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Gait Parameters in Recreational Runners with Early-Stage Achilles Tendinopathy

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ABSTRACT

Background: *The association between chronic Achilles Tendinopathy (AT) and altered gait has been demonstrated in a number of studies. However, there have been no reported studies on gait changes in the early stages of tendinopathy (<3 months).* ***Objective:*** *To establish the effects of early-stage AT on the temporo-spatial, kinetics and kinematic characteristics of gait.* ***Materials and methods:*** *Thirteen runners with AT (male/female: 8/5; age: 44.4 ± 4.6) and 15 apparently healthy runners (male/female: 8/7, age: 42.4 ± 9.9) were included in the study. All participants completed 10 trials of 5 m walking and 10 trials of 20 m running at a self-selected speed wearing their usual running shoes to obtain motion analysis and joint moment data.* ***Results:*** *There were no significant differences within temporo-spatial parameters (walking or running) between the tendinopathy and control groups. The tendinopathy group showed significantly increased knee angles during stance (walking: p=0.005; running: p=0.006) and toe off (walking: p=0.033; running: p=0.021). Significant differences in knee moments during stance were also found between the two groups for both walking (p=0.011) and running (p=0.032).* ***Discussion and conclusion:*** *Some differences in gait parameters are noted in early AT. Therefore, clinicians should monitor gait in early tendinopathy as part of rehabilitation to prevent the development of potential pathological gait biomechanics in the long term.*

Keywords: Tendon pain, Biomechanics, Kinetics, Kinematics

INTRODUCTION

The incidence of chronic Achilles Tendinopathy (AT), a common injury as a result of participation in physical activity and sport, is rising due to increased engagement in recreational sporting activities to maintain or improve general health [1]. Chronic AT is more prevalent in activities that have a significant running component such as long distance running, with injury rates of 10% reported in some elite cohorts [2,3]. Although the Achilles tendon can be injured anywhere on its length, the mid-portion, about 2-6 cm proximal to the calcaneal insertion, is the most common site of pathology [4]. Clinically, mid-portion Achilles tendinopathy presents as pain in the injured region, morning stiffness, nodular swelling and/or impairments in functional tasks of the lower limb; walking and running, which can negatively affect participation in sporting activities [5].

Lower limb tendon pathology can lead to altered walking or running gait patterns [6]. For example, altered running step length and cadence were reported in recreational runners with long-term (≥ 3 months duration) chronic Achilles tendinopathy [7]. Azevedo, et al. found lower knee range of motion and decreased muscle activity in the tibilais anterior, rectus femoris and gluteus medius muscles during pre and post-heel strike periods of the running cycles of runners with long-term (≥ 3 months duration) AT [8]. Over pronation of the subtalar joint has also been suggested in the aetiology of long-term chronic Achilles tendinopathy [9]. From these and other studies, it is evident that altered gait mechanics are either a risk factor for or are a result of long term (≥ 3 months' duration) chronic Achilles tendinopathy. However, there are, to our knowledge, no corresponding studies on gait changes in the early stages (<3 months' duration) of tendinopathy.

From a clinical management perspective, it is reasonable to propose that should these changes exist and are observable, the sooner they are noted and treated, the better the long-term prognosis most likely will be for the athlete. Therefore, this study sought to establish the effects of early-stage Achilles tendinopathy on the temporo-spatial, kinetics and kinematic characteristics of gait.

MATERIALS AND METHODS

Study design

Laboratory based case control study.

Participants

Participants were recruited from running clubs and race databases in the greater Cape Town area in South Africa from May to September 2018. Participants gave verbal and written informed consent and all procedures adhered to the Declaration of Helsinki. Ethical clearance and annual review to conduct the study was obtained from the faculty of health sciences' Human Research Ethics Committee at the University of Cape Town (HREC 311/2018). All the participants in the injured group reported posterior lower limb pain in the Achilles tendon area of less than three months duration and fulfilled at least one of the following additional clinical diagnostic criteria for Achilles tendinopathy: Early morning pain and stiffness over the mid-portion of the Achilles tendon; A history of swelling over the Achilles tendon area; Palpable nodular thickening and tenderness over the affected Achilles and/or; Movement of the painful area in the Achilles tendon with plantar-dorsi flexion (positive "shift" test) [1-4]. The participants in the uninjured group were runners who had been injury-free for at least one year at the time of recruitment and were matched with the injured group participants for age, sex and hours of training per week. In both groups, the runners had to have at least one year of endurance running experience and have no current or past history of congenital or acquired physical deformities, neurological or metabolic disorders, or previous lower limb surgeries (≤ 2 years), have a body mass index less than or equal to 30 mkg^{-1} and be 35 to 55 years of age. Participants were excluded from the study if they had an ankle range of motion limitation greater than 15 degrees for plantar-dorsi flexion in the total arc of motion or had a history of spinal or lower limb surgery with in the preceding two years.

Experimental procedure

After providing informed consent and clinical confirmation of Achilles tendinopathy by one of the authors (HS), the participants completed demographic, sporting, and medical history questionnaires. Additionally, the tendinopathy participants rated the current clinical severity of their symptoms and the impact on physical activity using the self-administered eight question VISA-A questionnaire. All participants then completed 10 trials of 5 m walking and 10 trials of 20 m running, both at a self-selected speed. They wore their usual running shoes and received no instruction on running style. Only the last five walking and running trials were analysed.

Instrumentation

An 8-camera VICON MX motion analysis system (Oxford Metrics Ltd, Oxford, UK), sampling at 250 Hz captured 3D marker trajectories. Joint moment data were collected using a 900 × 600 mm force platform (AMTI, Watertown, MA, USA), sampling at 2000 Hz [10]. Sixteen reflective markers were attached according to a modified Helen-Hayes marker set and the lower body PlugInGait model was applied [7,8,11].

Outcome measures

The main outcome measures were temporo-spatial gait parameters such as, but not limited to, cadence, stride length and stride duration. Additional outcome measures were kinetic and kinematic variables such as joint (ankle, knee, and hip) angles and moments at all points throughout the gait cycle. Pain scores from the Victorian Institute of Sports Assessment questionnaire-Achilles (VISA-A) and short form McGill Pain Questionnaire (sf-MPQ). The VISA-A questionnaire is a validated tool for assessing symptomatology in Achilles tendinopathy and the sf-MPQ has also been used to assess pain in Achilles tendinopathy previously [12,13].

Data analysis

One complete stance phase of the gait cycle was analysed for each valid trial. For the participants who presented with unilateral tendinopathy, the gait cycle was measured using their symptomatic leg while the dominant leg was used for the uninjured participants, as well as in the case of bilateral tendinopathy. Marker trajectory and force platform data were filtered using a low-pass fourth-order Butterworth filter with a cut-off frequency at 20 and 100 Hz, respectively. Three-dimensional lower extremity joint angles and net resultant joint moments were calculated using a Newton-Euler inverse dynamics approach [10,14,15]. Three-dimensional joint moments were expressed as external moments normalised to body mass ($Nmkg^{-1}$) [10]. Kinematic and kinetic data were presented as waveforms throughout the gait cycle and were defined with 100 data points, one for each percentage of the cycle, starting from initial ground contact.

Statistical analysis

STATA® v15 was used for statistical analysis. Descriptive statistics such as frequencies, means and standard deviation (where appropriate) where used to describe the demographic data. We used the Shapiro-Wilks test to assess the assumption of normal distribution of continuous variables. Normally distributed variables were presented as mean ± SD. Variables that violated the assumption of normality were presented as median (IQR) and non-parametric tests were used for comparison. Differences in temporo-spatial parameters, kinetic and kinematic variables between the two groups were compared using the t test for normally distributed data. Pearson’s correlation was used to evaluate correlations between demographic characteristics, temporo-spatial characteristics and joint moments. The level of significance was set at $p<0.05$.

RESULTS

Fifteen uninjured runners (CON) and 15 runners with early-stage (<3 months duration) Achilles tendinopathy (TEN) participated in this study. Two of the TEN participants were excluded because of incomplete datasets. The TEN and CON groups were matched for baseline characteristics (Table 1). Four (31%) of the TEN participants had injured their right tendon, while three (23%) reported bilateral symptoms. Besides Achilles tendinopathy, the TEN group did not report significantly more previous history of foot and ankle injuries (TEN: n=8, 62%; 145 CON: n=4, 27 %; p = 0.05). The median (IQR) VISA-A score for the TEN group was 74 (59; 80).

Table 1: Physical characteristics of matched asymptomatic controls (CON) and injured participants (TEN) (n=28).

	CON (n=15)	**TEN (n=13)**	**p-value**
Age (years)	42 ± 9.9	44 ± 4.6	0.75
Sex (% male)	53	62	0.62
Height (cm)	170 ± 10	172 ± 9.7	0.48
Weight (kg)	71 ± 14	71 ± 14	0.97
BMI (kgm^{-2})	25 ± 3.5	24 ± 4.2	0.57
Dominant leg (% right)	88	77	0.45
Running participation (years)	12 ± 12	14± 13	0.96
Running competition (years)	2.1 ± 3.2	6.8 ± 8.7	0.14
0 to 3 months training (hrs/week)	4.3 ± 2.2	4.5 ± 3.1	0.72
4 to 12 months training (hrs/week)	6.8 ± 5	6.2 ± 4	0.84
13 to 24 months training (hrs/week)	6.6 ± 7.5	7.9 ± 7.6	0.83
Other sport participation (%)	65	69	0.28
Other foot and ankle injuries (%)	27	62	0.05
Note: Sex, dominant leg and injured leg are expressed as a percentage (%). The remaining variables are expressed as mean ± standard deviation. The number of participants for which data were available is indicated in parenthesis (n).			

There were no statistically significant differences within the walking or running temporo-spatial parameters of the CON and TEN groups (Table 2). Additionally, there were no significant correlations between any of the temporo-spatial characteristics with years of running participation and competition, hours of training per week during the preceding 24 months, injury history, VISA-A or sf-MPQ scores (data not shown).

Table 2: Temporo-spatial characteristics of uninjured group (CON) and injured group (TEN) during walking and running trials (n=28).

	Walking			**Running**		
	CON (n=15)	**TEN (n=13)**	**p-value**	**CON (n=15)**	**TEN (n=13)**	**p-value**
Velocity (ms^{-1})	1.2 ± 0.9	1.2 ± 0.1	0.9	3.1 ± 0.5	3.0 ± 0.5	0.57
Force Max (N)	798 ± 126	800 ± 138	0.97	1 679 ± 418	1 655 ± 278	0.86

Initial rate (Ns)	5 222 ± 2100	5 386 ± 1 983	0.83	24 956 ± 6 411	25 791 ± 6 489	0.74
Foot contact time (s)	3.8 ± 8.7	1.5 ± 0.7	0.34	4.2 ± 7.1	2.0 ± 0.9	0.26
Toe-off time (s)	4.6 ± 8.7	2.2 ± 0.7	0.34	4.5 ± 7.1	2.3 ± 0.9	0.26
Cadence (steps.m^{-1})	106 ± 9.5	107 ± 8.7	0.87	173 ± 15	171 ± 12	0.66
Stride length (m)	0.16 ± 0.01	0.16 ± 0.02	0.68	2.27 ± 0.40	2.12 ± 0.36	0.31
Stride duration (s)				0.74 ± 0.09	0.72 ± 0.03	0.26

Note: The variables are expressed as mean ± standard deviation. Stride duration parameter only applicable to running and not walking condition.

There were significantly higher knee angles in the analysed symptomatic leg of the TEN group compared to the analysed dominant leg of the CON group during stance and toe-off in the walking and running conditions (Table 3). In addition, there were significantly greater knee angles in the TEN group during foot-strike while running. The ankle and hip angles between the two groups were similar and no significant associations were observed between kinematic data and the running and injury histories of the two groups and the pain scores of the TEN group. Joint angle waveforms were similar for both groups and in both running and walking conditions (Figures 1 and 2). Differences in knee moments during stance (Table 4) were observed between the two groups for both walking (p=0.011) and running (p=0.032). Furthermore, knee moment force was higher in the injured group from early stance to swing phase (10-100% of the gait cycle) while walking (p=0.032) and running (p=0.011).

Table 3: Joint angles of uninjured group and injured group during walking and running trials expressed as degrees (°) of Range of Motion (ROM) (n=28).

	Walking			**Running**		
	CON (n=15)	**TEN (n=13)**	**p-value**	**CON (n=15)**	**TEN (n=13)**	**p-value**
Ankle angle at/during						
Foot-strike	3.4 ± 4.2	5.6 ± 4.7	0.19	36 ± 49	28 ± 49	0.66
Stance	14 ± 3.8	15 ± 4.3	0.34	23 ± 25	30 ± 5.6	0.37§
Toe-off	-13 ± 3.8	-14 ± 6.9	0.85	-26 ± 17	-21 ± 7.2	0.34
Knee angle at/during						
Foot-strike	-2.3 ± 4.2	0.8 ± 3.9	0.06	6.1 ± 6.8	12 ± 5.3	0.021*
Stance	38 ± 7.5	45 ± 5.5	0.005*	33 ± 9.5	41 ± 4.4	0.006*
Toe-off	38 ± 7.5	43 ± 5.3	0.033*	7.1 ± 6.6	13 ± 7.1	0.027*
Hip angle at/during						
Foot-strike	32 ± 5.2	29 ± 7.2	0.21	44 ± 18	37 ± 6.4	0.18
Stance	33 ± 5.3	31 ± 5.2	0.39	46 ± 23	37 ± 6.4	0.26§
Toe-off	3.5 ± 6.3	3.5 ± 7.7	1	0.7 ± 30	-7.1 ± 6.3	0.36

Note: The variables are expressed as mean ± standard deviation for all walking and running trials. *: p<0.05; §: Mann-Whitney U.

Table 4: Joint moments (Nmm.kg^{-1}) of injured group (TEN) and uninjured group (CON) during walking and running trials (n=28).

	Walking			**Running**		
	CON (n=15)	**TEN (n=13)**	**p-value**	**CON (n=15)**	**TEN (n=13)**	**p-value**
Ankle moment at/during						
Foot-strike	24 ± 19	17 ± 19	0.36	36 ± 49	28 ± 49	0.65
Stance	1 467 ± 203	1 348 ± 287	0.21	2 545 ± 710	2 629 ± 656	0.75
Toe-off	-82 ± 23	-89 ± 23	0.41	-48 ± 37	-29 ± 39	0.21
Knee moment at/during						
Foot-strike	-171 ± 175	-106 ±215	0.38	-640 ± 349	-761 ± 207	0.28
Stance	277 ± 191	486 ± 233	0.011*§	1 690 ± 1 532	2 302 ± 1 092	0.03*§
Toe-off	94 ± 65	63 ± 88	0.3	-166 ± 206	-153 ± 135	0.84
Hip moment at/during						
Foot-strike	220 ± 305	116 ± 461	0.48	1 157 ± 756	1 614 ± 666	0.1
Stance	1 258 ± 433	1 275 ± 510	0.93	2 983 ± 1 514	2 658 ± 911	0.80§
Toe-off	-172 ± 136	-146 ± 187	0.67	-494 ± 350	-543 ± 398	0.73

Note: The variables are expressed as mean ± standard deviation for all walking and running trials. *: p<0.05; §: Mann-Whitney U.

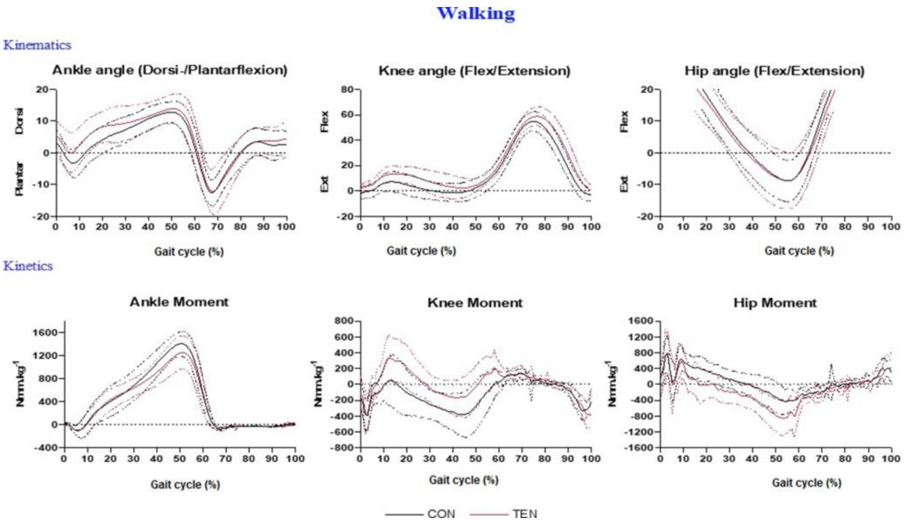

Figure 1: Kinematic (as degrees over entire gait cycle) and kinetic data (joint moments (Nm.kg^{-1})) expressed as mean (solid line) ± 1 standard deviation (dotted line) of injured group (TEN) and uninjured group (CON) during walking condition.

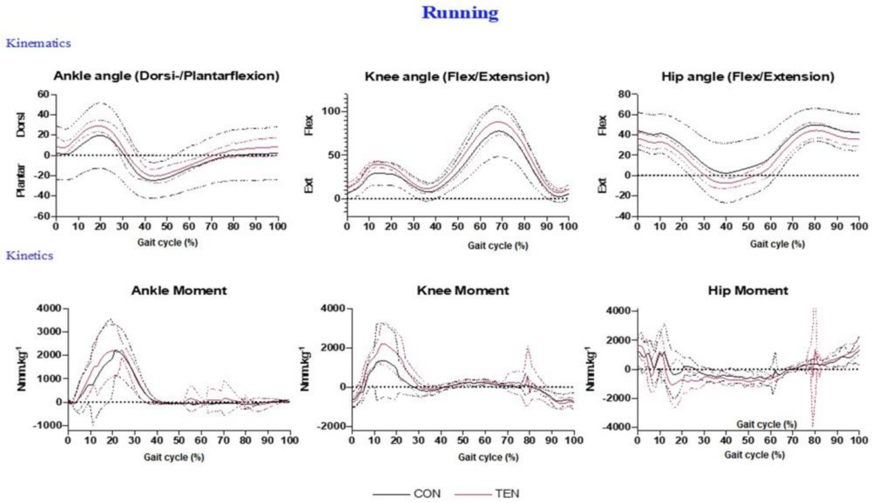

Figure 2: Kinematic (as degrees over entire gait cycle) and kinetic data (joint moments (Nm.kg^{-1})) expressed as mean (solid line) ± 1 standard deviation (dotted line) of injured group (TEN) and uninjured group (CON) during running condition.

DISCUSSION

The main finding of this study concluded that there were no significant differences between temporo-spatial variables in runners with early AT (<3 months duration) compared to healthy controls. However, the TEN group had significantly greater knee angles of the symptomatic leg at stance and toe off, during both walking and running when compared to the knee of the dominant leg of the control group. Additionally, the Achilles tendinopathy group had significantly greater knee moments at stance phase during walking and running. The ankle and hip kinematic and kinetic variables were however similar between the injured and uninjured groups. While data on gait changes in chronic tendinopathy of ≥ 3 months duration are available, this is, to our knowledge, the first study to characterise gait parameters in early Achilles tendinopathy.

The TEN group had lower mean foot contact time, toe-off time, cadence, and velocity when compared to the uninjured controls. However, this was not statistically significant. Presumably, lower spatio-temporal characteristics could be a response to the tendon pain, where runners try to reduce the amount of time that the foot is on the ground and the Achilles tendon is load bearing. While these differences and the association with pain were not statistically significant in this study, previous results have shown decreases in temporo-spatial characteristics in runners with chronic Achilles tendinopathy and other lower limb pathology [7,16-18]. The main difference between these studies is that the present cohort had tendinopathy symptoms of less than three months duration, *i.e.*, not chronic pathology. Chronic Achilles tendinopathy leads to altered matrix and tendon fibril repair and is associated with reduced muscle activation, both of which result in gait impairments [8,19-21]. These changes are likely to occur over an extended period of time as the condition progresses and perhaps three months is not sufficient time. This association between duration of pathology and gait impairments was previously noted by Baert, et al. who reported no differences in some temporo-spatial characteristics in early knee Osteoarthritis (OA) when compared to controls but observed them in the established OA group [22].

Another finding of our study is that there were significantly higher knee angles in the TEN group for most of the gait cycle in both the walking and running conditions while the ankle and hip angles between the two groups were similar. The former results are similar to those observed previously in runners with chronic Achilles tendinopathy but contrast to others in chronic tendinopathy as well [8,23]. A possible explanation for these results could be that, since the gastrocnemius is biarticular, its function is greatly influenced by knee kinematics. The increased knee angles seen in the TEN group could be a compensatory mechanism which uses the gastrocnemius muscle minimally, hence ameliorating the loading and thereby pain in the Achilles tendon. No differences were noted on the hip, but as this joint shows the least variability in gait, these findings are consistent with previous reports [8]. The knee flexion moments were also increased in the TEN group in both the walking and running conditions. This observation is similar to previous work that illustrated differences in kinetic values in runners with chronic symptomatic Achilles tendinopathy when compared to uninjured controls [16]. The increase observed may reflect neuromotor adaptations in the lower limb musculature as a result of the pathology. For instance, participants with Achilles tendinopathy were shown to have reduced gluteal activity which was associated with an increase in the joint moment further along in the kinetic chain.

That some changes in gait characteristics were noted in early tendinopathy in the present study while others have been observed in chronic tendinopathy but not in the present may suggest that some gait changes that occur in early tendinopathy could be adaptations that are overcome as the condition progresses. Alternatively, some gait changes may develop in the acute phase and persist in the chronic stage of tendinopathy or develop as a result of the chronicity of the condition. Additionally, some changes may well be unique to each stage of the condition. Consequently, further studies on larger sample groups ought to explore this in depth as this may have clinical rehabilitation implications.

Pain may also be the primary driver for most gait aberrations, however no correlations between pain and any of the temporo-spatial, kinematic, or kinetic variables were noted in the present cohort (results not shown). One potential explanation could include that the runners with tendinopathy experienced symptoms for less than three months and therefore had not endured the pain sufficiently long enough to effect marked pathological adaptations. Additionally, it is plausible that these gait changes may be related to passive soft tissue changes instead of pain avoidance.

Notably, the baseline characteristics of the study sample were similar; however, the TEN group had a higher incidence of past foot and ankle injuries. The cause and/or effect relationships between these injuries and tendinopathy is beyond the scope of this study although it has been shown to be bidirectional in the literature [24].

This study is not without limitations. This was a cross sectional study; therefore, a cause-and-effect relationship cannot be determined between our observations and tendinopathy. In particular, this cohort reported more foot and ankle injuries in the TEN group which potentially is also a risk factor for them developing gait changes. Additionally, joint angle calculations are influenced by marker placement accuracy, which could impact the analysis [25]. However, only one tester performed the placements in order to limit this variability. Another limitation of this study is the heterogeneity of the participants; some had bilateral tendinopathy, while others had unilateral tendinopathy. However, these were not analysed separately as the overall sample size was small to begin with, which would have further shrunk on sub-analyses. Additionally, there was heterogeneity in running styles; therefore, differences between the groups could be as much running style as the presence of early tendinopathy. Lastly, participants wore their own shoes, with the benefits of replicating their usual running pattern. Differences in footwear; however, could affect the kinematic and kinetic patterns of the participants, confounding the results.

CONCLUSION

From our findings, no changes were observed in temporo-spatial parameters in runners with early Achilles tendinopathy. Reflecting possibly that in early Achilles tendinopathy, the pain or muscle deficits experienced by the runners have not yet persisted long enough for individuals to develop pathological gait. For this reason, gait changes that are known to occur with long term Achilles tendinopathy could potentially be prevented with pre-emptive gait management. Furthermore, this study demonstrated that the knee joint plays an important role in the gait of runners with early Achilles tendinopathy, the extent of which needs further exploration.

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