Possible Effects of Ankle Taping on Achilles Tendon Strain and Risk of Achilles Tendon Rupture

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Abstract

Achilles tendon ruptures (ATRs) are the most common tendon tear in the human body and affect countless patients every year. However, in the NFL, the number of players suffering ATR each year has grown 300% to 500% in the past 25 years, leading researchers to believe that there may be another factor heightening the risk of ATR for these high performance athletes. Ankle tape is worn religiously by NFL athletes every week, and while it does have proven stabilizing benefits for the ankle, it may shorten the effective length of the tendon through compression. Ankle taping has also been found to limit dorsiflexion of the ankle and time to peak force in the lower extremities. By making the tendon tighter and reaching peak force faster, this puts the tendon in a vulnerable position for ATR. The purpose of this proposed study is to take a cohort of offensive and defensive players from the Stanford men's football team and measure the strain experienced by the achilles tendon under force for both taped and untaped ankles. After comparing these strains, we can compare the results to our original hypothesis that ankle tape increases the strain experienced by the achilles tendon and propose solutions to maximize ankle stabilization without putting the achilles tendon at risk.

Introduction

The achilles tendon is the largest and strongest tendon in the human body connecting the gastrocnemius and soleus muscles to the calcaneus bone in the heel. It comprises 3 sub tendons, the medial gastrocnemius subtendon, lateral gastrocnemius subtendon, and soleus subtendon, which are intertwined and all have slightly different tensile properties, which can all be approximated to have linear dynamics. It is this multi subtendinous structure that gives the achilles tendon its strength, being able to withstand forces 8 to 10 times larger than its patients bodyweight (Adam et al., 2023). However, despite these strength properties, achilles tendon rupture (ATR) in athletes affects over 1,000,000 athletes annually across a variety of different sports (Shamrock et al., 2023). This figure is particularly applicable to the National Football League (NFL) which haas seen drastic increases in ATR rates over the past 25 years. From 1980-2002, the NFL averaged between 4 and 5 ATRs per year. Unfortunately, this average has risen significantly, as from 2009 to 2014, 13 to 16 players suffered ATRs each year, while a record high 22 players, including notable stars such as Aaron Rodgers and Kirk Cousins, were sidelined with ATRs this season (Hewett et al., 2024). There is no definitive answer regarding why ATRs have become so much more prevalent over the past decade, but it is a growing concern for NFL players that must be addressed.

ATR occurs most commonly due to extreme dorsiflexion of the foot coupled with a high impact force, causing the tendon to stretch beyond its peak strain and rupture. These injuries are largely non contact with Aaron Rodgers' occurring as he spun away from a tackle trying to avoid a sack, and Dre Greenlaw's occurring while planting to run out onto the field for a defensive possession. Patients with ATR will often hear a loud pop and experience high levels of swelling and pain in the heel. Ruptures are most commonly seen in the weakest part of the achilles which is the band from about 2 cm to 6 cm above the attachment to the calcaneus bone (Tarantino et al., 2020). Ruptures can be treated either operatively or non operatively depending on the demographic of the patient. The nonoperative treatment includes rest, ice, and intensive rehab in order to strengthen the muscles around the ankle and regain range of motion. This treatment is most often only recommended for older patients with a relatively sedentary lifestyle or patients who are at high risk of experiencing complications upon undergoing surgery. Thus, most patients, especially athletes, will opt for the surgical treatment. The tendon can be surgically repaired via three different procedures: open repair, mini open repair, and minimally invasive repair, each of which have their own benefits and drawbacks. Surgery is then followed by intense rehab and return to play after about 9 months (Shamrock et al., 2023). However, rehabilitation after ATR reconstruction lacks standardized guidelines, with limited evidence available for an optimized regimen. This makes the return to play process for athletes post-ATR complex, with objective criteria for determining readiness still lacking. Mechanisms of injury, treatment modalities, and rehabilitation principles are essential considerations in addressing ATRs comprehensively and improving outcomes for affected individuals, especially athletes aiming to return to pre-injury levels of performance (Tarantino et al., 2020).

Hypothesis

One of the more interesting possible contributors to ATR in the NFL was ankle taping. Specifically in the NFL, around 50% to 60% of players get their ankles taped weekly for a variety of reasons. Medically, ankle tape is an important factor in decreasing the risk of ankle sprains by stabilizing the medial and collateral ligaments and reducing side to side rotation of the foot. However, some players are said to wear ankle tape for every game for superstitious reasons while others use bright colors for their ankle tape as somewhat of a fashion statement (Callaghan, 1997).

While ankle taping is beneficial for decreasing the risk of ankle sprains and stabilizing the ankle, it also may pose a greater risk of ATR to players. Various studies have shown that ankle taping has adverse biomechanical effects on load and flexion in the lower extremities. First, ankle taping decreases dorsiflexion of the foot by isolating the ankle in a fixed position (Cordova et al., 2005). This is indicative of a tight or effectively shorter AT.

Researchers also found that ankle taping caused athletes to reach peak muscle forces faster than without stabilizers (Riemann et al., 2002). The increased force experienced in the muscles coupled with the tighter tendon, increases risk of ATR by coupling the decreased time to reach peak force with decreased dorsi flexibility, and could provide an explanation for the staggering increase we've seen in ATRs in the NFL.

$$F = k\Delta L$$

Eq. 1. Hooke's Law

$$\varepsilon = \Delta L/L$$

Eq. 2. Strain

Biomechanically, we can approximate our achilles tendon as a spring. As seen in Eq. 1, force is associated with a change in length (ΔL). Assuming that no other properties of the tendon change with taping other than its length, we can use Eq. 2 to inform us that a shorter taped tendon would experience more strain for a given force. Given a typical stress-strain curve, as seen in Fig. 1 below, tendons have a toe region of low strain, followed by a linear region with a high rate of strain change, and finally a plateau region followed by the ultimate rupture of a tendon. Given this model, we expect a higher strain for a given force will ultimately cause the tendon to reach peak strain faster, resulting in an ATR.

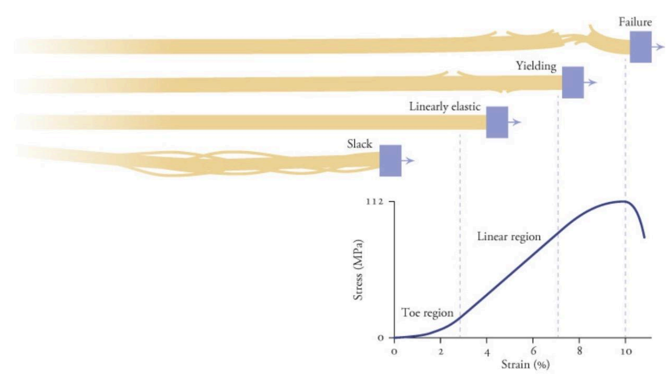

Figure 5.7 Tendon stress–strain relationship.

Figure 1. Stress vs. Strain of typical tenon (Delp & Uchida, 2020)

As evident in previous studies, ankle taping decreases dorsal flexibility, which could be an indication of achilles constriction. By binding the lower part of the ankle, taping could change the virtual insertion of the tendon from the calcaneus to higher up on the ankle, effectively shortening the tendon through compression. This leads us to our ultimate hypothesis that ankle taping shortens the achilles tendon, causing it to experience higher strain and, thus, increasing the risk of ATR.

Methods

Study Parameters

We are interested in analyzing achilles tendon strain across a range of forces: specifically, how the strain of an achilles tendon with a taped ankle compares to that of an non-taped ankle. For the sake of this study, we will model the AT as a monolithic structure that acts with linear, spring-like dynamics (seen above in Eq. 1 and Eq. 2) as opposed to a more complex, perhaps more accurate model that incorporates three intertwined, nonlinear sections. Ultimately, we want to derive two parameters: force and strain.

Data Collection

To derive these parameters we will utilize the Humac Norm, an isokinetic extremity machine and dynamometer. We will begin by applying a range of forces to the distal part from the plantar side of the foot to induce dorsiflexion. This will create a moment about the subject's ankle. We will use anthropometric data from 2017 to estimate the moment arm length of the tendon to derive the force experienced by the muscle (Patel & Labib, 2018).

To measure strain, we will utilize a non-invasive, though somewhat costly and time consuming, method: ultrasound imaging. Mifsud et al. used a form of ultrasound called supersonic shear wave elastography to characterize the achilles tendon. Fig. 2. illustrates the joint use of a dynamometer and an ultrasonic transducer on a subject's shank. When analyzing the ultrasonic image, a superficial ultrasound-absorbing marker was used in addition to landmarks – such as the musculo-tendonous junction of the gastrocnemius – to determine changes in tendon length. These landmarks should be horizontal to the direction of force applied to the tendon.

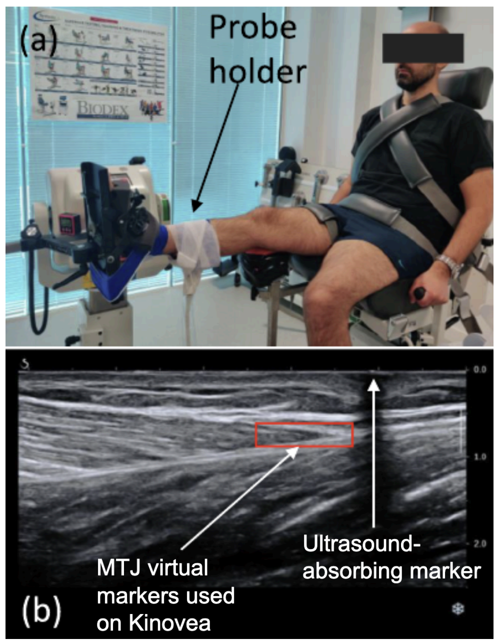

Figure 2. Figure (Mifsud et al., 2023) of measurement apparatus and ultrasonic landmarking.

Strain can be calculated by first measuring the resting length of the tendon: the length between two of our landmarks when no force is applied to the foot. Then we will increment the force applied to the foot. A typical weight-bearing ankle flexes as much as 34.7 degrees, so we will aim to increment from neutral in 5 degree steps, as determined by the operator to get at least 5 data points, or until the subject experiences discomfort (Baggett & Young, 1993). This will give us an array of pairs of data points (tendon force, tendon strain) associated with each test.

Study Design

For our study, we are interested in decreasing compounding factors as much as possible. To do so we would like to limit our subject pool to male athletes competing at the collegiate level and above. We know anecdotally that ankle taping is a requirement on the Stanford Football team, so we think this would be an ideal group from which to take subjects.

Previous research, such as the Mifsud et al. study, uses subject sizes of around 15-25 people, believing that this sample size is large enough to generate useful and statistically significant data. We plan to take 15 defensive and 15 offensive players from the Stanford Football team. We will forgo both offensive and defensive linemen due to their relative extreme size: the impact of excessive weight on ATR in elite athletics is beyond the scope of this paper. Furthermore, we will seek athletes that have had no chronic lower-extremity injuries.

Finally, we would like to control the ankle taping with just one athletic trainer, who will use the same tape method for each of the subjects. This trainer should be employed at the collegiate level or above. Each athlete will have both of their AT measured by the Humac Norm-ultrasound apparatus before getting their ankles taped – and once again more after both of their ankles are taped.

To try to isolate against possible effects of stretching, we will have our subject pre-stretch their AT before each Humac Norm-ultrasound measurement by standing on a slant board calf stretcher for 20 seconds.

Data analysis

We will use a one-way ANOVA analysis of our predictors (taped v. not taped) and our response variable (peak stress). Our p value of statistical significance will be $p < 0.05$. If our study were to be repeated – but with an array of different trainers, taping methods, brand of tape, etc. – we would add a post-hoc analysis to see if these additional variables indeed impact the results of our two groups. We expect to see a statistically significant separation between our predictors as seen in Fig. 3, where Force = ankle moment / tendon moment arm.

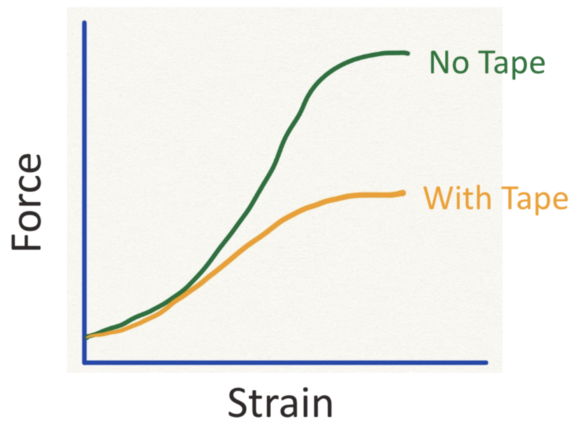

Figure 3. Simulated results of a Stran v. Force curve of an AT with tape and an AT without tape.

In addition, we want to create a Strain v. Force curve for each subject. This way we can visually inspect how strain changes across the ankle's range of motion. Furthermore, if we are stepping in 5 degree increments, we are able to see the extent to which the subject's AT adheres to our linear spring model. As seen in Fig. 4., we expect to see a flattening of the Force v. Strain curve for taped ankles vs not taped, such that ultimately the rupture point would be reached at a lower force.

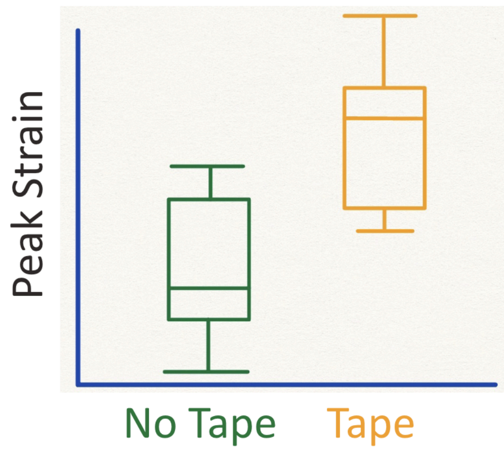

Figure 4. Simulated results of peak strain of AT with tape and without tape, on which ANOVA analysis can be performed

Drawbacks and Limitations

The main drawbacks of our study include the way we are measuring strain in the tendon in response to a static force. ATRs occur along with sudden dorsiflexion and load. Under these conditions, the AT may not behave linearly, or maybe the tape would fail before the tendon. The use of ultrasound to measure strain is also a fairly new, expensive, and time consuming method of characterizing tendons, further adding possible error to our strain calculations.

Conclusion

In this study, we investigated the potential relationship between ankle taping and Achilles tendon strain, with a focus on its implications for Achilles tendon ruptures (ATRs) among athletes, particularly in the NFL.

Our hypothesis proposed that ankle taping, while beneficial for ankle stabilization, might increase the strain experienced by the achilles tendon, thereby heightening the risk of ATR. Through a comprehensive analysis involving biomechanical testing using the Humac Norm and ultrasound imaging, we plan to collect data on Achilles tendon strain under varying forces for both taped and untaped ankles of Stanford football players. We believe that taped ankles should exhibit higher levels of strain across a range of forces, indicating that ankle taping could contribute to increased strain on the achilles tendon. This heightened strain may predispose athletes to ATRs, especially during high-impact activities common in sports like football. The implications of our study extend beyond the NFL, with potential applications in injury prevention and rehabilitation protocols for athletes across various sports. By understanding the biomechanical effects of ankle taping on Achilles tendon strain, sports medicine professionals can develop more targeted interventions to maximize ankle stabilization while minimizing the risk of ATRs. Further research is warranted to explore additional variables that may influence achilles tendon strain, such as taping techniques, tape materials, and individual biomechanical factors. Other taping mechanisms focusing on supporting the achilles tendon have also shown promising results in decreasing the risk of an achilles tendon injury (Tsai et al., 2018). Additionally, longitudinal studies tracking injury rates among athletes with taped versus untaped ankles could provide valuable insights into the real-world impact of ankle taping practices on ATR incidence. In all, our study highlights the importance of considering the biomechanical effects of ankle taping on achilles tendon strain in athlete populations. By addressing this factor, sports medicine practitioners can contribute to reducing the risk of ATRs and enhancing the overall health and performance of athletes.

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