FOOTFALL PATTERN IS NOT ASSOCIATED WITH ALTERED ACHILLES TENDON T2* RELAXATION TIME OF RECREATIONAL DISTANCE RUNNERS

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Achilles tendon (AT) tendinopathy was reported to be the pathology with one of the highest incidences of all running-related injuries. Non-rearfoot FP has been proposed to be the risk factor for AT overload. T2* relaxation time of Achilles tendon is considered to be a marker of AT tendinopathy. Therefore, the purpose of this study was to compare T2* relaxation time of Achilles tendon (AT) between recreational runner population with rearfoot (RF) and non-rearfoot (NR) footfall patterns (FP). Twenty-two middle age recreational runners (11 rearfoot and 11 non-rearfoot), matched according to running distance, participated in this study. Resting T2* relaxation time was determined using a 1.5 Tesla magnetic resonance imaging technique. Lower extremity kinematics and kinetics were recorded during over-ground running at a self-selected speed. No significant differences were found between T2* relaxation time of the insertion portion of the AT between RF and NR runners. Structural properties of the most injured part of the AT is not affected by running FP in healthy middle-aged runners.

KEYWORDS: rearfoot, non-rearfoot, running, tendon properties

INTRODUCTION: Running physical activity can affect the structure of the Achilles tendon (AT). T2* relaxation time of the AT has been shown to be longer in runners with a high training volume of running compared to non-runners (Devaprakash et al., 2020). The longer T2* relaxation time in runners may be associated with accumulated damage, disorganised collagen, and increased water content in the AT (Devaprakash et al., 2020; Juras et al., 2013). Runners can run with different footfall patterns (FP) that generally relate to AT loading during running. Non-rearfoot FP has been shown to have greater AT forces during the stance phase compared to RF running (Almonroeder et al., 2013; Gruber et al., 2011). However, different FPs did not resulted in altered cross-sectional area and stiffness of the AT in highly trained distance runners (Kubo et al., 2014). If no morphological adaptations are observed in NR runners, the question remains whether the structure and biochemical properties of the AT may be altered compared to RF runners. This question is becoming increasingly important if we consider that the early stages of tendinopathy usually alters biochemical but not morphological tendon properties (Samiric et al., 2009). Therefore, the purpose of this study is to compare T2* relaxation time of the AT between recreational distance runner population with RF and NR footfall pattern. We hypothesised that middle age NR runners will have longer T2* relaxation time of the insertion of the AT compared to middle age RF runners matched according to running weekly distance.

METHODS: This study is part of the larger healthy aging in an industrial environment study. Participants (n=1314) were recruited through a professional social science research company using quota sampling based on location, age, gender and running activity status. As the highest incidence of AT injury was reported between 30 and 50 years of age, we selected RF runners (n=11) and NR runners (n=11) of this age group, matched according to running distance in this age range (Lantto et al., 2014), for this study (Table 1). Participants completed two-day

baseline assessments in the Human Motion Diagnostic Center. Prior to the laboratory visit, each participant completed baseline questionnaires: physical activity habits as related to measured physical fitness (Kohl et al., 1988); running status and history questionnaire (Wiegand et al., 2019); and VISA-A - Index of the clinical severity of Achilles tendinopathy (Robinson et al., 2001) using the online Qualtrics platform (Qualtrics, Provo, UT, USA). The first day, a graded running exercise test was also conducted in order to determine maximum rate of oxygen consumption during running (Cipryan et al., 2020). On the second day, magnetic resonance imaging using a 1.5 T Siemens Magnetom Sempra Scanner (Siemens, Erlanger, Germany) was performed. A 90-degree angle scan of the ankle joint with the main focus on the AT was performed in a 16-channel head coil. Values from ROIs were analysed using a bi-exponential fitting procedure in an Interactive Data Language (IDL 6.3, Boulder, CO, USA). Consecutive $T2^*$ map was performed on a pixel-by-pixel basis using a custom-written MATLAB script (Juras et al., 2013). Analysis was performed in the three regions of the Achilles tendon (insertion part, middle part and muscle-tendon junction part). However for this study we used only data from insertion part of AT because it has been shown mostly clinically relevant for these data (Juras et al., 2013). Lower extremity kinematics and kinetics were recorded using a ten high-speed camera motion capture system (Oqus, Qualisys, Inc., Gothenburg, Sweden) during over-ground running at a self-selected running speed. Three force plates built into a 17 metres long runway (Kistler Instruments AG, Winterthur, Switzerland) were used to collect ground reaction force data. Kinematic and ground reaction force data were sampled at a frequency of 240 Hz and 2160 Hz, respectively. Overground running speed was controlled using two photocells (OPZZ, EGMedical s.r.o., Brno, Czech Republic). Overground running measurement consisted of eight successful trials in neutral running shoes (Brooks Launch 5, Brooks Sport Inc., Seattle, WA, USA). A running trial was successful if a participant landed on the force plate with the whole right foot at a speed ±5% of self-selected speed. Foot strike index was determined according to Cavanagh & Lafortune (1980). When the foot strike index was less than 33%, the participant was included to RF group. Participants with foot strike index greater than 33% were included in the NR group. A Wilcoxon signed-rank test was used to assess the difference between the groups for the $T2^*$ relaxation time of the AT insertion. Effect size (ES) was used to assess the biological relevance of the differences between the groups (Cohen, 1988). ES was interpreted as < 0.2 trivial; 0.2–0.5 small; 0.5–0.8 medium and > 0.8 large. The level of significance was set at $p < 0.05$. The statistical analyses were conducted using the IBM SPSS Statistics 24.

RESULTS:
There were no significant differences between RF and NRF runners in basic characteristics except for foot strike index (large effect size) and height (small effect size) (Table 1).

Table 1: Paired t-test and basic characteristics of matched group of runners.

	Non-rearfoot (n=11)	Rearfoot (n=11)	Effect size
	Mean ± SD	Mean ± SD	
Age (years)	40.82 ± 4.60	41.45 ± 5.57	0.12
Mass (kg)	72.18 ± 12.77	71.34 ± 11.98	0.07
Height (m)*	**1.78 ± 0.10**	**1.75 ± 0.11**	0.29
Fat (%)	24.76 ± 4.66	25.72 ± 4.98	0.20
Running distance (km/week)	43.45 ± 10.08	43.00 ± 9.58	0.05
VO$_2$Max	51.45 ± 8.18	48.39 ± 7.97	0.38
VISA-A (%)	96.81 ± 7.04	94.64 ± 6.83	0.31
Foot strike index (%)*	**50.08 ± 7.16**	**5.25 ± 5.50**	**7.02**

SD – standard deviation
*Statistically significant difference between groups (p-value<0.05).

No significant differences were found for the T2* relaxation time of the insertion part of the AT between RF and NR runners (small effect size) (Figure 1).

Figure 1: Comparison of mean and standard deviation of the insertion part of Achilles tendon T2* relaxation time (ms) – short component between RF and NR runners.
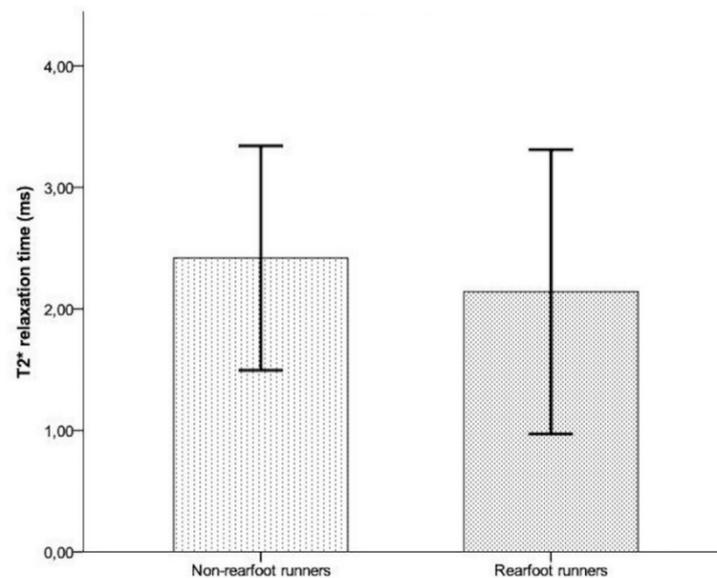
DISCUSSION: The purpose of this study was to compare T2* relaxation time of the AT between recreational runners' population with RF and NR footfall pattern. We hypothesized that middle-aged NR runners will have longer T2* relaxation time of the AT compared to middle-aged RF runners. However, the findings of the current study do not support our hypothesis which we ultimately rejected. Although the FP determines the forces acting on the AT, this force does not seem to significantly affect its structural properties. If we know that T2* relaxation time is higher in healthy long distance runners than in healthy non-runners, then the different biomechanical loading strategies of individual tissues during running should also determine the structure of AT (Devaprakash et al., 2020). Although it is sometimes speculated that NRF running is riskier in terms of AT injury than RF running, we found no prospective study that provided research evidence for this suggestion. It is possible that the biomechanics of the knee joint play a greater role in terms of the change in AT properties and injury risk during running.

Finally, a number of important limitations need to be considered. It is questionable whether the NR runners included in this study also maintained the same FP in fatigue. Some recent studies suggest a transition from NR running to RF running in fatigue (Jewell et al., 2016; Urbaczka et al., 2021). We did not investigate the whole AT, but only the usually most affected part of AT (Juras et al., 2013). We used only the short T2* relaxation time component and did not evaluate the T2* relaxation time long component. However, we used only short component because from a biochemical perspective, the short component of T2* is related to bound water and the long component to free water (Du et al., 2012). Another limitation may be the use of a magnetic field with a strength of only 1.5 Tesla. However, precision of the fitting curves suggested that bi-exponential analysis was valid.

CONCLUSION: This study has shown that structural properties of the most injured part of the AT is not affected by running FP in middle aged runners (population at highest risk of AT injury) as evidenced by the lack of a difference in T2* relaxation time.

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