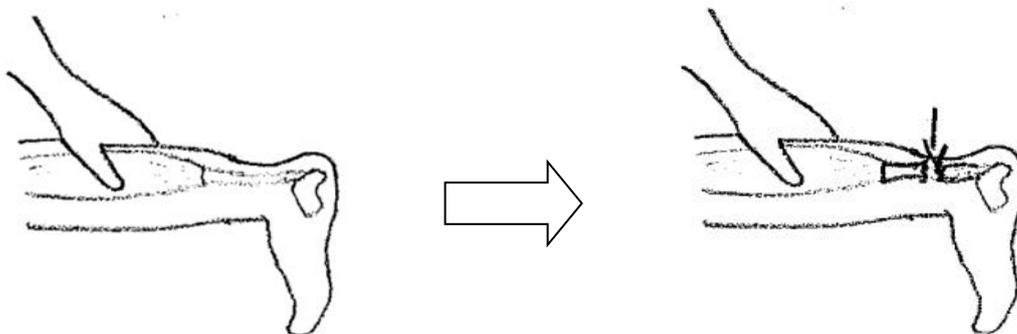
The Thompson test

1. The patient lies on his stomach with the examined, lower limb straight at the knee joint.
2. The examiner presses on the calf muscle.
3A. Negative - under the influence of pressure on the calf muscle, the foot is plantarflexed.
3B. Positive - under the influence of pressure on the calf muscle, plantar flexion of the foot does not occur.

3A.



3B.



[27]

Ultrasound examination (USG) is very important in the diagnosis of the disease. This is the preferred first-line diagnostic imaging method [29]. Due to the anatomy of the tendon, it is easy to visualize it with this test. Moreover, it is also a very safe test [30]. A rupture of the Achilles tendon has a characteristic appearance during an ultrasound examination at rest, namely, a void is visible at the site of its rupture. However, during dynamic testing, the tendon gap between the state of the ankle at rest and in plantar flexion can be quantified. On this basis, patients are qualified for surgical correction [31]. The dynamic test is not performed in real-time, it is only a comparison of two static images. Therefore, an ultrasound examination combined with the Thompson test (RAUT) is much more measurable and valuable. Especially if there is doubt about the diagnosis [32]. It allows for more accurate visualization of the Achilles tendon laxity and morphological changes typical of its rupture, such as a hypoechoic zone, most often in its central part, tendon swelling, accumulated fluid under the tendon, and the image of a shooting target on transverse images [33]. The RAUT test has high specificity and sensitivity, which allows for reliable tendon assessment and diagnosis [32]. Magnetic resonance imaging (MRI) is also used in diagnostic imaging. In addition is a very accurate method. This examination should be performed at 3T and include the sagittal and axial planes as well as a combination of fat-saturated sequences (e.g., STIR and fat-saturated T2-weighted or proton density-weighted sequences). By means of this examination, it is feasible to ascertain whether the tendon has been torn and, if so, to what degree [34]. X-rays of the lateral ankle are also an important examination in diagnosis and qualification for surgery. They enable the identification of tendon edema and increased density of soft tissue in the Kager fat pad, as well as the detection of calcific changes and Heglund's eminence. It is also possible to visualize whether there has been a fracture of the heel bone, which, together with visible calcifications, may suggest a degenerative cause of the disease or chronic tendinosis [35].

Prevention:

The primary strategy to prevent Achilles tendon rupture is to avoid the degenerative changes within the tendon [36]. It could be very essential to preserve the power of collagen [37] and right blood circulation, which is ensured through normal bodily activity [38]. Regular physical activity, specifically with warm-up periods, will increase the tissue temperature, increase blood delivery, and enable prepare the tendon for loading [38]. Additionally, regular exercise, especially stretching, leads to tendon hypertrophy, increased tensile strength, and lengthening of the musculotendinous unit leading to decreased strain during ankle motion

[39]. The extensibility of the fibers increases with the warm-up time [40]. It is likewise crucial to strengthen the strength of the ankle plantar flexors, as it helps prevent Achilles tendon rupture [41]. Anatomical foot defects are a risk factor for this disease, therefore the use of corrective shoe inserts in the case of varus and valgus deformity of the hind and forefoot has a preventive effect. Moreover, in some cases, corrective orthoses can be used to correct incorrect foot positioning [41]. It is also recommended to use risk medications with caution, such as fluoroquinolones or corticosteroids [42].

Treatment methods:

Currently, Achilles tendon rupture can be treated conservatively or surgically. The issue of discussion is the selection of the appropriate course of treatment. The conservative concept is to apply an equine cast quite early and wear it for 6-8 weeks to bring the edges of the ruptured tendon closer together and facilitate healing. The surgical concept consists of two methods: open and percutaneous. Surgical methods are more often recommended to athletes by experts due to faster recovery, reduced frequency of recurrences, and faster return to sport [43,44]. Currently used AT repair techniques involve approximating the free ends of the torn tendon and connecting them. We distinguish between open and percutaneous repair with its modifications. Pen correction involves making incisions of different lines depending on the method used (straight, inverted L, lazy S). The Achilles tendon is debrided until only healthy tendon fibers are seen. There are several methods for repairing AT: Kessler, Bunnel, Krakow, and Giftbox techniques. The most satisfactory effect is provided by the Kraków and Giftbox techniques [45]. The percutaneous method was first used in 1977 by Ma and Griffith [46]. Despite the lack of clear guidelines, research shows that the percutaneous surgical method is preferred for athletes due to the faster recovery time and full physical activity [47,48]. The technique of percutaneous suturing of the Achilles tendon requires the use of 10 skin incisions, 5 alongside the lateral and 5 alongside the medial fringe of the Achilles tendon. In this way, we obtain a minimally invasive option to repair the Achilles tendon. With the development of new technologies, modifications to this method were created, which improved it and gave more favorable results. These include ultrasound, endoscopic, and mini-open techniques [49,50,51]. Any surgery may result in complications, the most common of which include sural nerve damage, postoperative wound infection, and adhesions. Nevertheless, compared to conservative treatment, it gives a greater chance for a faster and more reliable return to full fitness, which is important for professional athletes [52,53] which this type of injury may exclude them temporarily or permanently from the sports discipline in

which they perform [54,55,56]. An aspect of treatment that clearly reduces the risk of recurrence in patients, regardless of whether they are treated non-surgically or surgically, is the implementation of functional rehabilitation, which should be included in the post-operative rehabilitation plan [57]. People after surgical correction of the disease show better early and late functional results, for example in tests such as the jump test or the heel raise muscle endurance test. The fact that surgical patients are rehabilitated faster is probably also important in achieving such improvement [58,52]. Researchers showed that within 18 months after the event, people undergoing surgery experienced a 10–18% increase in strength and a 14% increase in maximum torque compared to patients treated conservatively [55]. In the population of athletes, it is important to quickly regain full physical functionality of the lower limb, quickly return to training, and, above all, minimize the maximum risk of re-injury, which is ensured by surgical intervention [54,55,56,58,59]. It is unclear which surgical procedure is best for athletes, but several studies suggest that percutaneous repair provides better cosmetic results, lower costs, and yet comparable functional outcomes and complication rates compared to open repair [60,61,62].

Complications and their relation to future sports performance in the athletic population:

In 2017, the American Journal of Sports Medicine conducted a study observing the return to professional play of a population of athletes (NBA, NFL, MLB, and NHL) 1 and 2 years after surgical treatment of a ruptured Achilles tendon in 1989-2013. It has been shown that professional athletes often report a decline in their athletic performance regardless of the management plan chosen. Over 30% of respondents did not return to professional sports. The group that returned to professional play one year after surgery was characterized by suboptimal levels of performance, fewer match appearances, and shorter playing time. However, the group that returned 2 years after the event did not show statistically significant differences in the level of results. This suggests that a portion of the population of athletes who return to competitive sports one year after the event should expect their baseline performance to improve over time [63]. Based on the study Mai HT. (2016), lower performance, shorter game time, and fewer games played were observed in NFL players returning to professional play after the first year after the incident [63,64, 65]. However, if the return to professional play took place 2-3 years after the event, athletes more often return to their original level of play, and the number of matches played is the same as the period before the Achilles tendon rupture. Nonetheless, the estimated duration of their NFL career is shorter than that of healthy individuals [64, 66]. A meta-analysis by John et al. based on 15

studies, showed a 76% return to play (RTP) rate among professional athletes, while the average time to achieve it is approximately 11 months [67]. Similar results were presented by a meta-analysis by Zellers et al. Covering 85 studies, namely an RTP rate of 80% [68]. The RTP rate varies depending on the sport. It is the highest in the European group of football players and is approximately 96%, as shown by the research of Grassi et al. [69]. There is a large discrepancy in the results of the RTP index among football players (NFL), which, depending on the study, ranges from 61.3 to 92.5% [63,64,66,70,71]. In basketball (NBA), the RTP rate varies from 68.0% to 79.5% depending on the study [69,72,73]. In studies by Mavrodontidis A et al., and Hyer CF et al. asymmetries of calf strength were observed in a large proportion of subjects [74,75]. However, studies by Minhas SV et al. Jack RA 2nd et al. have shown that this phenomenon is most common among sports such as athletics, football, and basketball [66,72,73]. This correlation is probably due to the characteristics of the styles of these games, which involve series of jumps, short sprints, and frequent stopping and resuming movement. A meta-analysis by Zellers et al. showed that the ability of the studied population of athletes to perform the physical demands generated by specific disciplines is often limited due to the weakening of the muscles thus reducing their endurance. In some cases, this condition lasted up to 10 years after the injury [68]. One of the factors that may influence the value of the RTP index is the age of the athlete when the Achilles tendon was ruptured. As the age at onset of injury increases, the risk of poorer treatment outcomes increases [69] in the study by Carmont et al. It has been shown that the most important risk factor influencing functional results one year after surgery is age. Age over 30 years is associated with an increased risk of returning to play at the same level (OR = 4.46, p = 0.030), and an increased risk of another break in the first two seasons after RTP (OR = 6.36, p = 0.030). 0.05), as well as an increased risk of postoperative complications, such as surgical site infection, nerve damage, and wound healing complications [76]. Long-term, younger Achilles tendon rupture reconstruction patients have also been shown to experience less tendon lengthening, which correlates with an increased chance of regaining ankle plantarflexion and more successful AT recovery [76]. The study by Wise PM et al. showed that the presence of tendinosis in NFL and NCAA players affects the RTA value [71]. Tendinosis is a natural process accompanying aging, which involves a reduction in the tensile strength of collagen and a reduction in blood supply to specific areas of the tendons [77]. These changes lead to tendon stiffness, facilitate injury, and cause poor wound healing [14].

Overload injuries in people who regularly practice sports are quite common and usually end with a tendon rupture due to poor blood supply, especially in the central area [78].

Conclusion:

The Achilles tendon plays a very important role in the body by stabilizing the ankle joint, and its injuries have a significant impact on human sports activity. Moreover, Achilles tendon rupture affects the sports performance of professionals. In the professional athlete population, surgical treatment of this injury is preferred. Despite the lack of specific guidelines, percutaneous repair is recommended due to better cosmetic results, lower costs, and at the same time comparable functional results and complication rates compared to open repair. This method of repairing the injury is an excellent choice for people practicing competitive sports. Operative intervention in the event of a rupture of the Achilles tendon gives a good chance for quick recovery. Any surgery carries a risk of complications and failure, although surgical treatment of a ruptured Achilles tendon in athletes has more advantages than disadvantages. In the population of athletes, the RTP index is high and oscillates around 80%. Return to full fitness is possible, although less often in the first year after surgery, more often within 2-3 years. A rupture of the Achilles tendon is not a sentence that ends the career of a professional athlete. Selecting the appropriate treatment algorithm usually results in a return to playing at a high level.

Disclosure

Author's contribution

Conceptualization, Marta Skorupska, Magdalena Joanna Czczotka and Martyna Magdalena Martka; methodology, Justyna Śliz, Aleksandra Natalia Popławska and Krzysztof Woźniak; software, Marta Skorupska, Martyna Magdalena Martka and Krzysztof Woźniak; check, Natalia Aleksandra Popławska, Justyna Śliz and Magdalena Joanna Czczotka; formal analysis, Marta Skorupska, Natalia Aleksandra Popławska and Krzysztof Woźniak; investigation, Martyna Magdalena Martka, Justyna Śliz and Magdalena Joanna Czczotka; resources Justyna Śliz, Marta Skorupska and Martyna Magdalena Martka; data curation, Magdalena Joanna Czczotka, Krzysztof Woźniak and Natalia Joanna Popławska; writing-rough preparation, Marta Skorupska, Martyna Magdalena Martka and Krzysztof Woźniak; writing- review and editing Justyna Śliz, Natalia Aleksandra Popławska and Magdalena Joanna Czczotka; visualization, Natalia Aleksandra Popławska, Krzysztof Woźniak and

Justyna Śliz; supervision, Marta Skorupska, Magdalena Joanna Czeczotka and Martyna Magdalena Martka; project administration Justyna Śliz, Marta Skorupska, Magdalena Joanna Czeczotka and Natalia Aleksandra Popławska; All authors read and agrees with the published version of the manuscript.

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Conflict of Interest Statement

The authors of the paper report no conflicts of interest.

Data Availability Statement

The data presented in this study are available upon request from the correspondent author.

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