Original Research

Prevalence and factors associated with asymptomatic Achilles tendon pathology in male distance runners

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ARTICLE INFO

ABSTRACT

Objectives: This study investigated the prevalence of tendon pathology and associated factors in experienced, high mileage male endurance runners with no history of Achilles tendon pain.
Design: Cross-sectional study.
Setting: Achilles tendinopathy is a debilitating running injury affecting 50% of distance runners over their lifetime. It is diagnosed through a clinical examination and imaging, usually grey scale ultrasound (US) imaging. US imaging studies have shown that pathological changes can occur in asymptomatic individuals with no tendon pain.
Participants: Thirty seven male runners who had never had Achilles tendon pain.
Main outcome measures: Participants completed a running history survey, had their height, body mass, waist circumference, and ankle dorsiflexion range of movement (ROM) measured, and their tendons were assessed (normal, abnormal) using US imaging.
Results: Almost half (46%) of these asymptomatic distance runners had at least one abnormal tendon. The runners with tendon pathology had significantly (p = 0.024) more years of running training (abnormal: median 20 years, interquartile range 6–25.5) than runners with no pathology (normal: median 7 years, interquartile range 5–15). No other significant differences between the groups were identified.
Conclusions: Asymptomatic male distance runners had a high incidence of tendon pathology. Increased running years was associated with pathology in the Achilles tendon...

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1. Introduction

Committed endurance runners expose their Achilles tendons to high volume (quantity) and high intensity (speed) training loads over many years. The nature of running exposes the tendon to loads of approximately 12.5 times body weight each time the foot strikes the ground (Komi, Fukashiro, & Jarvinen, 1992). Thus, the potential for cumulative stress and subsequent injury to the tendon is high.

Achilles tendinopathy (AT) is a debilitating injury affecting up to 50% of distance runners over their lifetime (Kujala, Sarna, & Kaprio, 2005). Diagnosis of AT is established from a clinical examination and diagnostic imaging, commonly employing ultrasound (US) imaging. Ultrasonography is inexpensive, readily available and can be used to confirm the presence of pathology in the tendon and evaluate the structural integrity of the tendon, tendon thickness, hypoechogenicity, and vascularisation (Cook, Khan, & Purdam, 2002; Khan et al., 2003; Maffulli, Regine, Angelillo, & Capasso, 1987; Ohberg, Lorentzon, & Alfredson, 2001).

There is a poor association between these imaging findings and

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symptoms. Several studies have shown that the presence of asymptomatic Achilles tendon pathology identified on US imaging is relatively common, with a prevalence of 11—52% (Fredberg & Bolvig, 2002; Gaida, Alfredson, Kiss, Bass, & Cook, 2010; Gibbon, Cooper, & Radcliffe, 1999; Nicol, McCurdie, & Etherington, 2006; Ooi, Schneider, Malliaras, Counsel, & Connell, 2015). Recently, structural abnormalities in the Achilles tendon observed on US imaging have been identified as a risk factor for tendon pain (Comin et al., 2013), though other studies have shown that pathology alone does not predict onset of clinical symptoms (Fredberg & Bolvig, 2002).

High repetitive elastic loading is believed to be one of the main pathological stimuli causing AT (Silbernagel, Gustavsson, Thomee, & Karlsson, 2006). Repetitive mechanical overload of the Achilles tendon, particularly with a sport such as long distance running where load accumulates over time, has the potential to induce pathology (Khan & Cook, 2003). Long term load exposure as a consequence of greater years of running and greater running mileage has been associated with a higher incidence of AT (Knobloch, Yoon, & Vogt, 2008; Kujala et al., 2005). Further, greater life time loading has been associated with a larger cross-sectional area of the Achilles tendon (Rosager et al., 2002). While ageing is often thought of as a risk factor for tendon pathology, it is difficult to separate the effects of lifetime tendon loading from ageing. Other factors that may predispose a runner to develop tendon pathology are adiposity, ankle joint dorsiflexion (DF), and gender (Astrom, 1998; Gaida et al., 2010; Kaufman, Brodine, Shaffer, Johnson, & Cullison, 1999). A reduction in DF may limit the capacity of the triceps surae to absorb load and therefore can result in greater loading rates. Alternatively, an increase in DF range may prolong loads on the Achilles tendon over a larger range. Although there is some support for these theories, there are conflicting findings in the literature (Hein, Janssen, Wagner-Fritz, Haupt, & Grau, 2014; Kaufman et al., 1999; Mahieu, Witvrouw, Stevens, Van Tiggelen, & Roget, 2006; McCrory et al., 1999). Achilles tendinopathy also typically affects more men than women in both a physically active (Astrom, 1998) and the general population (Gaida et al., 2010), suggesting that gender may be another risk factor.

Research, exploring asymptomatic tendon pathology prior to symptom development is of clinical interest. To date, one research study has reported the prevalence of asymptomatic tendon pathology in a small distance running population (13 males, 8 females), however they did not evaluate factors associated with tendon pathology in their distance running population (Ooi et al., 2015). The purpose of this study was to determine the prevalence of asymptomatic tendon pathology in male distance runners and identify potential associated factors, including age, adiposity, ankle DF, and running history. It was hypothesised that distance runners would display a high prevalence of tendon pathology and that associated factors would include age, adiposity and years of running.

2. Methods

2.1. Participants

Thirty-seven experienced male endurance runners aged between 25 and 55 years were recruited for this cross-sectional study. Volunteers were recruited between June 2012 and March of 2013 using advertisements at running and triathlon clubs, running organisations, and online forums (www.coolrunning.com.au) in Melbourne. Women were excluded due to the difficulty for controlling and measuring the impact of oestrogen as a contributing factor (Cook, Bass, & Black, 2007).

Participants were included if they had (1) a minimum running history of 3 years or more, (2) high mileage (running a minimum of 30 km/week on average for the previous 3 months), and (3) had run a marathon or a half marathon in the last 2 years. The inclusion criteria were established to include predominantly experienced runners with a consistent period of running exposure. Volunteers were excluded if they had any history of or current Achilles tendon pain. Other exclusion criteria were any lower limb injury within the previous 6 months that forced them to stop running for more than 1 week, and any other significant medical condition (e.g. diabetes mellitus, systemic inflammatory disorders, previous Achilles trauma or rupture or insertional AT). This study was approved by the University's Human Research Ethics Committee and the rights of the participants were protected.

2.2. Procedure and data collection

2.2.1. Running and injury history survey

Each participant completed a preliminary survey on their running history, including details such as age, average running mileage per week, running history (years), number of marathons/half-marathons completed, and their injury history. An injury was defined as any musculoskeletal incident that sidelined or required modified training for a period of 6 weeks or greater, or anything that forced participants to stop running for a period of greater than 1 week in the previous 6 months. If the number of running sessions per week or mileage per week was reported as a range of two values on the running survey, the mean was recorded (e.g. 3—4 session/week: mean 3.5 sessions/week, or 50—60 km/week: mean 55 km).

2.2.2. Anthropometry and ankle range of motion

Height (cm), body mass (kg) and waist circumference (cm) measures were recorded for each participant. Waist circumference was measured in a horizontal plane at the midpoint between the iliac crest and lower costal margin. Each measurement was taken twice and the mean of the two measures was recorded. If there was a discrepancy of greater than 1% between measures, a third measure was taken and the median recorded. Dorsiflexion was measured using a standing lunge test as described by Bennell et al., 1998. Each participant aligned their heel and their second toe on a line. Participants were then instructed to dorsiflex their ankle as much as possible, ensuring that their heel remained flat on the ground. The participants also completed a straight knee DF test based on the technique outlined by Munteanu et al. (Munteanu, Strawhorn, Landorf, Bird, & Murley, 2009). The straight knee DF test provides an indication of the influence of the gastrocnemius muscle on ankle DF range of motion (ROM). Both measures of ankle DF ROM were measured with a digital inclinometer (Baseline® Digital Inclinometer, 12—1057, New York, USA) and the angle between the anterior border of the tibia and the vertical plane were recorded. For both tests, the mean of three measures was recorded.

2.2.3. Ultrasound imaging

Bilateral grey scale ultrasound scans were performed on each participants Achilles tendons (GE VIVID-I, GE, USA). Left and right Achilles tendons were classified as abnormal or normal using a high-resolution grey scale (B-mode) ultrasound with a linear array probe at a frequency of 13 MHz. The images were taken by an experienced musculoskeletal radiologist (40 years radiology experience, 22 years in musculoskeletal imaging). The ultrasound images were collected with the participant in a prone position with their ankle at 90°. During scanning the probe was positioned perpendicular to the tendon to avoid anisotropy or artefacts. A mark was made on the participants' leg with a non-permanent marker one probe length from the position where the calcaneus

was last visible in the longitudinal plane. A transverse image was taken at this point of the tendon. Another transverse image was taken at the thickest point of the tendon as determined by the radiologist. Thickness was measured inside the boundary of the tendon with the calliper measurement tool provided in the manufacturer's software (Echopac BT09, GE Vingmend Ultrasound Medical Systems, Milwaukee, Wisconsin, USA) preinstalled on the ultrasound equipment.

2.3. Data analysis

Participants' tendons were categorised into abnormal or normal groups based on the imaging findings. A tendon was defined as abnormal if; (1) one or more focal hypoechoic regions were visible in both the longitudinal and transverse scans, (2) diffuse hypoechogenicity associated with bowing of the anterior tendon border was detected, (3) if diffuse hypoechogenicity associated with generalised thickening of the tendon in comparison to the contralateral tendon was found, or (4) if the tendon was thicker than 6 mm (Gaida et al., 2010; Khan et al., 2003). Individuals identified as having tendon pathology on either side were classified as abnormal.

Measurements for age, weekly mileage, training sessions per week, running history body mass, height, waist circumference, and DF ROM (standing lunge, straight knee) were collated for all participants in an Excel spreadsheet (v2013, Microsoft, Redmond, WA, USA) and grouped according to whether their tendon(s) were categorised as normal or abnormal. For participants whom were identified with an abnormal tendon(s), the pathology classification(s) from the four aforementioned criteria were also recorded.

2.4. Statistical analysis

Statistical analyses were completed using Statistical Packages for the Social Sciences (SPSS, version 22.0, IBM, Somers, New York). An alpha level of 0.05 was set for all analyses. Not all of the data were normally distributed and due to the sample size, we took the conservative option and used non-parametric statistical procedures and data were therefore described using medians and interquartile ranges (IQR). Mann-Whitney U tests were used to examine the effect of group (normal, abnormal) on the survey, anthropometry and ankle ROM data. Effect sizes were then calculated if any significant findings were identified (Effect size $= z/\sqrt{N}$) (Fritz, Morris, & Richler, 2012). Cohen's effect sizes were interpreted as <0.1 as trivial, 0.1—0.6 as small, 0.6—1.2 as moderate and >1.2 as large (Bradshaw, Hume, Calton, & Aisbett, 2010; Joseph, Bradshaw, Kemp, & Clark, 2013; Saunders et al., 2006). Association between age and years of running were examined with a Spearman's rho test. A post-hoc power calculation was done using software (G* power version 3.1.9.2, University of Kiel, Germany) to determine the power of the sample size and Cohen's d effect sizes for any significant findings.

3. Results

All volunteers for this study met the inclusion criteria. Data were collected from 37 male distance runners with a median age of 36 years (IQR = 32—42 years), height of 180 cm (IQR = 174.0—183.5 cm) and a body mass of 77.4 kg (IQR = 73.8—83.4 kg). Almost half (46%, margin of error = 17%) of the participants had at least one abnormal tendon (Table 1), with 47% of the athletes in the abnormal group having unilateral abnormalities.

Participants with Achilles tendon pathology had significantly more years of running (median = 20.0 years, IQR = 6.0—25.5, p = 0.024, ES = 0.37) than those with no pathology on US imaging

Table 1
Comparison of tendon measurements and classifications, where n denotes the number of cases observed and % is percentage.

	Abnormal tendons (n = 17)	Normal tendons (n = 20)
Total tendons n (%)	26.0 (35.0%)	48.0 (65.0%)
AP tendon thickness(mm)	5.4 (0.8)	4.7 (0.5%)
Unilateral n (%)	8.0 (47.0%)	
Bilateral n (%)	9.0 (53.0%)	

(median = 7.0 years, IQR = 5.0—15.0) (Table 2). No significant differences between the groups were identified for age, adiposity, ankle ROM, number of weekly running sessions, weekly mileage and number of long distance (marathon and half marathon) running events completed (Tables 2 and 3). Running years was moderately correlated with age (Spearman's rho = 0.518, p = 0.001). Post-hoc power calculation for years of running suggests that despite the sample size, the study was underpowered with a power of 0.70 and a moderate effect size of 0.86.

4. Discussion

The results of this study showed a high prevalence of asymptomatic tendon pathology in a male distance running population. Cumulative running years was also identified as an associated factor of tendon pathology instead of age.

The high prevalence of asymptomatic tendon pathology observed in this group of runners may be due to a combination of the high cumulative loads that distance runners expose their Achilles tendons in addition to the older age of participants recruited. Whilst age was not identified as an associated factor, older runners are more likely to have run for a greater number of years. Our findings were similar to Gibbon et al. (Gibbon et al., 1999), who reported that 33% of the tendons in their asymptomatic volunteers (ages were not reported) had abnormalities on US imaging and were also similar to the findings of Ooi et al. (Ooi et al., 2015), who reported a prevalence of 38% in a small group of marathon runners (13 males, 8 females: mean age 37.1 [SD 11.3 years]). However our prevalence was lower than Nicol et al. (Nicol et al., 2006), who reported 52% of tendons in an active asymptomatic population (mean age 33.1 years [SD 6.8 years]) with no tendon pain.

Importantly, ultrasonographic abnormalities do not always result in a symptomatic tendon. However, McAuliffe et al. (McAuliffe, McCreesh, Culloty, Purtill, & O'Sillivan, 2016), identified that changes in the tendon such as hypoechoic regions on US imaging may increase the risk of developing tendinopathy by almost 5 times. Additionally, Fredberg and Bolvig (Fredberg & Bolvig, 2002) calculated the risk of developing symptoms of AT over the course of a single soccer season as 45% when abnormal US imaging changes were identified as compared to 1% for tendons with normal imaging. Although we did not collect prospective data, future studies should consider following distance runners over time to investigate whether tendon pathology is a risk factor for AT. This further research in line with the findings of McAuliffe et al. (McAuliffe et al., 2016), would then strengthen the case for the management and potential injury prevention in a running population with asymptomatic tendon pathology.

Running years has been identified as an associated factor of tendon pathology in this distance running population. These findings do need to be interpreted with care due the small effect size (ES = 0.37) observed. McCrory et al. (McCrory et al., 1999) as well as Knobloch et al. (Knobloch et al., 2008), also identified years of running as an associated factor of AT, suggesting that cumulative

Table 2
Descriptive data of participants. Abnormal tendon group are participants whom had one or both tendons abnormal on imaging. Normal tendon group are participants with both tendons normal on imaging. IQR is the interquartile range, cm is centimetres, kg is kilograms, and km is kilometres.

	Abnormal tendons (n = 17)		Normal tendons (n = 20)		p value	All tendons (n = 37)	
	Median	IQR	Median	IQR		Median	IQR
Age (years)	39.0	33.5–46.0	35.5	32.0–38.8	0.110	36.0	32.0–42.0
Height (cm)	180.0	173.5–181.7	181.0	176.0–185	0.149	180.0	174.0–183.5
Mass (kg)	74.6	71.8–80.3	81.0	74.8–84.2	0.104	77.4	73.8–83.4
Waist (cm)	81.8	77.2–83.8	81.5	79.8–87.3	0.498	81.7	77.2–85.9
Running years	20.0	6.0–25.5	7.0	5.0–15.0	0.024*	10.0	5.0–21.5
Mileage(km/week)	60.0	45.0–66.3	47.5	36.3–63.8	0.270	55.0	40.0–65.0
Sessions/week	4.3	3.5–6.0	4.0	3.1–5.0	0.270	4.0	3.5–5.3
Half marathons	5.0	3.0–16.0	7.0	4.0–10.0	0.557	6.0	3.0–10.0
Marathons	3.0	1.0–8.0	2.0	0.0–6.0	0.598	2.0	0.0–7.0

Table 3
Ankle dorsiflexion measurements during standing lunge test and straight knee dorsiflexion (DF) test.

		Abnormal tendons (n = 17)		Normal tendons (n = 20)		p value	All tendons (n = 37)	
		Median	IQR	Median	IQR		Median	IQR
Standing Lunge Test	Right ankle (°)	41.3	39.2–45.9	39.0	35.8–46.2	0.244	40.7	37.0–46.0
	Left ankle (°)	45.7	40.9–47.3	42.0	36.0–46.7	0.219	43.0	38.4–47.3
Straight Knee DF Test	Right ankle (°)	38.7	37.4–42.9	37.9	33.6–43.9	0.357	38.7	36.2–42.9
	Left ankle (°)	41.7	39.8–45.2	40.0	35.4–45.6	0.187	40.7	37.5–45.5

running is associated with the development of AT. McCrory et al. (McCrory et al., 1999), observed that injured runners with AT (average age 38.4 years) had been running on average for 11.9 years as compared to the control (average age 34.5 years) who had run for 9.6 years. Knobloch et al. (Knobloch et al., 2008), had a similar finding, observing that in a cohort of elite runners (average age 42 ± 9 years), runners with more than 10 years of running experience had increased risk of AT. Despite the observation that running years is an associated factor of Achilles tendon pathology, age was not associated with pathology in this population. Although it could also be assumed an older runner is likely to have run for more cumulative years, it was identified that running years and age was only moderately correlated. These findings suggest that older runners have not always been running for a greater number of years. Distance runners frequently start running at an older age, which may explain this observation. Chronic loading history should also be taken into account when evaluating tendon ultrasound findings and the utility of imaging in diagnosis of patients with high chronic load history may be questionable.

No other factors were associated with tendon pathology in this population. This was contrary to previous research where adiposity and lipid profile has been associated with tendon pathology (Gaida, Ashe, Bass, & Cook, 2009; Scott et al., 2015). This may be due to the highly trained population in this study, with little variation in weight and waist circumference. Limited or increased ankle DF was not identified as an associated factor. Our findings were in agreement with McCrory et al. (McCrory et al., 1999) and Hein et al., (Hein et al., 2014), however these researchers utilised non-weight bearing positions for assessment of ankle DF. In contrast, Kaufman et al. (Kaufman et al., 1999), and Mahieu et al. (Mahieu et al., 2006), who both prospectively utilised non-weight bearing DF tests, identified conflicting results. Reduced and increased ankle DF ROM were respectively identified as risk factors for developing AT.

Further prospective studies using weight bearing methods to assess ankle DF is warranted.

A number of limitations were identified for this research. First the sample size was small in this study. Post-hoc testing revealed that the study was underpowered. The small size may partly be due to strict inclusion criteria in addition to the limited availability of the population under investigation. However, the criteria were set to be reflective of seasoned distance runners to add strength to the quality of the research. A further limitation of this study was interpreting years of running as a potential measure of cumulative running load. Participants were asked how many years they have been consistently doing long distance running with previous running-based sport not included. For example, a distance runner with a swimming background will have exposed their tendon to less cumulative running load than a retired football player. In addition to loading history, other considerations that were not controlled or assessed were running surface, terrain and current running load. Whilst age was not identified as an associated factor, the limited age range of this cohort means caution should be taken generalising this finding to all distance runners.

5. Conclusion

There is a high prevalence of tendon pathology in an asymptomatic male running population with no history of Achilles tendon pain. Years of running appears to be an associated factor of Achilles tendon pathology. Further research to determine if these changes are transient, irreversible or predictive of future symptom development is needed. . Clinicians should consider running history when evaluating AT US findings because the longer a patient has been running the more likely that tendon pathology would be identified.

Conflicts of interest

The authors have no conflict of interest to declare.

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