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The Effect of Pressure on the Achilles Tendon Structure and Ecotypes Studied in Athletics Athletes

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ABSTRACT: This research aims to investigate the effect of pressure on the Achilles tendon structure and ecotypes among athletics athletes in 2023.
In order to conduct the present applied research, which was conducted in a semi-experimental manner, 28 people from among the athletics athletes who were in one of the country's athletics league teams voluntarily participated in the present research as a sample. Before doing the exercises, the subjects completed the informed consent form to participate in the research. The criteria for entering the research were not to be injured and to exercise at least 20 km per week. Also, runners with any neuromuscular disorders were excluded from the study. Participants were only accepted if they had limited prior running experience, where limited experience was defined as not following a regular running program in the past 12 months and not exercising more than once per week during the past 3 months. The participants were excluded from the program if there were musculoskeletal injuries in the lower limbs or if there was a medical excuse to participate in the exercises.
The findings of the research show that there is no difference in the structure of the Achilles tendon after imposing high and low pressure. It appears that the high pressure applied in this study was too low to induce a pressure-dependent response in the structure of the Achilles tendon. Reductions in ecotypes 3 and 4 indicate that low to moderate pressure can be applied without damaging the structure of the Achilles tendon.

Key words: Pressure, Achilles Tendon, Ecotypes, Sports, Athletics

INTRODUCTION

Problem Statement

Running is one of the most common sports that is not limited by time and place. There is a lot of evidence about the beneficial effects of running on health, such as preventing diseases and reducing premature mortality. The running pattern requires coordination between muscles and appropriate range of motion and strength. Finally, preservation of lower limb joints, kinetics, morphology, and mechanical properties may be essential in maintaining performance during running. Tendinopathy is a common disease that is estimated to include 30-50% of sports injuries. A systematic and new study regarding musculoskeletal injuries has shown that Achilles tendinopathy is the second most common injury after injury with a rate of 9.1 to 10.9%. It is believed that repeated pressures on the tendon during physical activities without enough time to recover are one of the most important factors in the development of tendinopathy. In the scientific literature, a model has been presented to show the continuity of damage to the tendon and its relationship with the pressure applied to it. Based on this model, a natural healthy tendon is adapted and strengthened by imposing optimal pressure on it. On the other hand, a healthy tendon that is stressed too much and without enough rest, can deteriorate during different stages of tendon damage. Imposing excessive pressure on the tendon with poor management can eventually lead to tendon rupture (Jaafari Rajini et al., 2022).

Therefore, it is possible to return it from a pathological state to a normal state by reducing the pressure on the tendon. Treadmill against gravity is a tool that is used to reduce the pressure on the lower body by using the technology of positive pressure of the lower body. The pressure imposition equal to the main body weight can be adjusted from 100% to 20% of the body weight as a decrease of one percent. Previous research showed a decrease in ground reaction force and muscle activity when using Alter-G treadmills compared to normal treadmills (Dehghani, 2013: 47).

Several imaging tools can be used to evaluate the tendon structure, such as when the muscle is under pressure. Four ecotypes can be introduced based on the intensity and distribution of continuous cross-sectional images when the muscle is under pressure, and related to the integrity of the tendon. Type I and II ecotypes refer to tendinous joints that have more regularity and health. Ecotype III refers to a more filamentous and irregular state of the tissues, and type IV introduces an amorphous matrix composed mainly of fluid. It is possible to monitor the structural changes caused by the tendon pressure through the technology of time when the muscle is under pressure. The previous research based on the imaging of the time when the muscle is under pressure shows acute unstable changes (less than 72 hours) in the tendon structure when bearing the maximum pressure (professional sports competition) and also the presence of irregular ecotypes, 2 days after the imposition. They were stressed and returned to their original state within the next 4 days (Khalili Qalabin and Rizvani, 2023).

Researches on the time under pressure of the previous muscle, which monitored the changes of the Achilles tendon, were carried out on trained people and by applying maximum pressure. maximum (slightly less) experiences a similar change that results from their appropriate response to most training programs. Therefore, acute tendon destruction or loss of its structure in the case of stress or lack of stress in beginner runners. Treadmill can be checked by using the technology of the time when the muscle is under pressure (Arazpour et al., 2009).

The aim of this study was to observe the changes in the Achilles tendon structure of beginner runners with two conditions of maximum pressure (100% body weight) and minimum pressure (20% body weight). The hypothesis of our study was that we would observe a transient change in the type II ecotype after the imposition of maximal stress caused by two intensive periods, which would be associated with an increase in the number of the same type of ecotype two days after heavy running, and its return to the baseline state during It is 7 days after running. A change in these cases was not expected after light running (Periara and Silva, 2006).

Research Literature

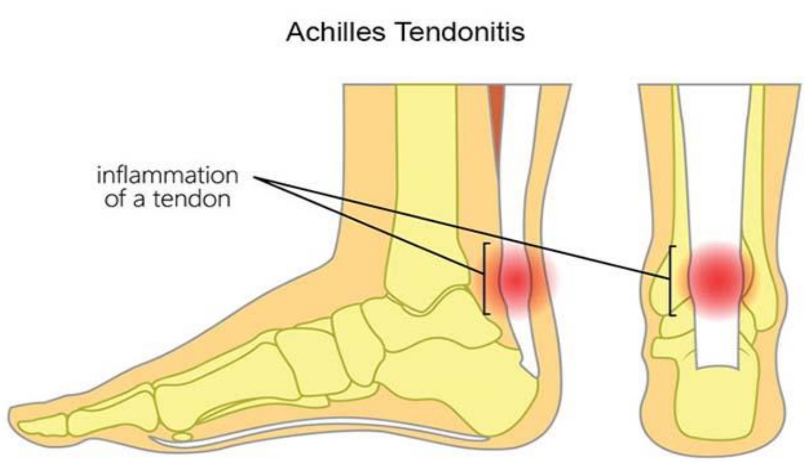

Figure 1. Achilles Tendon

Types of Achilles Tendon Injuries

Achilles tendon injury can be mild or moderate and pain, burning or stiffness can be felt in that part of the leg. If the pain is severe, the Achilles tendon may be partially or completely torn. Achilles tendonitis is another type of injury where part of the tendon becomes inflamed.

In general, two common types of Achilles tendon injuries are:

• ***Acute Rupture***

A complete or partial tear occurs when the tendon is stretched beyond its capacity.

• ***Achilles Tendinopathy***

A chronic (long-term) disease that causes weakness and atrophy of the Achilles due to a series of very small tears (tendinosis) (Sarzaim et al., 2019).

• ***Achilles tendon rupture symptoms***

The most obvious sign of tendon damage is pain at the top of the heel, especially when the ankle is extended or you stand on your toes. The pain may be mild and get better or worse over time. If the tendon is torn, the pain is immediate and severe and you may have the following symptoms:

• Tenderness, swelling and stiffness of this area
• Hearing the sound of banging or bursting
• Bruising and swelling
• Difficulty in moving and pressing the toes when walking

Weakness or stiffness at the back of the heel (stiffness may be more noticeable in the morning and get better as the tendon warms up after using it)

Effective factors in Achilles tendon rupture

Usually, this happens when the person has very fast movements or sudden turns. Achilles tendon damage is more likely in the following sports:

- Run
- Gymnastics
- Dance
- Soccer
- baseball
- basketball
- Tennis
- Volleyball

These injuries occur when you suddenly start moving and lift your leg while walking instead of stopping. For example, a sprinter may suffer Achilles tendon rupture at the start of a race while getting up from the starting line to run fast (Behfar and Farjah, 2022).

Effective Factors Affecting Achilles Injury

These things may put a person more at risk of Achilles tendon injury:

• Wearing high-heeled shoes

Flat soles (in this case, when you take a step, there is an impact on the foot that stretches the muscles and tendons.)

• Stiffness in the muscles or tendons of the leg
• Having a heel spur
• Very intense and intensive sports activity and performing non-standard exercises
• Starting a new sport and putting too much pressure on yourself to do all the moves
• Wearing inappropriate shoes or shoes not related to sports activities
• Exercising on uneven surfaces
• Taking medications called glucocorticoids or antibiotics called fluoroquinolones
• Chronic diseases such as rheumatoid arthritis, lupus, gout or diabetes (Alipour et al., 2023).

RESEARCH METHOD, STATISTICAL POPULATION AND SAMPLE SIZE

In order to conduct the present applied research, which was conducted in a semi-experimental manner, 28 people from among the athletics athletes who were in one of the country's athletics league teams voluntarily participated in the present research as a sample. Before doing the exercises, the subjects completed the informed consent form to participate in the research. The criteria for entering the research were not to be injured and to exercise at least 20 km per week. Also, runners with any neuromuscular disorders were excluded from the study. Participants were only accepted if they had limited prior running experience, where limited experience meant not following a regular running program in the past 12 months and not exercising more than once a week during the past 3 months. The participants were removed from the program if there were musculoskeletal injuries in the lower limbs or if there was a medical excuse to participate in the exercises. This protocol was approved by the medical ethics committee and written consent was obtained from all participants.

Table 1. Background information of the sample size

Measure (average)	feature
22 ±2.9	**AGE**
12 men, 8 women	gender
1.76 ±0.09	Height
74 ±13.4	weight
24 ± 3	BMI

This study uses a crossover-random design. All participants participated in two separate intensive running sessions and were scanned 6 times during muscle tension. The sessions included a maximum pressure stage (100% body weight, HL) using a standard treadmill and a minimum pressure stage (20% body weight, LL) using an Alter-G treadmill. Since the Alter-G treadmill is rarely used for high-pressure physical activity measurements, a standard treadmill was used to approach the best possible condition. After dividing the participants into two equal groups, exercises were randomly presented to each group; The first group ran on the Alter-G treadmill in the first period and on the standard treadmill in the second period; While this arrangement was the opposite in the case of the second group.

Measurements of time under muscle tension were performed on both Achilles tendons of all participants in 6 time intervals; The first 3 scans were performed as follows: day zero, which was one day before participating in the first run, day 2, which was two days after the first run, and day 7, which was seven days after it; After that, the participants had 7 days of rest to participate in the second period on a different treadmill; The second 3 scans were also performed without intervention on the zero day of running (day 14), two days after running (day 16) and 7 days after running (day 21).

This program was chosen according to the already known physiological changes that occur in the tendon tissue structure after loading. An acute up-regulation of collagen gene expression and an increase in its protein synthesis occurs, the magnitude of the changes probably being related to the amount of stretching experienced by the resting fibroblasts. Increased collagen persists for approximately 72 hours after loading. It was anticipated that the day 2 muscle stress scan would record the changes, and by day 7 these changes were expected to return to baseline. Minor changes to the test protocol had to be made to suit the personal circumstances of some participants (the UTC scan was performed the day after the program). Daily reports of daily activities were collected from day 1 to day 21 and participants were also asked to refrain from running during the study period.

The activities performed in the test included a 20-minute period of running after a 5-minute walk (to warm up). Male participants started running at 8 km/h and female participants at 6 km/h. Referring to the developed BORG scale, it can be said that the participants run with a number around 3-5 ratings of perceived pressure.

This quantity was measured every minute until the participants reached the desired level. As soon as the participants were placed in this range, to ensure the stability of this situation, the rating of perceived pressure was measured every 5 minutes; If the rating of perceived pressure exceeds the number 5, the speed of the treadmill will be reduced by 1 km/h, and if it is less than the number 3, the speed of the treadmill will be increased by 1 km/h.

The structure of the Achilles tendon was qualitatively measured by an experienced technician in the field of imaging when the muscle was under pressure. Analyzing the time when the muscle is under pressure can sometimes indicate a degree of lack of a general pattern. To minimize this problem, the images were coded based on the time and name of the volunteer to be checked at another time. A 7 to 10 MHz ultrasonic linear transducer was placed in an interceptor; By moving on the 12 cm long axis of the Achilles tendon, this automatic system records regular images with 0.2 mm intervals. The task of this device is to standardize the rotation, angle, gain, focus and depth of field of the transducer.

Coupling gel was used between the skin, the neutral pad of the interceptor device, and also the transducer, to have an optimal contact surface, before performing the scan. The participants were lying on the stomach in a hospital bed and their ankles were pressed to maximal dorsiflexion. The interceptor device was placed on the posterior surface of the Achilles tendon, parallel to its long axis. The transducer was also set on the end of the tendon, located on the calcaneus. The information was collected in the proximal to distal direction, which was reconstructed in the form of a 3D ultrasound data block using the software of the time when the muscle was under pressure and the images saved from the devices. The software's algorithm allows it to quantify the ecotypes across a rolling window of 25 consecutive images.

The time under pressure of the muscle is a tool that can qualitatively evaluate the tendon structure based on the stability of the ecotype. It can also distinguish between symptomatic and asymptomatic Achilles tendinopathy. Symptomatic tendons have a higher percentage of ecotypes 3 and 4 compared to tendons without symptoms. Reproducibility and high inter-observer reliability are other positive features of muscle tension time (ICC > 0.92).

The cross-section used in the study is a 2-cm cut from the middle part of the sagittal plane of the Achilles tendon, which starts from 2 cm from the upper side of the calcaneus and extends upwards. This cutting method has been used in previous researches. To test the change of ecotypes 1-4 in scans 1-3 and 4-6, the estimation of the generalized equation was used. In this study, a separate model was used for each type of ecotype in such a way that the ecotype was the dependent variable and the participant (identification number) and the group were called subject variables (other variables such as foot, type of treadmill and at the time of scanning, intra-subject variables were defined. The general effects of group, time, condition, and gender, as well as the mutual effects of time and condition, were identified. A transformable correlation matrix structure was used for the supplementary analysis of a series of t-tests, and for the analysis the platform (SPSS version 26); set to alpha 0.05) was used.

Research Data Analysis

The percentages of each ecotype from 1 to 4 for the 3 baseline conditions, two days after running and seven days after running can be seen in Table 2. There is no clear percentage difference between any of these 4 types of ecotypes either in low pressure periods or in the period There were no high pressures; It was also revealed that the mutual effects of time and conditions are not noticeable on any of the ecotypes one to four.

In addition, effects considered for group, condition, or gender were not revealed for any of these 4 ecotypes (Table 2). The effect of time was evident only on ecotypes 3 and 4. post-event analysis for ecotype III showed significant change between baseline and 2 days later and between baseline and 7 days later. The same type of analysis for ecotype 4 showed that the main difference between the base day and 7 days later Wald chi-square = 6.244, d.f. = 1, P = 0.012.

It turned out that the values based on the time the muscle is under pressure do not differ significantly between the two studied groups; between the first scan (mean ± SD 80.97 ± 4.98; 15.76 ± 3.79; 1.35 ± 1.56; 1.72 ± 1.71) and the fourth scan (mean ± SD 4.69 ± 80.45; 16.35 ± 4.04; 1.42 ± 1.52; 2.00 ± 1.67), respectively for ecotypes 1, 2, 3 and 4, no tangible difference can be seen; t (77) = 0.470, p = 0.640, t (77) = 0.671, p = 0.504, t (77) = 0.136, p = 0.892, t (77) = 0.091, p = 0.928.

The average speed of the volunteers in the high-pressure run was about 7.8 km/h (range 6-11 km/h) and in the low-pressure run was about 8.4 km/h (from 6 to 16 km/h).

RESULTS

Although the research with the time under pressure technology of the muscle showed transient and acute changes in the echo type structure after an intense exercise, but the latest information about the sensitivity of that device is not available, so some caution should be taken into account when interpreting the results of this study. The results of this study indicated that there was no weight-dependent change on the ecotype in beginner runners due to intense or slow running on both types of treadmills.

The hypothesis that an increase in ecotype 2 will be visible after the acute phase of activity is based on the research of Rosengarten et al. (2008) who reported ecotype 2 from a mean number of 6.9 (before the competition) to 8.6 (2 days after the competition), which is the result of imposing the pressure was above that of a full AFL match in professional athletes, and these values returned to baseline after 4 days. The aforementioned research puts the Achilles tendon under maximum pressure, which is similar to the current conflict.

The intense activity of this study was set based on a 20-minute run at an approximate speed of 3 km/h with an average RPE (based on corrected BORG) of 4, but athletes run about 12 km during an AFL match, regardless of their position. The average load during an AFL match is 856 relative units of pressure rate per period, which is the product of the RPE rate times the time in minutes), which is a significant difference compared to the 80au number during high-load running in the present study.

Gives. It has been shown that the measurement method used in this research is a valid and reliable method to estimate the internal training pressure with the correlation of the pressure rate in a period and the total heart rate recorded with the range of r = 0.75 to 0.9. It is possible that the high load imposed in the current study was not severe enough or long enough to provide an answer regarding the discussed characteristics of the Achilles tendon. Also, another study pointed to the lack of change in the structure of the Achilles tendon after a run-in recreational runner.

A possible explanation for this phenomenon could be related to the load imposed on the foot during a running lap. The participants of that study were runners who regularly and recreationally ran in 5 km rounds; A 10 km round may not have the necessary pressure to evoke a tissue response; In this case, the pressure imposed in this study is even less than the mentioned research by Wang and his colleagues (1018) (3 km in this study compared to 10 km). Also, due to differences in people, the changes were expected. The present study compares beginner runners and recreational runners; Inexperienced or novice athletes responded better to most training protocols compared to their more experienced counterparts.

In another study on the patellar tendon after 5 consecutive days of activity during a volleyball tournament, no change was reported for this tendon either. This study evaluated the imposed pressure in a different way than the current study, so a direct comparison would not be useful, but overall, this tournament has imposed a lot of pressure on the athletes' knees. That study was a self-reported, individual-based national rate of change scale. This scale measures the pressure imposed on the knee in the past week compared to the previous 3 months.

The above study was considered the first study on the patellar tendon; A possible reason for the patellar tendon structure not changing was discovered; Despite imposing higher pressures, the patellar tendon may require different pressures to change its structure compared to the Achilles tendon.

In addition, the difference in the participants and characteristics of the ecotypes can be another reason to justify the existing differences; Rosengarten and his colleagues investigated a male group of young and professional athletes and finally reported numbers of 92.3, 6.9, 0.22 and 0.53 respectively for ecotypes 1 to 4 as mean percentages. Wang et al. reported mean values of ~90, ~6, ~0.2, and ~0.5, respectively, in a study of a mixed group of hypertensive and type 1 diabetic runners. The study by Fen ark et al., on a mixed group of teenage volleyball players, detected average values of 58.7, 39.4, 1.6 and 0.3 for ecotypes 1 to 4, respectively. Finally, in the following study, by examining a group consisting of young and beginner male and female runners, we obtained numbers of ~81, ~16, ~2 and ~2 for ecotypes 1 to 4.

Although previous studies had reported significant differences in ecotypes as a result of stress tolerance, the observed changes are about 2% for ecotypes 1 and 2. Such a small difference between ecotypes 1 and 2 was also observed in the present study, which proved to be insignificant. The difference between the findings in two studies can be based on the difference in the statistical analysis method.

Other points to pay attention to are the body position during scanning, the time under pressure of the muscle and its models. Some researchers scanned the participants with open arms, and others used a position similar to this study (lying on the stomach). Compared to this study and the studies of Fen ark and his colleagues, previous studies used an older model of when the muscle is under pressure; As a result, comparing the results of time under muscle pressure is reasonable only if a model of time under muscle pressure and a body position during scanning is used.

The effect of time on ecotypes 3 and 4 was not predicted and showed a decrease in the percentage of these ecotypes over time. These findings show the change of tendon structure from a state with low stability (ecotypes 3 and 4) to more stable states (ecotypes 1 and 2). The reason for this increase in stability can be due to the increase in collagen synthesis from its destruction up to 48 hours after training. Also, with the increase in collagen synthesis, the cross-linking of collagen molecules also increases, which leads to the improvement of the integrity of tendon fibrils.

In the images of the time when the muscle is under pressure from the ecotypes, this increase in integrity can be interpreted as an increase in stability. This improvement in the images of the tendon body has been confirmed by a previous study, which indicates the beneficial adaptation of the tissue after a training session. It is worth noting that small changes independent of load can be related to rest and recovery. Although resting time was also investigated to investigate the effect of imposed load, however, only resting itself can have an effect on ecotypes 3 and 4.

Low to moderate pressures can be useful for the composition of the tendon body by reducing the percentage of ecotypes 3 and 4. A potential limitation of this study is that some participants were physically active during the research, based on exercise reports, and were involved in strength training in addition to cycling as a form of transportation.

Cycling and combining it with strength training can increase the load tolerance of the Achilles tendon, and finally, more pressure is needed to create a transient response in the Achilles tendon, as stated in the hypothesis. As the time sensitivity of the muscle was not pre-determined, the results should be interpreted with caution.

Ecotype percentage (I-IV) during the period of low and high pressure at the beginning, 2 days after the implementation and 7 days after the implementation; and analyzing the results for time, group, time, condition and sex conditions for each of the four ecotypes.

Table 2. Ecotypes Results

Low Pressure	Zero Day 2 Day 7	ecotype 1 (4.98) (5.37) (5.57)	ecotype 2 (1.25) (3.79) (4.61)	ecotype 3 (1.32) (1.35) (1.06)	Ecotype 4 (1.72) (1.09)
High Pressure	Zero Day 2 Day 7	4.67 (80.5) 4.24 (85.1) 4.45 (82)	4.04 (16.3) 3.64 (15.3) 3.69(15.8)	1.42 (1.5) 1.13(1.2) .97 (1.1)	2 (1.7) 1.29(1.3) 1.081(1.1)
State Duration	Wald chi-square d.f. P	2.800 2 0.247	2.888 2 0.236	1.385 2 0.500	4.190 2 0.123
Group	Wald chi-square d.f. P	1.054 1 0.305	1.129 1 0.288	0.024 1 0.877	0.075 1 0.784
Time	Wald chi-square d.f. P	5.230 2 0.073	1.073 2 0.585	6.785 2 0.034	7.491 2 0.024
State of	Wald chi-square d.f. P	0.791 1 0.374	0.763 1 0.382	0.359 1 0.530	0.017 1 0.898
Gender	Wald chi-square d.f. P	0.292 1 0.589	0.100 1 0.751	0.250 1 0.617	0.075 1 0.785

CONCLUSION

There was no difference in the structure of the Achilles tendon after high and low pressure. It appears that the high pressure applied in this study was too low to induce a pressure-dependent response in the structure of the Achilles tendon. Reduction of ecotypes 3 and 4 show that low to moderate pressure can be applied without damaging the Achilles tendon structure.

Research proposals

• It is suggested that the adopted protocol be used for the structure of novice runners between the ages of 18 and 30.

• The imposition of low to moderate pressure on the Achilles tendon structure of beginner runners can also be investigated in research.

• Since the imposition of low to moderate pressure may be useful in the treatment and rehabilitation of Achilles tendinopathy, therefore, the study was put on the agenda of the responsible organizations.

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