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ORIGINAL RESEARCH

THE DEGREE OF TENDINOSIS IS RELATED TO SYMPTOM SEVERITY AND PHYSICAL ACTIVITY LEVELS IN PATIENTS WITH MIDPORTION ACHILLES TENDINOPATHY

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ABSTRACT

***Background*:** Achilles tendinopathy negatively affects a person's ability to be physically active. However, remaining physically active during the rehabilitation process does not impact clinical outcomes when a pain-monitoring model is followed. There are several factors, such as the progression of pain and structural changes, kinesiophobia, functional impairments, or medical advice, which may explain why some patients become physically inactive while others maintain a physically active lifestyle.

***Purpose*:** The purposes of this study were 1) to compare the clinical presentation of patients with Achilles tendinopathy with high and low activity levels 2) to examine the relationship between tendon thickening and symptom severity in patients with Achilles tendinopathy and 3) to determine the proportion of patients with Achilles tendinopathy who have a high degree of kinesiophobia and if this proportion differs based on activity level.

***Study Design*:** Cross-sectional

***Methods*:** Fifty-three patients with Achilles tendinopathy were dichotomized into low activity ($n=30$) and high activity ($n=23$) groups based on their physical activity level. Patient characteristics, symptom severity, kinesiophobia, tendon thickening, and lower leg function were quantified and analyzed to test the study hypotheses.

***Results*:** Patients with low activity levels had greater tendon thickening and a larger body mass compared to patients with high activity levels. There were no differences in symptom severity, kinesiophobia, or lower leg function between groups. A negative relationship ($r=-0.491$; $p<0.001$) was found between tendon thickening and symptom severity. Thirty-eight percent of patients demonstrated a high degree of kinesiophobia, but the proportion did not differ between groups.

***Conclusion*:** Patients with Achilles tendinopathy who have low physical activity levels demonstrate greater tendinosis than patients who are highly active. These structural changes are negatively associated with symptom severity. However, symptom severity, kinesiophobia, and functional deficits do not differ between patients with different activity levels.

***Level of evidence*:** Level 3

***Key words*:** Achilles tendon, kinesiophobia, physical activity, tendon structure

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INTRODUCTION

Achilles tendinopathy is a clinical syndrome characterized by pain, swelling, and impaired functional performance.[1] It has a reported incidence rate of 2.35 per 1000 in the adult population[2] and frequently affects people who are highly physically active and people who have recently modified their physical activity.[3,4] These people may be able to continue their physical activities throughout the early stages of the injury, but as symptoms progress, their ability to participate in physical activities is negatively affected.[5] This reduction in physical activity not only impacts a patient socially, but also has discernible psychological effects[6] and can negatively affect overall health and quality of life.[7] Since the primary goal for many patients with Achilles tendinopathy is to safely return to their physical activities, it is important to understand what factors hamper their ability to maintain a physically active lifestyle.

Historically, patients with chronic Achilles tendon pain were recommended by medical professionals to rest, take anti-inflammatory medication, and avoid physical activities that caused symptoms.[8,9] This approach was commonplace when Achilles tendon pathology was thought to be an inflammatory process, but pivotal evidence[10,11] has since revealed that this pathology is degenerative in nature, not inflammatory. With this paradigm shift from inflammatory to degenerative, both terminology and treatment for chronic Achilles tendon disorders have changed. The term "tendinitis," which refers to inflammation of the tendon, has been largely abandoned and replaced with "tendinopathy."[1] Tendinopathy is a clinical syndrome that is diagnosed based on patient history and findings on physical exam.[1] Furthermore, when a patient with tendinopathy undergoes diagnostic imaging or histologic evaluation, a diagnosis of tendinosis can be made if the tendon's structure is altered (e.g. increased thickness and/or cross-sectional area) or if histopathological manifestations are found that suggest tendon degeneration (e.g. abnormal collagen fiber structure, hypercellularity, and increased vascularity).[12,13] Tendinosis however does not imply pain and occurs in both symptomatic and asymptomatic individuals.[1]

In addition to changes in terminology, treatment for chronic Achilles tendon pathology has shifted away from rest and towards exercise therapy, which promotes tendon healing through mechanical stimuli (i.e. mechanotherapy or mechanotransduction[14,15]). Effective loading programs have been established[16–20] and were recently compared in a systematic review by Malliaras et al.[21] Two commonalities exist between these loading programs: 1) the tendon is loaded and 2) pain is allowed to increase to a certain degree during the exercises. Taken together, these two characteristics demonstrate the importance of loading the tendon during treatment and using pain to ensure loads are adequate enough to cause positive adaptive changes. This treatment approach was further supported in a randomized-controlled trial by Silbernagel et al.[20] who found no detrimental effect of allowing patients with Achilles tendinopathy to continue activities that involved running and jumping during the treatment process as long as they adhered to a pain-monitoring model. These findings illustrate that patients with Achilles tendinopathy can be physically active during treatment, but it remains unclear what causes people with Achilles tendinopathy to reduce their physical activity levels in the first place.

There may be several reasons why patients with Achilles tendinopathy reduce their physical activity levels, including the progression of symptoms and structural degeneration, kinesiophobia, functional impairments, or following advice from a medical professional. Depending on which of these variables are contributing to decreased physical activity, treatment modification may be required to enable a safe return to physical activity participation. Therefore, it is important to determine the differences between patients with Achilles tendinopathy who have high levels of physical activity and those who have low activity levels (i.e. fall below the recommended 150 minutes per week of moderate to vigorous physical activity[22]).

The purposes of this study were 1) to compare the clinical presentation of patients with Achilles tendinopathy with high and low activity levels 2) to examine the relationship between tendon thickening and symptom severity in patients with Achilles tendinopathy and 3) to determine the proportion of patients with Achilles tendinopathy who have a high degree of kinesiophobia and if this proportion differs based on activity level. It was hypothesized that patients with low physical activity levels at the time of evaluation would present with greater symptom severity and degree of kinesiophobia, but not necessarily have greater tendinosis or functional impairments compared to patients with high physical activity levels. It was also hypothesized that the degree of tendon thickening would be related to symptom severity in patients with Achilles tendinopathy and the proportion of patients with high kinesiophobia would be greater in patients with low levels of physical activity compared to those with high levels of physical activity.

METHODS

Study Design

All patients in the current study were recruited as part of a larger longitudinal study looking at various Achilles tendon injuries (e.g. midportion tendinopathy, insertional tendinopathy, rupture). The current study is cross-sectional and only includes patients with midportion Achilles tendinopathy. All data were collected during the patient's baseline visit. All 153 patients who were enrolled in the larger longitudinal study from November 2014 to February 2017 were screened against the current study criteria. Approval for this study was obtained from the institutional review board at the University of Delaware. All participants received verbal and written information about the study and consent was obtained.

Patients

Inclusion/Exclusion Criteria

In order to be included in the current study, patients were required to be at least 18 years of age and have a primary clinical diagnosis of midportion Achilles tendinopathy.[1] Criteria for diagnosis were 1) pain with palpation to midportion of the Achilles tendon (i.e. 2-6 cm proximal to calcaneal insertion) 2) reported pain that increased with loading activities 3) focal or diffuse swelling 4) altered functional status (e.g. inability to perform high-demand activities, self-reported calf muscle weakness or impaired endurance). Diagnosis was confirmed by a licensed physical therapist with a patient interview and physical examination. Patients were excluded from the study if they had a history of Achilles tendon rupture or did not complete the questionnaire necessary for group allocation. Of the 153 patients in larger longitudinal study, 53 fit the current study criteria.

Classification of Physical Activity Levels

Each patient's current level of physical activity was quantified with a physical activity scale (PAS) (Table 1) as originally described by Grimby[23] and previously used in clinical trials involving patients with Achilles tendon injury.[20,24] Using the patient's current PAS score and the United States national guidelines[22] for physical activity, which states that adults should perform 150 minutes of moderate to vigorous intensity exercise each week as our cutoff, patients were dichotomized into high activity (PAS$\geq$5; n = 23) and low activity (PAS < 5; n = 30) groups. In addition to using current PAS scores for group allocation, patients were also asked to indicate PAS scores for their activity level prior to injury (Table 1).

Patient Reported Outcomes

The Victorian Institute of Sport Assessment- Achilles questionnaire (VISA-A) was used to evaluate symptom severity of the patient's Achilles tendon injury.[25] The VISA-A is a measurement tool with good validity and reliability[25] that contains eight questions that

Table 1. *Physical Activity Scale.*

Level	Activity Description
1	Hardly any physical activity.
2	Mostly sitting, sometimes a walk, easy gardening or similar tasks.
3	Light physical exercise around 2-4 hours a week, e.g. walks, fishing, dancing, ordinary gardening, including walks to and from shops.
4	Moderate exercise 1-2 hours a week, e.g. jogging, swimming, gymnastics, heavier gardening, home-repairing or easier physical activities more than 4 hours a week.
5	Moderate exercise at least 3 hours a week, e.g. tennis, swimming, jogging, etc.
6	Hard or very hard exercise regularly and several times a week, where the physical exertion is great, e.g. jogging, skiing.

are scored from 0 to 100, with a score of 100 indicating symptom-free and physically active. Due to inherent differences between groups with respect to physical activity levels, scores from questions 7 and 8 were subtracted from the overall score as they pertain to current physical activity levels. This led to a maximum possible score of 60. Both the overall VISA-A and the adjusted VISA-A scores are reported to allow for comparisons to previous literature; however, only the adjusted VISA-A score was used in the interpretation of group differences.

Kinesiophobia was quantified using the Tampa Scale for Kinesiophobia (TSK).[26] This questionnaire contains 17 Likert-scale items with scores ranging from 17 to 68. Furthermore, each patient's TSK score was used to categorize them as having a high degree of kinesiophobia (> 37) or not (≤37). This cut-off score was selected as it has been previously used in populations with chronic lower extremity pain.[27] Raw scores as well as proportions of patients with a high degree of kinesiophobia were used for analysis.

Tendon Thickening

Tendon thickening was quantified using ultrasound imaging. Ultrasound images were obtained using a LOGIQ *e* Ultrasound system (GE Healthcare, Chicago, IL, USA) with a wide-band linear array probe (5.0-13.0MHz). Thickness measurements were taken as described previously.[28] Briefly, three extended field of view images were gathered bilaterally. Tendon thickness was measured 2 cm proximal to the calcaneal notch and at the thickest portion of the tendon (Figure 1). After averaging the three trials, tendon thickening was calculated as the difference (Tendon thickening = Thickness at the thickest portion – Thickness 2 cm proximal to insertion) and used for analysis. Tendon thickening, rather than typically reported raw value of tendon thickness, was used in this study as it controls for the baseline thickness of the tendon (i.e. thickness in the absence of pathology) and does not require a healthy, control side. Achilles tendinosis has been measured previously by comparing tendon thickness of a pathologic tendon to the thickness of a healthy side.[29]

Lower Leg Function

Each patient's jump performance and calf muscle endurance were measured using a countermovement jump (CMJ) and heel-rise endurance test, respectively. Both of these tests were performed as described in the literature and have been used for evaluating outcomes of patients with Achilles tendinopathy.[30,31] All measures were obtained with a MuscleLab® measurement system (Ergotest Innovation, Porsgrunn, Norway). Functional testing procedures were not performed when patients reported a score of greater than five on the Numeric Pain Rating Scale during testing, demonstrated compromised balance, or had a diagnosed comorbidity that affected their ability to partake in strenuous exercise. This resulted in 14 subjects not performing the jumping task (four high activity; 10 low activity) and 5 not performing the heel-rise test (one high activity; four low activity).

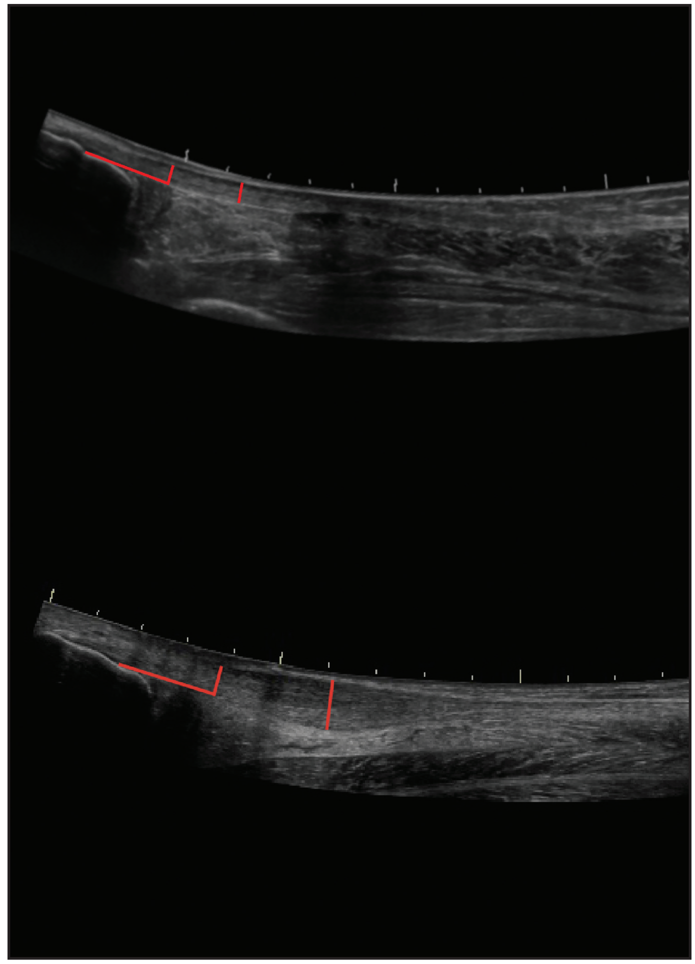

Figure 1. *Representative ultrasound images. Top Image– Healthy Achilles tendon. Bottom Image– Achilles tendon with tendinosis. Lines demonstrate how tendon thickening was calculated. Tendon Thickening = Thickness at the thickest portion – Thickness 2 cm proximal to the calcaneal notch).*

Countermovement Jump (CMJ)

Patients performed three single-leg CMJs alternating between legs as described previously.[30] For each jump, patients were instructed to stand upright, place both hands behind their back, flex their knee as far as desired, and then immediately perform a single maximal vertical jump. Each CMJ was recorded using a field of infrared lights located approximately 4 mm above the ground, which allowed for calculation of jump height based on flight time (Height (m) = $\frac{1}{8}$ × gravity × time^2). The average jump height of the three trials for each leg was used for analysis.

Heel-Rise Endurance Test[30]

A single-leg heel-rise endurance test was performed on each leg to measure calf muscle endurance as described previously.[30] While standing on a 10° incline, with two fingers from each hand at shoulder height for balance, patients were instructed to perform as many heel-rises as possible while keeping their knee straight and maintaining a frequency of 30 repetitions/minute guided by a metronome. The test was terminated when the patient was unable to perform more repetitions or maintain the testing parameters. During the testing, a linear encoder was attached to the patient's heel in order to quantify the total work performed in joules, which was calculated with the following equation.

Work (J) = ∑displacement × mass × gravity

Statistical Analysis

The outcome variables of interest included those related to demographic and injury characteristics, physical activity levels, symptom severity, kinesiophobia, tendon thickening, and lower leg function. Due to the data being non-normally distributed, statistical analyses were performed using nonparametric tests. Descriptive data are reported as median and interquartile range (IQR). Cohen's d effect sizes were calculated for each independent variable to improve interpretation of between group differences. All statistical analyses were performed using a significance level of $p < 0.05$. Sample sizes are reported for each outcome variable since patients were removed from individual analyses if they did not complete the test or questionnaire. The reason for missing questionnaire data (i.e. PAS, VISA-A, TSK, demographics) was because patients would skip questions and each data collection was completed before these outcomes were viewed or entered into data management software.

Mann-Whitney U tests were used to analyze differences between the high and low activity groups for demographic and injury characteristics and patient-reported outcomes (Adjusted VISA-A, TSK, PAS). Since 34 of the 53 patients presented with clinical signs of bilateral Achilles tendinopathy, each tendon was labeled as either the 'more' or 'less' symptomatic side based on patient reported symptoms and used for independent analyses of tendon thickening and lower leg function.[30] Mann-Whitney U tests were used to analyze differences in tendon thickening and lower leg function between groups for both the more and less symptomatic sides. Additionally, a limb symmetry index (LSI (%) = more symptomatic/less symptomatic x 100) was calculated for the functional tests. LSI is a common metric reported in the literature[30,32,33] and allows for group comparisons of side-to-side functional deficits. LSI values for CMJ and the heel-rise endurance test were analyzed with Mann-Whitney U tests. Wilcoxon Signed Rank tests were used to analyze changes in physical activity levels from before injury to the time of evaluation and to compare tendon thickening and functional tests between the more and less symptomatic side within each group. Pearson's Product-Moment Correlation was used to examine the relationship between tendon thickening and symptom severity. Fisher's Exact tests were used to compare the proportions of patients with bilateral pathology in each group and to compare proportions of patients with high levels of kinesiophobia in each group.

RESULTS

Group Characteristics

Group characteristics are reported in Table 2. The low activity group had greater body mass than the high activity group ($p = 0.031$, $d = 0.634$) and had a higher BMI ($p = 0.007$, $d = 0.797$). However, there were no significant differences in age, sex, height, duration of symptoms, or the proportion of people with bilateral pathology (Table 2). When comparing current physical activity levels to activity levels prior to injury for all patients using the PAS, current physical activity levels were significantly ($p < 0.001$,

Table 2. *Group Characteristics.*

	High Activity Group (n=23)	Low Activity Group (n=30)	p-value	Cohen's d
Age (y)	52 (34-60)	57 (44-65)	0.184	0.429
Sex (Male: Female)	17: 6	18: 12	0.384	0.351
Height (cm)	180 (175-185)	178 (168-185)	0.560	0.207
Weight (kg)	78 (70-88)	91 (79-105)	0.031*	0.634
BMI (kg/m^2)	24 (22-26)	28 (23-31)	0.007*	0.797
Duration of Symptoms (m)	8 (4-36) †	6 (3-14)	0.469	0.165
Unilateral: Bilateral	6: 17	13: 17	0.253	0.426

Data presented as Median (IQR) other than 'Sex' and 'Unilateral: Bilateral' which are presented as frequencies.
* Significant difference at the p<0.05 level † Sample size of 22

d = 0.508) lower than activity levels before injury. However, when analyzing each group individually, there was a significant reduction in physical activity for the low activity group ($p = 0.001$, $d = 0.917$) but not for the high activity group ($p = 0.102$, $d = 0.404$) (Table 3).

Patient Reported Outcomes

For symptom severity, there was no significant difference ($p = 0.078$, $d = 0.491$) in adjusted VISA-A scores between the low and high activity groups (Table 4). For kinesiophobia, there were no significant differences in TSK scores ($p = 0.969$, $d = 0.027$) or proportions of patients with a high degree of kinesiophobia ($p > 0.999$, $d = 0.049$) between the low and high activity groups (Table 4). However, 38% (19 of 50 patients) of the entire cohort presented with a high degree of kinesiophobia when using scores greater than 37 on the TSK to operationally define a high degree of kinesiophobia.

Tendon Thickening

The low activity group had significantly greater tendon thickening than the high activity group on the more symptomatic side ($p = 0.037$, $d = 0.616$), but this was not seen on the less symptomatic side ($p = 0.128$, $d = 0.466$) (Table 5). Furthermore, the more symptomatic side had significantly greater tendon thickening than the less symptomatic side for both the low activity group ($p < 0.001$, $d = 1.056$) and the high activity group ($p = 0.002$, $d = 0.656$). When assessing the relationship between tendon thickening of the more symptomatic side and Overall VISA-A scores, there was a negative correlation ($r = -0.49$; $p < 0.001$) (Figure 2).

Table 3. *Physical Activity Levels.*

	PAS Before Injury	PAS Currently	p-value	Cohen's d
All Patients (n=53)	5 (4-6)	4 (3-6)	<0.001*	0.508
Low Activity Group (n=30)	5 (4-5)	3 (3-4)	0.001*	0.917
High Activity Group (n=23)	6 (6-6)	6 (5-6)	0.102	0.404

Data presented as Median (IQR)
PAS= Physical Activity Scale
*= statistically significant difference at the p<0.01 level

Table 4. *Symptom Severity and the Degree of Kinesiophobia.*

	Active Group (n=23)	Inactive Group (n=30)	p-value	Cohen's d
Overall VISA-A Scores	66 (56-79)	50 (37-70)*	0.007	0.868
Adjusted VISA-A Scores	48 (37-55)	39 (29-46)	0.078	0.491
TSK Scores	36 (32-40)	35 (33-40) †	0.969	0.027
Kinesiophobia (≤37: >37)	14: 9	17: 10 †	0.999	0.049

Data presented as Median (IQR) other than 'Kinesiophobia' which is presented using frequencies
TSK= Tampa Scale of Kinesiophobia; VISA-A= Victorian Institute of Sport Assessment- Achilles questionnaire; Adjusted VISA-A= VISA-A score with questions 7 and 8 removed, (max score of 60)
* Sample size of 29 † Sample size of 27

Table 5. *Tendon Thickening and Lower Leg Function for Patients with High Activity (PAS≥5) and Low Activity (PAS < 5).*

	High Activity Group (n=23)	Low Activity Group (n=30)	p-value	Cohen's d
Thickening				
More Symptomatic (mm)	1.3 (0.6-3.6)	3.6 (2.4-5.0)	0.037*	0.616
Less Symptomatic (mm)	0.8 (0.6-1.5)	1.5 (0.7-2.7) †	0.128	0.466
CMJ				
More Symptomatic (cm)	5.8 (4.8-8.8) ‡	6.3 (4.2-9.1) §	0.999	0.003
Less Symptomatic (cm)	6.4 (5.3-9.6) ‡	6.2 (3.8-9.2) §	0.488	0.127
LSI (%)	93 (79-110) ‡	98 (79-110) §	0.663	0.332
Heel-Rise Work				
More Symptomatic (J)	1738 (1470-2074)**	1447 (298-2041) ††	0.237	0.354
Less Symptomatic (J)	1868 (1410-2330) **	1662 (901-2378) ††	0.508	0.275
LSI (%)	97 (81-104) **	88 (47-99) ††	0.237	0.422

Structural and functional data are presented as Median (IQR).

PAS= Physical Activity Scale; CMJ= Countermovement Jump; LSI= Limb Symmetry Index; J=Joules

* p<0.05 † Sample size of 29 ‡ Sample size of 19 § Sample size of 20 ** Sample size of 22 †† Sample size of 26

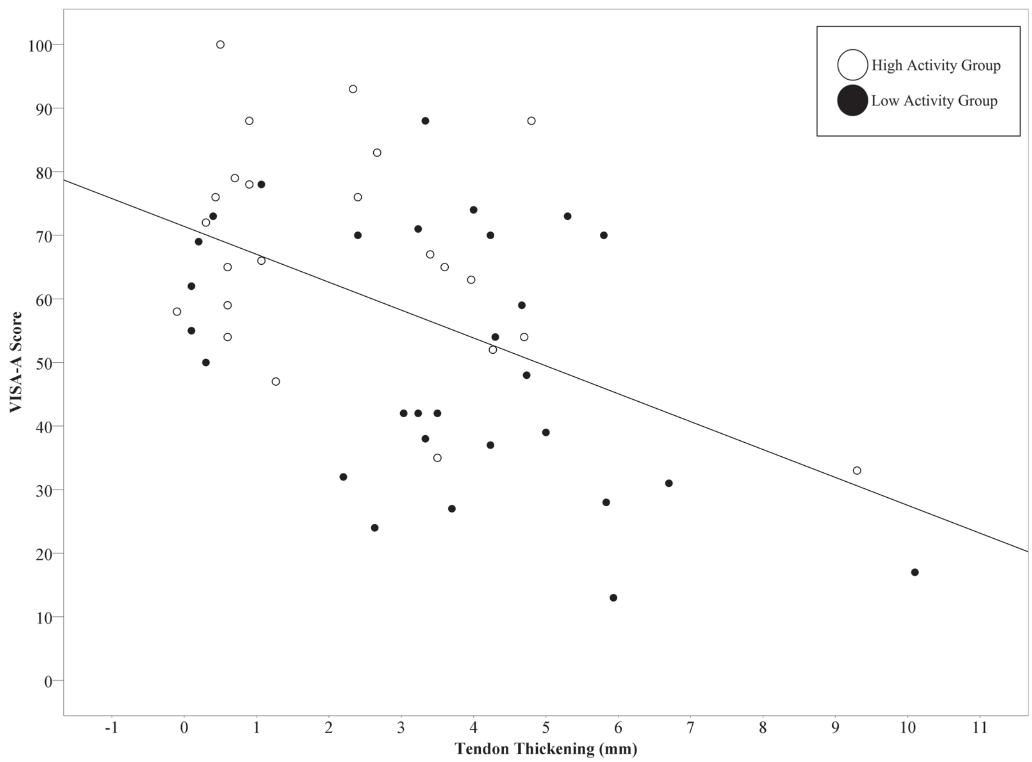

Figure 2. *Relationship of tendon thickening and overall VISA-A Score in patients with midportion Achilles tendinopathy. Physically active patients are represented as open circles while physically inactive patients are represented by closed circles.*

Functional Testing

There were no significant differences (p = 0.488-0.999, d = 0.003-0.332) between the low activity and high activity groups for CMJ height on the more symptomatic side, less symptomatic side, or LSI (Table 5). Additionally, there were no significant side-to-side differences in CMJ height for either the low activity (p = 0.459, d = 0.025) or high activity groups (p = 0.117, d = 0.217). Similarly, there were no significant differences (p = 0.237-0.508, d = 0.275-0.422) between the low activity and high activity groups for work performed on the heel-rise test on the more symptomatic side, less symptomatic side, or LSI (Table 5). However, the low activity group performed a significantly greater amount of work on the less symptomatic side compared to the more symptomatic side ($p = 0.010$, $d = 0.291$), but this was not observed in the high activity group ($p = 0.072$, $d = 0.282$).

DISCUSSION

The key finding of this study was that patients with Achilles tendinopathy who are below the recommended amount of physical activity (PAS < 5) did not have greater symptom severity, degree of kinesiophobia, or functional deficits compared to patients with high activity levels (PAS≥5), rather, showed a greater amount of tendon thickening and higher BMI. Furthermore, tendon thickening was associated with self-reported symptom severity. Although the groups did not differ in regards to kinesiophobia, it is worth noting that 38% (19 of 50) of the patients demonstrated a high degree of kinesiophobia. Additionally, patients with low physical activity levels had significant reductions in their physical activity and a larger body mass compared to patients with high activity levels. Taken together, these findings led to rejecting the hypotheses that patients with low activity levels would have greater symptom severity, degrees of kinesiophobia, and no differences in tendon thickening or lower leg function compared to patients with high activity levels. This suggests that patients with Achilles tendinopathy who present clinically with low physical activity levels have a greater amount of tendon degeneration and greater body mass, but do not necessarily have worse symptoms or more fear of movement compared to their counterparts who have maintained high activity levels.

Describing characteristics of patients with different activity levels

There may be numerous interacting factors that explain why a patient reduces participation in physical activity. In addition to taking symptoms, kinesiophobia, tendon structure, and lower leg function into consideration, the current study allows for a better understanding of how patient demographics may play a role in physical activity participation. In the current study, patients with low activity levels had a greater body mass and a larger BMI than patients with high activity levels. This led to a secondary analysis which showed that 28% (15 of 53) of patients were below the recommended amount of physical activity even before injury. This finding parallels previous reports that 31% of patients with Achilles tendinopathy do not participate in sports or vigorous activity.[34] However, given the study design, each of these patients were included in the low activity group. These findings suggest that Achilles tendinopathy commonly affects people who are relatively inactive, which may partially explain why some patients with Achilles tendinopathy present with low activity levels at the time of evaluation.

Symptom severity is not related to low activity levels

Quantifying clinical severity in patients with Achilles tendinopathy using the VISA-A is commonplace in research and recommended for evaluating patient-reported outcomes and response to treatment.[35] It is often noticed that once a patient's symptoms reach a certain level of severity, they reduce their physical activity and seek treatment. However, the existing evidence shows no detrimental effect of allowing continued physical activities during the rehabilitation process as long as a pain-monitoring model is followed.[20] Results from the current study show that patients with midportion Achilles tendinopathy who are below the recommended amount of physical activity at the time of evaluation do not report worse symptoms compared to patients with high physical activity levels. This indicates that current symptoms do not explain the difference in clinical presentation between patients with different physical activity levels. However, patients often describe reductions in symptoms when decreasing their physical activity level. Therefore, despite no differences in symptom severity between these patients, it may be that the patients in the low activity group reduced their physical activity levels to minimize their symptoms.

Differences in Kinesiophobia

Current literature indicates that psychosocial variables, such as kinesiophobia, negatively impact clinical outcomes of patients with musculoskeletal pathologies.[36–38] Although kinesiophobia has been mainly described in patients with low back pain, there is growing evidence that patients with lower extremity overuse injuries are also affected.[27,39] In a five-year follow-up study of patients with Achilles tendinopathy who were treated with exercise alone, the patients' level of kinesiophobia explained 35% of the recovery of calf muscle endurance.[38] This finding may partially explain the positive results seen in two randomized controlled trials[16,20] that implemented a pain-monitoring model by inherently addressing both patients with low degrees of kinesiophobia who are at risk of continuing deleterious loading activities and patients with high degrees of kinesiophobia who may potentially neglect loading when painful which may be necessary to promote adaptive tissue changes.[40,41] Results of the current study illustrate that the degree of kinesiophobia does not differ between patients with midportion Achilles tendinopathy of high and low physical activity levels. This contradicts findings by Lundberg et al.[27] who found a significantly greater degree of kinesiophobia in inactive patients compared to active patients with chronic lower limb compartment syndrome. This discrepancy can most likely be attributed to differences in the study population, the longer duration of symptoms (median = 37 months), and the severity of pain. Despite determining that no differences existed in kinesiophobia between patients of high and low physical activity levels, 38% of patients with Achilles tendinopathy presented with a high degree of kinesiophobia. Therefore, the use of the pain-monitoring model and assessing for kinesiophobia is recommended to identify both patients who may be perpetual overloaders and patients who may avoid loads that are necessary for recovery.

The role of tendon structure

Achilles tendinosis, which is diagnosed using either diagnostic imaging or histologic samples, occurs when the collagen architecture has been altered, interfibrillar ground substance has increased, and vessels have infiltrated the tendon.[12,13] Although tendinosis is characteristic of pathology[1] and has been shown to predict future symptoms in asymptomatic tendons,[42] there are mixed results on the association between tendon structure and symptoms.[43–46] This has led many clinicians and researchers to call to question the utility of structural measures in the evaluation and management of tendinopathy.[47–49] Growing evidence indicates that recovery of structure may simply follow a lengthier trajectory of recovery compared to symptoms.[50,51] This notion is further supported by the finding that symptomatic recovery does not ensure functional recovery.[31] The results from the current study show that greater amounts of tendon thickening occur in patients with low physical activity levels and to a greater extent on the more symptomatic side. This suggests that patients with low physical activity levels have greater structural changes. Additionally, a negative relationship ($r = -0.49$; $p < 0.001$) between tendon structure and symptom severity was found (Figure 2). Therefore, it appears that tendon structure may be a critical factor to monitor and address during the rehabilitation process to enable a safe return to physical activity participation. With training, clinicians can obtain valid and reliable measures of tendon structure that can be monitored over time with relatively low cost ultrasound systems.[52,53]

Study Limitations

This study was not without limitations. This was the first study to compare patients with Achilles tendinopathy who have different physical activity levels and to use an adjusted VISA-A score as the primary outcome. Therefore, an a priori power analysis was not completed. The lack of between group differences in the adjusted VISA-A scores and functional outcome variables may represent Type II error. However, the group allocation ratio was determined to be representative of patients with midportion Achilles tendinopathy as it paralleled group allocation in a previous randomized controlled trial.[20] A post-hoc sample size estimation was completed, which showed a sample size of 142 patients would have been needed to adequately power (power of 80%; $\alpha = 0.05$) a comparison of symptom severity (adjusted VISA-A) between the groups.

Physical activity levels were patient-reported, which may introduce a source of error and bias.[54] However, the PAS has been widely used in Achilles tendon research, it captures a wide array of physical activities and intensities, and the national recommendations for physical activity are based on self-report.[22] There is also the possibility of recall bias when asking participants to report their activity levels prior to injury. Thus, changes in physical activity level should be viewed with caution.

There is currently no consensus for the cutoff score on the TSK that defines high levels of kinesiophobia. A cut-off score of >37 was used as it has been used in research of chronic lower extremity pathology.[27] It is worth noting however that if a cut-off score of >35, which has also been used previously,[55] was used, 56% (28 of 50) of our cohort would have presented with a high degree of kinesiophobia with still no differences between groups. Further longitudinal research is needed to determine the modifiable factors that can be used to predict positive clinical outcomes and safe return to physical activity.

CONCLUSION

Patients with Achilles tendinopathy with physical activity levels below the recommend 150 minutes per week at the time of evaluation have a higher BMI and greater amount of tendinosis and these structural changes are negatively related to symptom severity. These findings indicate that tendon structure is an important factor to consider at the time of clinical evaluation and potentially throughout the rehabilitation process. Furthermore, kinesiophobia might be a factor that influences the rehabilitation process in patients with Achilles tendinopathy, but it does not differ between patients who present with high and low physical activity levels. Similarly, symptom severity and lower leg functional deficits do not differ between patients with different activity levels, but nonetheless should be addressed during the rehabilitation process.

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