ORIGINAL ARTICLE

Acute changes of Achilles tendon thickness investigated by ultrasonography after shotokan and kyokushin karate training

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A Study Design
B Data Collection
C Statistical Analysis
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Abstract

Background and Study Aim: Ultrasonography proved to be a useful tool to investigate the morphology of the Achilles tendon. Studies exist assessing the role of exercise on Achilles tendon morphology after vertical jump and treadmill running, and Achilles tendon dimensions noticeably decreased following heavy resistance exercise. However, little is known regarding the influence of different karate disciplines as shotokan and kyokushin on Achilles tendon thickness. Thus, this study aimed to establish whether the acute changes of Achilles tendon are a phenomenon characteristic of different styles of karate training.

Material and methods: Twenty-four male partcipants (12 shotokan and 12 kyokushin karate athletes) underwent sonographic examination with Honda HS – 2200 (Honda, Japan) ultrasound scanner. The Achilles tendon of both legs was measured twice before and then immediately following training. The sagittal thickness of the tendon was observed at a point exactly 10 millimetres proximal to the calcaneal insertion.

Results: In shotokan karate athletes, Achilles tendon thickness decreased significantly from before (7.9 ±1.0 mm) to after the training session (5.4 ±0.2 mm). In kyokushin karate athletes, the thickness of Achilles tendon did not change significantly. Before training it was (5.6 ±0.7 mm), after training was (5.6 ±0.7 mm). Significant differences were also found between shotokan and kyokushin karate athletes (p = 0.001).

Conclusions: Achilles tendon thickness decreases immediately after specific training in shotokan karate, but there are no observable changes in kyokushin karate group. In order to establish a concrete diagnosis for preventative and rehabilitative techniques, it is necessary to expand on the current research to observe the long-term effect of training on Achilles tendon thickness and morphology.

Keywords: combat sports • *in vivo* measurement • kumite • martial arts • tendon diameter • tendinopathy

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INTRODUCTION

The Achilles tendon is one of the strongest tendons in the human body. The constant contraction of gastrocnemius during daily living activity and sports actions (that lead to high-intensity stress) are important elements to predict tendinopathy and/or tendon degeneration [1]. Moreover, some studies observed the influence of physical activity/exercise on the Achilles tendon morphology [2, 3]. For example, Wearing et al. [2] found in human a substantial drop in Achilles tendon dimensions immediately after a heavy resistance exercise due to water evacuation from the tendon matrix, while Kubo et al. [3] found that after three months of isometric plantar flexion exercises, the adaptive tendon reached a stiffness increase of 50.3% (effects of increased type 1 collagen production).

Recently, the use of ultrasound technology has shown to be a reliable and accurate tool for the analysis of soft tissue in vivo [4], in particular, to evaluate the Achilles tendon morphology [5]. Indeed, as demonstrated in prior studies it is possible to assess the tendon degeneration and/or regeneration as well as tendon diameter [4–6]. In point of this, could be interesting to assess the diameter of Achilles tendons in karateka practitioners.

Karate, one of the most famous martial art, implies a high level of balance control [7], rapid kicks and sagittal/frontal hopping [8] performed barefoot. It is worth remembering that 35% of injuries in this discipline are localised in the lower extremities [9] and the important role of the Achilles tendon during load transfer with continuous implications during the stretch-shortening cycle [10].

Thus, we assessed tendon thickness after specific training in two different styles of karate (shotokan and kyokushin). Indeed, the definition of the magnitude of acute changes of Achilles tendon thickness (using ultrasonography) after exercise exposure could lead to useful information about the prevention of overuse injuries according to the technical action of lower limbs.

This study aimed to establish whether the acute changes of Achilles tendon are a peculiar characteristics of different styles of karate training.

MATERIAL AND METHODS

Participants

Subjects (n = 24) participating in this study were 12 elite karate shotokan athletes (aged 27.2 ±4.1 years; height 181.2 ±4.3 cm; body mass 76.2 ±7.1 kg, BMI 23.1 ±2.3 kg/m^2) and 12 elite karate kyokushin contestants (aged 30.9 ±12.9 years; height 182.9 ±4.5 cm; body mass 88.6 ±14.2 kg, BMI 26.5 ±4.1 kg/m^2). Participants belonged to the Polish National Team WKF–(World Karate Federation recognised by the International Olympic Committee) and Kyokushin National Team, they were competing in international-level karate events (Premier League, Karate 1, European Championship, World Championship and The World Games), and some were medalists in such competitions. Training experience of the whole group was on average 10 ±2 years.

Subject with any current or prior injuries involving the Achilles tendon was excluded. Participant athletes were healthy and able to perform the disciplines shotokan and kyokushin at an optimal level (inclusion criteria).

The study was approved by the ethics committee of the University School of Physical Education in Wrocław (Poland) and conducted in accordance with the Declaration of Helsinki.

Experimental procedures

Sonography was performed using a Honda HS – 2200 (Honda, Japan) ultrasound scanner with a 7.5 (6.0 to 11.0) MHz linear array transducer (HLS – 584 M, Honda, Japan) in grey scale B-mode. Settings of the ultrasound system were standardised for all the participants and kept constant during measurements. Ultrasound images were obtained by a single examiner. Additionally, average heart rate (HR) [beats/min] – sport tester (Polar Electro, Finland) and blood lactate (La^-) [mMol/l] (Lactate Scout, SensLab GmbH, Germany) were measured.

The Achilles tendon thickness measurements were performed before and after eight kumite shotokan and kyokushin (sparring fights with an opponent). Each fight lasted 2 min and was separated by a 2 min rest period. Subjects were instructed to lie prone with both ankles kept dorsiflexed at a 90-degree angle. The Achilles tendon of the dominant lower extremity was then observed in the longitudinal axis (sagittal plane). Measurements were conducted with software embedded in the ultrasound scanner and saved

Ultrasonography – a process that uses the reflection of high-frequency sound waves to make an image of structures deep within the body. Ultrasonography is routinely used to detect fetal abnormalities [24].

Magnetic resonance imaging (MRI) – an imaging technique that uses a large circular magnet and radio waves to generate signals from atoms in the body. These signals are used to construct images of internal structures [24].

Microdialysis – a technique for measuring extracellular concentrations of substances in tissues, usually in vivo, by means of a small probe equipped with a semipermeable membrane. Substances may also be introduced into the extracellular space through the membrane [25].

Achilles tendon – is a tough band of fibrous tissue that connects the calf muscles to the heel bone (calcaneus) [26].

Shotokan – style of karate started and developed by Sensei Gichin Funakoshi. Initially, shotokan was the name of the first karate dojo (the "***honbu dojo***" - central dojo), but over time it became the name of the style of karate that Sensei Funakoshi taught/practised [27].

Kyokushin – is a style of stand-up, full contact karate, founded by Masutatsu Oyama which means the "Ultimate Truth". Based on Sosai's point and circle concept by which one draws a circle around one point and attach the lines around the circle [28].

Kumite – is a semi-contact karate competitive concurrence, where two athletes perform various kicking, punching and blocking techniques towards each other with maximum control in order to gain points and win the match.

Gastrocnemius *noun* – the largest muscle in the calf of the leg, extending from the thigh bone to the Achilles tendon [29].

Tendon *noun* – a sinew or strand of strong connective tissue that attaches a muscle to bone [29].

Tendinopathy *noun* – any pain felt in a tendon [29].

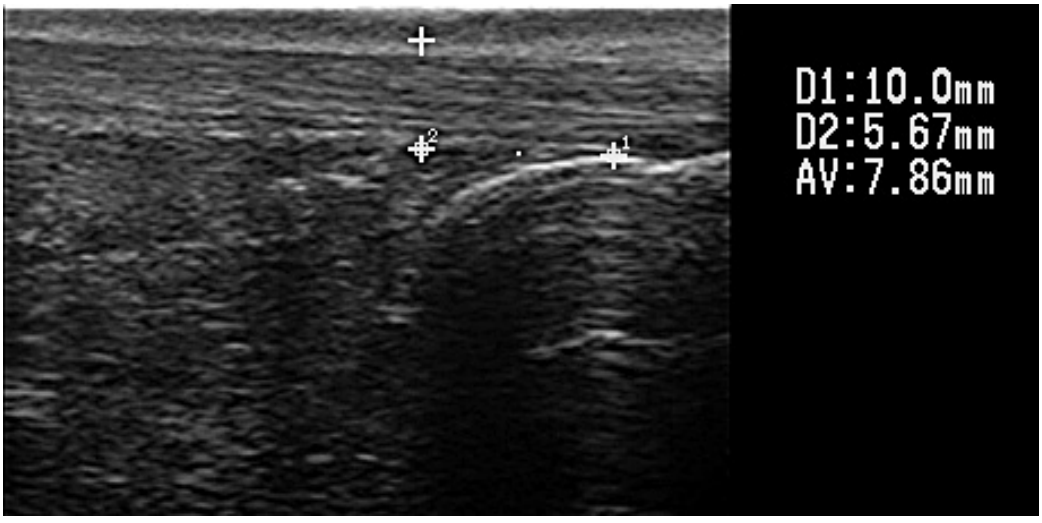

Figure 1. Achilles tendon thickness in the long-axis. The tendon thickness measure (10 mm) lateral to the calcaneal insertion.

on the hard drive of the unit. The measurement of Achilles tendon thickness was taken at 10 mm proximal to the attachment of the tendon to the reference point of the calcaneal insertion. The reference point was defined proximally as the first hyperechoic region of the calcaneal insertion (Figure 1).

This measurement was taken two consecutive times and then averaged for optimal accuracy. Intra-rater test-retest reliability of Achilles tendon thickness method revealed excellent reliability and acceptable measurement error [ICC(3.2) = 0.91; MDC90 = 0.7 mm; SEM = 0.2] in a pilot study of n = 10 participants (unpublished material). Immediately after training, average HR and blood lactate concentration $[La^{-})]_b$ were measured.

Statistical analysis

SPSS 18 statistical software (SPSS Inc., Chicago, USA) was used for data analysis. A two – way ANOVA with repeated measures was used to compare the recordings before with those after sparring fights for the two karate groups. Statistical significance was set at $p \leq 0.05$.

An *a-priori* power analysis was performed to determine the required sample size using G*Power software (version 3.1.9.2; Kiel University, Kiel, Germany) [11]. For the Achilles tendon thickness measure, a sample size of 16 subjects per group was deemed adequate to provide 90% power and an alpha level of 0.05. Cohen's d effect sizes were calculated by dividing the mean difference between the group standard deviation (±). Effect sizes were interpreted as small (0.20 to 0.49), medium (0.50 to 0.79), and large (greater than or equal to 0.80) [12].

Intraclass correlation coefficient ICC3.2 was used to determine the intra-rater reliability of the Achilles tendon thickness variable. Measurement error was calculated with the standard error of measure (SEM), and minimal detectable change (MDC90) represents the error when a measure is taken twice (change over time) [4].

RESULTS

Immediately after training, HR was 182 ±7 beats/min, while La^{-} 12.4 ±0.6 mMol/l. For shotokan contestants Achilles tendon thickness decreased significantly from pre (7.9 ± 1.0 mm) to post training measure (5.4 ±0.2 mm) [mean difference = 2.5mm (95% CI: 1.5, 3.1); effect size = 0.85; p = 0.001]. For kyokushin contestants, Achilles tendon thickness have not changed significantly. Before training was (5.6 ±0.7 mm), while after training was (5.6 ± 0.7 mm) ($p>0.05$). The analysis also revealed significant differences in pre-training Achilles tendon thickness between shotokan and kyokushin karate contestants [mean difference = 2.3 mm (95% CI: 1.57, 2.98); effect size =0.80; p = 0.001] (Table 1).

DISCUSSION

Biological adaption to imposed stress on the lower extremities is inevitable in order to maintain healthy and efficient force output. The

Table 1. Changes in Achilles tendon thickness (ATT) (mean and standard deviation) after two different karate styles training sets.

Variable	Shotokan karate		Kyokushin karate	
	pre	post	pre	post
ATT [mm]	7.9 ±1.0[a, b]	5.4 ±0.2[a]	5.6 ±0.7[b]	5.6 ±0.7

The significance of differences between means, $p<0.05$: [a] differences between pre- and post- measurement in both groups; [b] differences in pre-measurement between both groups.

Achilles tendon is the main contributor to this adaption due to the constant excessive force applied to it. After observing the decrease in tendon thickness immediately post karate training, we need to observe the type of physical stress that shotokan and kyokushin place on the body. Physical activity's influence on the stimulation of soft tissues is dependent on intensity, time duration, and specific patterns of movement [3, 13].

The present study showed that Achilles tendon thickness decreased significantly as the effect of specific training load only for shotokan karate athletes. This was the first study to investigate changes in Achilles tendon thickness as the effect of specialised karate training. Some authors achieved similar effects. Wearing et al. [2] reported these results after short-intensive resistance exercise consisting of plantar and dorsal flexions of the ankle joint. Additionally, Grigg et al. [14] compared the influence of concentric and eccentric isolated exercises, and in both cases, the thickness decreased, but the size of the reduction was higher after the eccentric loads. However, the exercises set in shotokan karate connect both types of muscle contraction and in addition there is more explosive work during the activity than in isolated exercises used by the other researchers. There are some conjunctures which could be useful for explanation of the observed phenomenon. Radial extrusion of water from the tendon core, as well as changes in turnover of collagen type I are possible contributing factors. Results from Langberg et al. [15] show a decrease in collagen production and greater disintegration directly after long-distance running and the opposite trend after 72 hours resting due to collagen type I overproduction. These results also may explain why Achilles tendon volume has risen in some other investigations. Prior studies have shown the effect of long-term training on the collagen overproduction. Our main findings may suggest that the collagen overproduction could occur in relation to the stimulation of collagen production. Moreover, the adapted tendon thickening meant an increase in strength and minimised risk of injury [16, 17].

Tendons have the potential to accumulate the passive elastic energy like a spring and have the role of buffering force to prevent muscle tear. We suppose the decrease in tendon thickness could be caused by increased tension in the gastrocnemius muscle after shotokan karate training. The tension could mean shortening of sarcomeres which would pull and stretch the Achilles tendon. The stretching may cause transverse compressive forces between tendon fibres and likely minimises the measured a-p dimension [14, 18]. Described arguments are based on the tendon's helical collagen characteristics. When the helical structure is under the influence of longitudinal stretching, collagen fibres are twisting along the tendon axis which changes the area and perimeter of the tendon [19]. This theory is conjecture at the moment and requires more investigations for confirmation.

Several studies investigated the influence of physical activity on Achilles tendon stiffness [20, 21]. In particular, Pozarowszczyk et al. [10] investigated acute changes in Achilles tendon after shotokan karate fights. The Authors found increases of AT stiffness in only the dominant leg and lack of changes in the non-dominant leg. In the current study, we did not observe differences between dominant and non-dominant legs in tendon thickness. There is a necessity to compare thickness changes and stiffness to understand the relationship between these two indicators better.

Results by van Drongelen et al. [22] are opposite to those obtained in our study. Their research observed the biceps brachial tendon in wheelchair basketball and wheelchair rugby athletes, who even outside of their sports activity, strictly use upper extremities in everyday activities. We hypothesise that these results may be due to an inflammatory response to excessive strain on the muscles and tendons of the upper extremities from participating in vigorous sports activity.

As for kyokushin karate, no significant changes in Achilles tendon thickness were observed after training. These results coincide with the studies of Fredberg et al. [23] who had not observed any changes after activity. It should be noted that there were methodological differences between this current study and Fredberg's et al. [23] study because they had not performed assessment directly post-exercise, but 20 minutes after the exercises' end. It is difficult to explain the lack of thickness change, but we wonder if the high level of physical fitness and adaptation to the routine of this training could create a need to apply higher stimulus directed to the lower extremities to induce a change of thickness in the Achilles tendon.

There are some potential limitations to the current study. The first is that a majority of existing research regarding tendon properties come from animal samples observed in vitro. Therefore, the chemical properties of the human tendon in relation to biomechanical performance need to be bridged by what we can observe through means of ultrasound, magnetic resonance imaging (MRI), and microdialysis. The second is the lack of repetitions in measurements after activity. When comparing acute changes in Achilles tendon thickness after one set of training in the two presented styles of karate, differences can be observed, but it would be useful in future studies to measure multiple sets of training at a variety of intensities as well as at varying durations of time. Even though both styles fall into the karate category of combat sports, the profile of physical fitness and technique vary immensely between the two styles. In order to establish a trend of variation in Achilles tendon thickness between these particular styles of karate, it is necessary to observe long-term changes in Achilles tendon thickness in relation to training. This data will then serve as a useful source for the prevention of injury for karatekas during training as well as during recovery.

CONCLUSIONS

Achilles tendon thickness decreases immediately after specific training in shotokan karate, but there are no observable changes in kyokushin karate group. In order to establish a concrete diagnosis for preventative and rehabilitative techniques, it is necessary to expand on the current research to observe the long-term effect of training on Achilles tendon thickness and morphology.

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