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Research article

The Achilles Tendon Response to a Bout of Running is not affected by Triceps Surae Stretch Training in Runners

Coulter D. Neves, Joshua K. Sponbeck, Katy Andrews Neves, Ulrike H. Mitchell, Iain Hunter and Aaron Wayne Johnson ✉
Department of Exercise Sciences, Brigham Young University, Provo, UT, USA

Abstract
An acute bout of distance running decreases Achilles tendon CSA. The purpose of this study was to examine if three-week stretch training of the Achilles tendon alters the Achilles tendon thinning response to running. Thirty-three recreational runners were divided into a control group (n = 17) and an intervention group (n = 16). The intervention included a three-week soleus stretch (knee flexed) and gastrocnemius stretch (knee extended). Three gastrocnemius stretches and three soleus stretches were performed each day, six days per week. Stretches were held for 30 s per repetition for a total duration of 180 s per leg per day. Achilles tendon CSA and range of motion measures were completed pre and post-run before and after the three-week stretching intervention. The runs prior to and following the three-week stretch training intervention both resulted in a 6% decrease in Achilles tendon CSA ($p < 0.0001$). There was no interaction across time between control and intervention groups in CSA ($p = 0.446$). Only the intervention group experienced a significant increase in dorsiflexion range of motion following the stretch training ($p = 0.009$). We therefore conclude that even when an increased dorsiflexion range of motion occurs, three weeks of triceps surae stretching does not alter the response of the Achilles tendon CSA.

Key words: Cross sectional area, ultrasound imaging, dorsiflexion range of motion

Introduction

Running is a lifelong activity (Koplan et al., 1995) that has considerable health benefits for people of all ages (Junior et al., 2015). One of the biggest reasons for running dropout is injury (Fokkema et al., 2019). Each runner experiences a 46% - 92% chance of injury every year (Benca et al., 2013). Approximately two thirds of runners are forced to interrupt their normal training schedule due to an injury (Benca et al., 2013).

One common overuse pathology that afflicts runners is Achilles tendinopathy (Paavola et al., 2002; Heckman et al., 2009; Kvist, 1994) which affect up to 52% of elite distance runners (Kujala et al., 2005). Runner's Achilles tendon injuries are thought to be the result of repetitive loading of the tendon, which results in disruption of tendon fibers, causing dysfunction and pain (Paavola et al., 2002). One predisposing risk factor for Achilles tendinopathy is limited dorsiflexion range of motion (Kvist, 1994; Lorimer and Hume, 2014). Limited dorsiflexion is thought to increase subtalar ankle pronation (Kvist, 1994), resulting in excessive force and tension leading to Achilles tendinopathy (Clement et al., 1984, Becker et al., 2017).

In an attempt to prevent Achilles tendon injury many runners perform stretching before and/or after exercise (Welsh and Clodman, 1980). Stretching reduces muscle and tendon stiffness (Kay et al., 2015; Konrad et al., 2017), is thought to increase muscle length, and prepares the muscle and tendon for activity (Park and Chou, 2006; Shehab et al., 2006). While stretching is reported to have no effect on all cause injury, it might have some mediating effect on acute muscle injuries associated with running, sprinting, or other repetitive contractions (Behm et al., 2015). Thus, most coaches, athletes, and clinicians still favor including stretching within a training program (Shehab et al., 2006). Stretching has been shown to increase dorsiflexion range of motion effectively in as little as three weeks (Dinh et al., 2011; Peres et al., 2002; Johanson et al., 2009).

Tendons adapt to the stresses imposed upon them (Kubo et al., 2002; Reeves et al., 2003; Tardioli et al., 2012), leading to changes in tendon cross sectional area (CSA), length, thickness, and stiffness (Wilson and Lichtwark, 2011; Tardioli et al., 2012). These adaptations are seen acutely and in long term situations. Acutely, tendon CSA decreases following a single bout of running (Tardioli et al., 2012; Neves et al., 2014). In long term situations, tendon CSA has been shown to increase in response to running in 3 weeks (Sponbeck et al., 2017). It is not understood if long-term intervention training impacts acute responses of tendons to exercise.

Ultrasound imaging is a reliable (Neves et al., 2014) and non-invasive method used to assess tendon structure and CSA changes (Farris et al., 2011; Martinoli et al., 2002). Ultrasound use is increasing to assess function and injury in many sports medicine settings. It allows for detailed assessment of tendons and dynamic testing of tendon integrity (Jacobsen, 2018).

To date, no studies exist to our knowledge that examine how a stretching regimen alters the tendon response to a bout of running. Since limited dorsiflexion is a risk factor for Achilles tendinopathy (Kvist, 1994), increasing dorsiflexion may decrease Achilles tendinopathy risk. Therefore, the aim of this study was to examine if a three-week stretching program alters Achilles CSA response to a 20-minute run. We hypothesized that the magnitude of within session changes in Achilles tendon CSA will be greater in response to a three-week triceps surae stretching program.

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Table 1. Participant demographics. Data are means (± standard deviation).

	Control		Intervention	
	Male	**Female**	**Male**	**Females**
Age (y)	26.88 (3.72)	24.25 (2.12)	26.88 (3.4)	22.38 (1.69)
Height (m)	1.80 (0.04)	1.66 (0.06)	1.86 (0.06)	1.63 (0.05)
Mass (kg)	72.93 (8.95)	56.86 (4.80)	78.78 (5.19)	57.39(4.77)
Years Running	12.63 (4.20)	9.5 (1.92)	8.5 (3.81)	8.25 (2.66)
Weekly Mileage	22.25 (17.47)	32.64 (26.47)	19 (12.85)	26.25 (18.52)

Baseline characteristics of each group. Participants were randomly assigned groups. At baseline no significant difference existed between groups.

Methods

Research design

This was a randomized controlled interventional study.

Participants

Thirty-three runners (16 female, age = 23.31 ± 4.31 years, height = 1.65 ± 0.10 m, mass = 57.12 ± 8.12 kg, running history = 8.88 ± 4.13 years, weekly mileage = 29.23 ± 50.77 miles and 17 male, age = 26.71 ± 4.71 years, height = 1.83 ± 0.10 m, mass = 75.12 ± 16.12 kg, running history = 10.35 ± 7.35 years, weekly mileage = 20.88 ± 39.12 miles) completed this study (Table 1). Participants were recruited from local universities and running centers via fliers and announcements. Their running experience ranged from recreational to sub-elite athletes. None of the participants consistently stretched the Achilles tendon for one month prior to participation in the study. They had not suffered an Achilles tendon injury within six months, a lower extremity injury within three months of data collection, or were pregnant. Participants were currently running at least 3 times per week and able to run 5000m in under 24:00 min. All procedures were granted approval by the Institutional Review Board at the university (study protocol x15033). Power assessment indicated that with a mean of .36 cm^2 and SD of 0.04 cm^2, sixteen participants were needed to detect a significant difference of .4 cm^2 between pre and post-run Achilles tendon CSA measurements at (p = 0.05, ß = 0.8). Thirty five participants started the study (18 control group, 17 treatment group). One participant dropped out of treatment group because the stretching was causing pain to the Achilles tendon and another dropped out from the control group due to an unrelated injury that prevented further participation.

Procedures

Participants read and signed an informed consent and completed a pre-participation questionnaire to determine eligibility before starting data collection. They were then scheduled for their running visits, a pre-intervention run and a post-intervention run, separated by three weeks per previously published protocols. (Magnusson et al., 1996; Toft et al., 1989). Each participant received instructions to maintain normal eating and hydration habits, and follow normal sleep patterns during the duration of the study. On the testing day participants were asked to refrain from eating a meal two hours prior to testing, and avoid any exercise previous to testing. Adherence to these parameters was assessed with a participation questionnaire.

Ultrasound imaging of the achilles tendon cross-sectional area

Ultrasound images were collected on the initial running visit and the post-intervention visit. Upon arrival to the biomechanics lab, each participant rested prone with the ankle in a comfortable position on a training table for 10 minutes. Cross-sectional area of the Achilles tendon was then measured on each leg according to previously published methods (Farris et al., 2012, Neves et al., 2014). This procedure was performed on the right foot then the left foot. Specifically, a strap, connected to the end of the table, was placed around the plantar surface of the forefoot to ensure that the measured 90-degree angle at the ankle was maintained. Ultrasound (GE Logic E, GE Healthcare, Little Chalfont, United Kingdom) with a 12L probe was used for imaging the Achilles tendon (Figure 1). Images were taken at the point on the Achilles tendon directly between the apex of the medial and lateral malleoli. This point was marked with a permanent marker to ensure pre-run and post-run images were taken at a consistent location. This mark was maintained by researchers and participants during the three-week intervention period using permanent marker. Three separate transverse ultrasound images per leg were taken at this mark. Our calculated intraclass correlation coefficient test and retest reliability were of 0.97 (95% CI: 0.959, 0.986).

Figure 1. Ultrasound imaging procedure and probe placement. Image showing foot placement of participants during ultrasound imaging as well as probe placement.

Range of motion measurements

With the participant supine and the knee fully extended, three passive ankle dorsiflexion range of motion measurements were then taken using a standard goniometer (EMI Goniometer, Elite Medical Instruments, Fullerton, CA, USA) and averaged. Subjects were stretched by the researchers until "slight discomfort" was reported by the subject (Mitchell et al., 2007; Johnson et al., 2014). Our calculated intraclass correlation coefficient test and retest reliability were of 0.987 (95% CI: 0.983, 0.990).

Running session

After these baseline measurements were taken participants completed a twenty-minute run on an indoor treadmill at 3.13 m/s at 0% of level incline. Immediately after running, they returned to the training table where post-run ultrasound images were taken.

Stretching intervention

Upon completion of the post-run ultrasound imaging, participants were randomly assigned to the control or intervention group. Researchers taking the ultrasound images and measuring CSA were blinded to the group assignment. Participants assigned to the intervention group were then taught the stretching protocol. Two traditional stretches were used, one with the knee extended (gastrocnemius stretch) and one with the knee slightly flexed (soleus stretch). Each stretching position was performed three times, held for 30 s per repetition for a total duration of 180 s per leg. The participants were instructed to choose the position of stretch at which they perceived a "good" stretch with slight discomfort, but not to the point of pain. They were asked to time each stretch with a stop watch. They were instructed to complete this protocol six days/week for three weeks. Participants reported their compliance to the stretching protocol daily via an online survey program. Semi-weekly reminder emails were also sent to participants in the intervention group. The emails contained pictures and explanations of the stretching protocol. The participants returned to the Biomechanics Lab once within a week of their initial visit to perform the stretches under the supervision of a research assistant to ensure they were being performed properly. The control group was instructed to maintain their normal activity level with no stretching to the calf muscles.

Three weeks after their pre-intervention run, participants returned for a post-intervention run where the same ultrasound and running protocol was followed.

Data Processing

Three separate transverse images were taken of each right and left Achilles tendon. Using internal software of the GE Logic, the images of the Achilles tendon were outlined manually and the CSA was computed. The average of the three measurements were taken as the tendon CSA.

Statistical Analysis

A 2-way mixed model repeated measures ANOVA (2 groups x 4 times) was utilized to determine Achilles tendon CSA main effects of time and group and interaction between these factors. A pair-wise post-hoc test for significance was done to determine specific difference between the variables. Initial Achilles CSA was a significant co-variate and was included in the statistical model. To determine if a change in range of motion occurred we performed a 2-way mixed model repeated measures ANOVA. (2 groups x 2 times) Alpha was set at $p < 0.05$. Statistical analysis was completed using SPSS v26 (IBM Armonk, NY).

Results

Descriptive variables of the groups are listed in Table 1. There was no difference between the variables at baseline. There was a significant increase in dorsiflexion range of motion of 3.5 degrees within the intervention group over the three-weeks of stretching. ($p < 0.001$) The control group showed a non-significant within change in dorsiflexion range of motion. ($p = 0.217$) (Figure 2). There was a significant difference in dorsiflexion range of motion between groups after the intervention ($p = 0.009$).

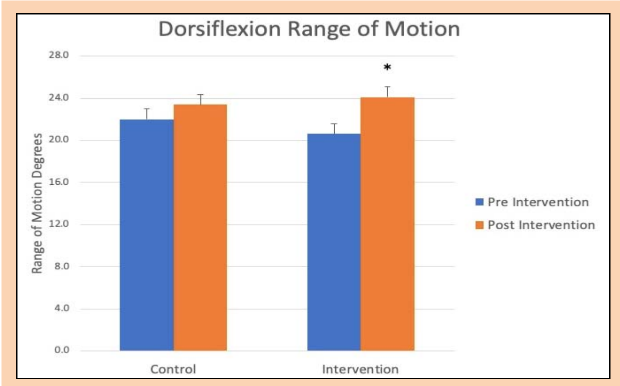

Figure 2. Dorsiflexion range of motion measurements for each group at both the baseline run as well as at the post intervention run. * indicates a significant increase in dorsiflexion in the intervention group ($p = 0.009$).

There was a significant decrease in CSA between pre and post run for both groups at both time points ($p < 0.001$) (Figure 3). Consistent CSA changes of 0.03 cm^2 were observed pre and post run for both groups ($p = 0.446$). A difference of 0.03 cm^2 equates to a CSA change of 6% during running in both groups. The calculated effect size for the pre run to post run in both groups at both time points was large to very large (Cohen's D = 0.81 - 1.68).

Discussion

The aim of this study was to examine if a three-week stretching program changed how the Achilles tendon CSA responds to a 20-minute run. We found that our stretching program did not change how the Achilles tendon CSA responded to a 20-minute run. These results are similar to a previous finding that show that Achilles tendon CSA remain unchanged despite eccentric exercise with a stretching protocol (Kubo et al., 2001). In this particular study, the participants performed eccentric exercises on both legs, but on one leg the participants also performed a gastrocnemius stretching protocol. The researchers showed that the stretching protocol decreased the hysteresis of the tendon but did not affect its elasticity. After correlating hysteresis to tendon viscosity, they hypothesized that the tendon's internal structural changes accounted for the difference in viscosity while CSA remained constant (Kubo et al., 2001). Our study did not examine stiffness or viscosity of the tendon, but we recognize that the participants' tendons may have experienced internal structural changes, that were not measured, as a result of the stretching protocol.

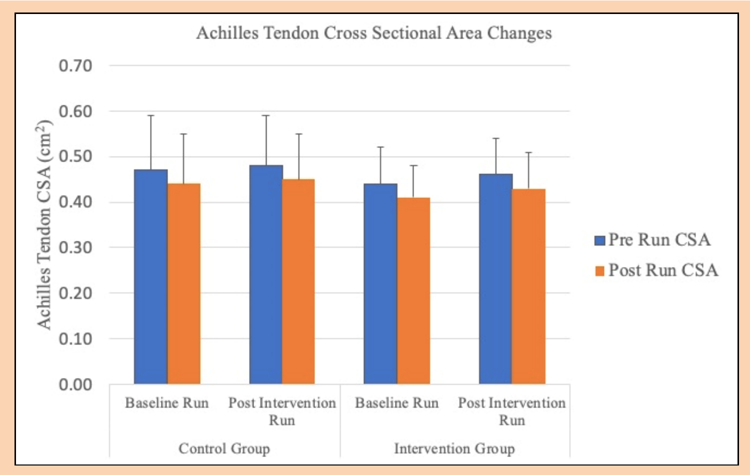

Figure 3. Achilles tendon CSA changes for both the control group and the intervention group at both the baseline run, and the post intervention run. At all-time points, both groups had a significant decrease in Achilles tendon CSA ($p < 0.0001$). There were no Achilles tendon CSA thinning differences following the three-week intervention stretching program.

The Achilles tendon CSA experienced significant thinning before and after the stretch training. Our research agrees with previous findings that have shown significant decreases in Achilles CSA following a running bout (Tardioli et al., 2012; Neves et al., 2014). This study is the first time that an intervention, like stretching, has been viewed in connection with Achilles tendon thinning following running. Stretching the Achilles has been linked to a decrease in viscosity (Kubo et al., 2002), and we hypothesized that the tendon would experience increased thinning after running. Further research investigating a longer stretch training intervention would be worthwhile as many tendon adaptations are only seen after a more extended time period (Freitas et al., 2018).

Limited ankle dorsiflexion is one intrinsic risk factor that is thought to be a predisposing factor for Achilles tendinopathy (Kvist, 1994). In this study runners participated in a stretching protocol that increased dorsiflexion range of motion significantly, without affecting the acute response of the Achilles tendon to running. Therefore, we believe that runners can safely increase dorsiflexion range of motion, during training periods, without disturbing the Achilles CSA response to running.

Achilles tendons experience some hypertrophy in response to loading sports, that include running and jumping, such as volleyball (Cassel et al., 2016). This hypertrophy also occurs over time as a response to habitual running with increasing mileage and/or intensity (Magnusson and Kjaer, 2003), and was observed to happen in as little as a three-week period in competitive runners who ran up to twice a day every day of the week (Sponbeck et al., 2017). Thus, there was a potential to see tendon hypertrophy in our running study. However, we did not see any hypertrophy of the Achilles tendon in our recreational runners. This is likely due to the decreased running frequency of only running three times per week which may not have provided enough stimulus for hypertrophy.

The intervention group in this study showed an anticipated increase in dorsiflexion compared with the control group, indicating that the stretching program was successful. Static stretching is a popular activity that is documented to increase range of motion (Young et al., 2013). Our study agrees with previous three-week triceps surae stretching protocols that show increased dorsiflexion range of motion in an intervention group of about four to five degrees (Dinh et al., 2011, Peres et al., 2002, Johanson et al., 2009).

Conclusion

A 20-minute run among recreational runners with at least a five-year history of running causes a statistically significant decrease in Achilles tendon CSA. However, the change in Achilles tendon CSA are not affected by a three-week triceps surae muscle-stretching program. While stretching increases dorsiflexion range of motion, which may decrease a risk factor, associated with tendinopathy, it does not change the Achilles CSA response to running.

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The experiments comply with the current laws of the country in which they were performed. The authors have no conflict of interest to declare.

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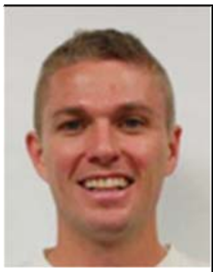
Key points

- Achilles tendon cross-sectional area does not change following a three-week triceps surae stretching protocol in recreational runners.
- Achilles tendon cross-sectional area significantly decreases following running.
- A three-week triceps surae stretching protocol is effective for increasing dorsiflexion range of motion.

AUTHOR BIOGRAPHY

Coulter D. NEVES
Employment
Department of Exercise Sciences, Brigham Young University
Degree
MD
Research interests
Anesthesia, running, Achilles tendon
E-mail: coulterneves@gmail.com



Joshua K. SPONBECK
Employment
Department of Exercise Sciences, Brigham Young University
Degree
MSAT
Research interests
Adaptation to exercise and rehabilitation of athletic injuries
E-mail: jspon44@gmail.com

Katy Andrews NEVES
Employment
Department of Exercise Sciences, Brigham Young University
Degree
MSc
Research interests
Performance in sport (distance running)
E-mail: katyandrews100@gmail.com

Ulrike H. MITCHELL
Employment
Department of Exercise Sciences, Brigham Young University
Degree
PhD, PT
Research interests
Musculoskeletal rehabilitation with an emphasis on the spine
E-mail: rike@byu.edu

Iain HUNTER
Employment
Department of Exercise Sciences, Brigham Young University
Degree
PhD
Research interests
Biomechanics of distance running related to performance and injury
E-mail: iain_hunter@byu.edu

A. Wayne JOHNSON
Employment
Department of Exercise Sciences, Brigham Young University
Degree
PhD, PT
Research interests
Rehabilitation and rehabilitative ultrasound imaging of spinal, leg and foot muscles, Minimalist shoe running, Whole-body vibration, Flexibility, and outcomes of rehabilitation
E-mail: wayne_johnson@byu.edu

✉ **Aaron Wayne Johnson, PhD, PT**
Department of Exercise Sciences, Brigham Young University
266 Smith Fieldhouse, Provo, UT 84602