**Immediate effects of two, isometric calf muscle exercises on mid-portion Achilles tendon pain.**

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**Abstract**

The objectives of this pilot, randomised, cross-over study were to determine if isometric plantarflexion exercises resulted in an immediate change in Achilles tendon pain during a loading task and if this differed in knee extension or flexion. Eleven participants with mid-portion Achilles tendinopathy were recruited from NHS community physiotherapy services and local running clubs. Participants were then randomised to complete an isometric calf muscle exercise with the knee fully extended or flexed to 80 degrees. Participants switched to the alternate exercise after a minimum seven-day period. Achilles tendon pain during a specific, functional load test was measured on a 11-point numeric pain rating scale (NPRS) pre and post-intervention. There was a small, immediate, mean reduction in pain following isometric plantar flexion performed in both knee extension (1.6, 95%CI 0.83 to 2.45, p=0.001) and knee flexion (1.3, 95%CI 0.31 to 2.19, p=0.015). There were no significant differences between the two positions. A non-significant, potentially clinically relevant finding was a 20% larger reduction in symptoms in knee extension versus flexion (p=0.110). In conclusion, isometric plantarflexion holds gave an approximately 50% immediate reduction in Achilles tendon pain with a functional load test. There were no significant differences between the two positions and both were well tolerated.

**Key Words**

Tendinopathy; Physiotherapy; Exercise; Pain

## Introduction

Achilles tendinopathy is a musculoskeletal disorder characterised by pain and loss of function [1, 2]. Exercise is the cornerstone of management of tendinopathy, but pain experienced during or following exercise may present a barrier to adherence [3]. Exercise is more effective than wait-and-see in the management of mid-portion Achilles tendinopathy [4] and by 12 weeks appears to result in clinically meaningful improvements in tendon-pain related disability [5]. Thus, improving adherence to exercise and reducing transition to less efficacious, invasive procedures should be a focus. For in-season athletes, interventions that target immediate reductions in symptoms may also be important, however few interventions demonstrate an immediate~~,~~ beneficial effect on tendon pain [6, 7]. Studies that investigate the immediate effects of calf muscle exercises and whether they are tolerable (and beneficial) to participants with Achilles tendinopathy may assist with exercise prescription and provide options for clinicians when faced with those who have irritable symptoms or fear of exercise, particularly in the early phases on rehabilitation [8].

Isometric exercise has been investigated in a small case series in people with Achilles tendon pain with variable effects on pain during a functional load test [9]. Currently most of the research on isometrics is based in patellar tendinopathy with variable results. Improvements were first demonstrated in a small laboratory based-cross over study [7] and then a 4-week case series of 20 athletes [10]. Further, both isometric and isotonic exercises were shown to be beneficial in a 4-week RCT [11] indicating two potential options for clinicians treating athletes with patellar tendon pain in-season. It has also been shown that short-duration isometric contractions were as effective as longer duration contractions in relieving patellar tendon pain, potentially giving clinicians greater options in the prescription of isometric exercise [12].

Research suggests that of the two main calf muscles forming the Achilles tendon, soleus weakness, more than gastrocnemius weakness, may be a feature of chronic Achilles tendinopathy [13, 14]. Evidence suggests that activities with the knee flexed at 80-90 degrees inhibits the force production capabilities of the gastrocnemius muscle [15] and may be considered a suitable method of biasing the soleus muscle during the assessment of muscle strength and subsequent exercise prescription [16]. Conversely, in full knee extension, the entire Triceps Surae (Gastrocnemius and Soleus) are recruited, and maximal force production may differ from that of the flexed knee position [17]. Therefore, one position may be superior to the other with respect to patient tolerance of load and result in increased adherence to rehabilitation. The primary objectives of this pilot study were to determine if isometric plantar flexion resulted in an immediate change in Achilles tendon pain during a loading task and investigate if differences exist between isometrics performed in a position of knee extension, versus knee flexion.

## Methods

This study was a participant-blinded, randomized, cross-over pilot trial. We confirm that we have read and understood the journal's ethical standards document [18] and confirm that the study meets the ethical standards of the journal. Ethical approval was obtained from the National Research Ethics Service (NRES) in September 2018.

**Participants**

Participants were recruited from patients referred to the Norfolk Community Health and Care NHS Trust (NCH&C) physiotherapy services by their GP and in addition, from local running clubs. Participants wishing to take part provided written informed consent at their initial assessment. Participants were eligible for inclusion if they were over 18, had mid-portion Achilles tendon pain for greater than 3 months (Supplementary File A: participant selection of Image B or D) had a score of less than 80 points on the Victorian Institute Sport Assessment – Achilles (VISA-A) and reported only mid-portion Achilles tendon pain during at least one of the following tests performed at the initial physiotherapy appointment: I) double leg heel raise (II) single leg heel raise (III) double leg hop on spot (IV) single leg hop on spot. All four tests were performed consecutively to establish the test that reproduced the patient's pain between 2 - 7/10 on the NPRS (Supplementary File B). This range was pre-defined as our "clinical tolerance range" based on previous research [19, 20]. The test with the highest level of pain was documented as these tests represent increasing Achilles tendon load. Participants were excluded if they had pain outside the "clinical tolerance range" during any of the four tests above, a history of inflammatory systemic disease or fluoroquinolone(s) usage and pain in any area other than the mid-portion of the Achilles tendon.

Participants completed both interventions but were randomized to one of two intervention groups, isometric plantar flexion with the knee in flexion (FLX) or extension (EXT), at their first session of data collection. The order of completion for the two interventions were randomized for all participants by the drawing of sealed, opaque envelopes containing the allocation sequence.

**Baseline Strength Assessment**.

Isokinetic dynamometry was used to measure participant maximal voluntary isometric contraction (MVIC) torque (Nm) for the two test positions. The participant was positioned in long sitting, with the back rest and hip joint range of movement standardised to 60 degrees. This position demonstrates test retest reliability, accuracy and reproducibility [21, 22, 23]. The lateral malleolus was aligned with the rotational axis of the dynamometer lever arm and the ankle positioned in 10 degrees of dorsiflexion. This range of movement was selected because prior pilot testing demonstrated peak MVIC torque between neutral and 20 degrees of ankle dorsiflexion. The participant completed a five-minute stationary cycle and three sub-maximal isometric contractions as a warm-up. The highest recorded value from three, maximal efforts was then recorded as the MVIC for that position. The guidance and encouragement given during the procedure was standardized to reduce the risk of performance bias.

**Intervention**

Each participant completed two exercises for this study: isometric ankle plantarflexion (at 10 degrees of dorsiflexion) with an extended knee (EXT) and knee flexed to 80 degrees (FLX). The two test positions are shown in Figure 1 below. To ensure recovery of the calf muscle(s) there was a minimum of five minutes rest following the MVIC testing procedure. Each participant was positioned so that they could monitor the torque vs time graph displayed on the computer monitor. The participant completed five isometric, ankle plantarflexion contractions at 70% of their MVIC each lasting 45 seconds. 70% of MVIC was chosen as the target exercise intensity because in a previous laboratory study, an isometric quadriceps exercise performed at 70% of MVIC reduced patella tendon pain immediately and for up to 45 minutes during a previously painful functional load test [7, 10]. The participant was advised that it was acceptable to maintain the isometric contraction within a range 5% above and below this value. Each set of 45 second contractions was separated by a two-minute rest period [7, 24]. The guidance given during each phase of data collection was standardized to reduce the risk of bias influencing performance (Supplementary File C). Participants were blinded to the hypotheses of the study but supervision of the exercise(s) and outcome measure assessment were completed by the principal investigator (BB). Participants switched to the alternate exercise after a minimum of one week.

**Outcome Measure**

The primary outcome measure was the level of patient-reported Achilles tendon pain during one of four specific, functional load test(s) on a Numeric Pain Rating Scale (NPRS). The intention was to establish which of the four progressive Achilles tendon tests reproduced the patients Achilles tendon pain between 2 and 7/10 on the NPRS. In the event that more than one test reproduced pain, the test with the highest level of pain was used as the pre and post-intervention outcome measure as these tests represent increasing Achilles tendon load. The guidance given during performance of each Achilles tendon test was standardized (Supplementary File C) to reduce the risk of performance bias. The NPRS is an 11-point verbal, pain-rating scale ranging from 0 (no pain) to 10 (worst pain ever) and has been shown to be a reliable, valid and responsive measurement of pain for musculoskeletal pain conditions [25].

Previous research in the patellar tendon have shown large effect sizes (>0.8) for within-group change when performing isometrics [7, 10] and between group change when comparing isometrics to isotonics [10]. However, the within-group change in the only paper examining Achilles isometrics displays a small effect size (0.27). As the diagnostic criteria for this pilot study are more similar to those of the patellar tendon it was hypothesised that participants would experience a large effect size (>0.8). Therefore, a minimum sample size of 12 was determined for paired t-tests using G.Power version 3.1.9.4 based on detecting an effect size of 0.9 with 80% power and two-tailed significance set to 0.05.

**Statistical Methods**

Data analysis was conducted using SPSS v25 (IBM Corp. released 2017). Participant age, sex, height, weight, body mass index (BMI), symptom duration (months), baseline VISA-A and which side the participant had symptoms were described using count, mean and standard deviation (SD), where appropriate. The value for the NPRS at each timepoint are reported as mean (SD). Changes in the

NPRS which reduced pain are reported as a negative value. The effect of isometrics on tendon pain, for both FLX and EXT were reported as absolute mean (SD), percentage mean (SD). Within-group differences were determined using paired t-tests. A generalised estimating equation (GEE) was used to determine if there was a difference between plantar flexion isometrics performed with FLX versus EXT when controlling for confounding/ influencing factors. It has been suggested that clinically, people with Achilles tendon pain who have larger baseline NPRS may have a larger absolute value reduction in the NPRS following isometrics. (Cook, Personal Communication, 2020). Therefore, in additional to testing order being included as a factor, baseline pain was reported as a covariate. To account for baseline pain as a possible influence, the relative effect (percentage change in the NPRS) with isometrics was assessed in an additional GEE to determine if there was a difference between plantar flexion isometrics performed with the knee straight versus the knee bent when controlling for testing order as a factor. Significance was set as <0.05.

## Results

Between 01 January and 01 October 2019, 42 patients with Achilles tendon pain were screened for eligibility. 17 out of 42 patients were not eligible to participate (7 patients had pain for <12 weeks, 7 patients self-reported pain other than the mid-portion of Achilles tendon and 3 patients had a rheumatological condition.) 14 participants declined to participate. 11 participants with chronic, mid-portion Achilles tendinopathy were recruited to study. There were no differences between the groups allocated to FLX first or EXT first in terms of age, height, weight, BMI and baseline VISA-A score with all baseline data presented in Table 1 below. The difference in the mean symptom duration was likely due to the randomisation to FLX first of a participant who had had episodic Achilles tendon pain for 6 years.

**Within-group differences**

Individual patient data are presented in Supplementary File D. Isometric ankle plantarflexion in FLX and EXT resulted in a significant reduction of pain when performing a load test (Table 2). Isometric ankle plantar flexion with EXT resulted in a 52% mean reduction in symptoms (p=0.001) whereas isometric ankle plantar flexion with FLX resulted in a 47% mean reduction in symptoms (p=0.016).

**Between group differences**

The GEE using the absolute change value on the NPRS (Table 3) showed that there was an additional 0.47 point reduction in pain on the NPRS during a functional loading task for every 1-point increase of the baseline NPRS (p=0.002). Due to this influence a subsequent GEE was performed using the relative change score (percentage change) instead of the absolute score (raw-value) (Table 4). This subsequent GEE showed that there was no significant effect of the knee position or testing order on the percentage of pain change when completing isometric plantar flexion. However, whilst not significant (p=0.110) isometric plantar flexion in knee extension appeared to give a 20% larger reduction in pain when compared to isometric plantar flexion in knee flexion.

## Discussion

This pilot study demonstrated that two positions for isometric exercise were well tolerated for people with mid-portion Achilles tendinopathy, resulting in pain reduction of approximately 50% in a functional task. For this small study, a 20% reduction in tendon pain was observed with EXT compared to FLX but this was not statistically significant. However, the clinical significance of these changes is uncertain and this warrants further investigation in a larger RCT.

Complete rest is detrimental for musculoskeletal capacity so ensuring the musculoskeletal system is getting as much load as tolerated, as soon as possible is vital for effective rehabilitation [26]. Isometric holds may provide a well-tolerated start point for rehabilitation, especially if patients have a fear of movement/ loading which has been demonstrated in tendinopathy [27]. The immediate pain relief observed following isometric plantar flexion in this study may assist the management of the patient with Achilles tendon pain in several ways. Firstly, it may allow completion or participation in a previously painful task or activity. Secondly, as a non-pharmacological treatment, exercise is not associated with the side effects of medications that may typically be taken for tendon pain (e.g. non-steroidal anti-inflammatory medications)[28]. Furthermore, exercise is likely to have many other, general positive impacts for the patient that will not occur with medication use [29]. Finally, if patients had strategies to independently manage their pain, it may improve adherence with any further rehabilitation [30].

This study differs from a previous case series study [9] investigating the efficacy of isometric exercise in Achilles tendinopathy in several respects. Only 9 of the 16 participants in O'Neil's study (2019) [9] reported pain during a bilateral or unilateral heel raise or subsequent hopping test, the loading test(s) used for inclusion within our study. O'Neil et al [9] placed a stronger emphasis on palpatory pain. Other differences between the two studies include how MVIC torque was assessed, the apparatus used for assessment and treatment and the range of dorsiflexion in which isometrics were performed. The diagnostic criteria for tendinopathy are not universal [31]. It is not clear from the current literature if there is a heterogenous response to isometric (or any) exercise or alternatively if there is heterogeneity in the included participants and procedures. In this study participants demonstrated increasing pain with increasing load that remained localised and the clinical take home is that isometric exercise is well tolerated in people with that phenotype. Whether this can be applied to people that have pain with Achilles tendon palpation and imaging change (common inclusion criteria used) is not known [32].

Although we primarily sought to recruit participants through the NHS, we struggled to recruit the numbers expected. Therefore, any interpretation of our data must acknowledge that the sample size was small. Despite these difficulties, it was felt that the robustness of the study was improved by the implementation of strict eligibility criteria to ensure that the final sample was representative of the patient with chronic, mid-portion Achilles tendon pain [33]. The number of participants that were included in the final analysis are comparable to other studies that have examined the use of isometric exercise in the management of tendon pain [7,11] including those that did not find any effect from isometric exercise on tendon pain [9, 34]. Finally, it is acknowledged that due to the absence of a placebo intervention, and as blinding of the outcome assessor was not possible, this does introduce the potential for bias. However, to negate the possibility of performance bias influencing the participants response to the exercises, we chose to standardise our methods of data collection, including the use of standardised explanations of the study intervention(s) and all procedures for data collection (Supplementary File C).

Whilst recognising the methodological limitations of this pilot study, the isometric exercises investigated were well tolerated and regardless of the position of the knee joint offered small but statistically significant reductions in pain during a functional load test. The protocol investigated two options for isometric contractions and provides a viable option for clinicians to use in the management of Achilles tendon pain. For example, it may be that clinicians look to implement isometric exercise as the starting point to rehabilitation, to demonstrate to the fearful patient that loading the tendon with exercise is safe or as a means of promoting self-efficacy and adherence with any ongoing strengthening programme. Finally, isometric exercise should never be expected to provide comprehensive rehabilitation and restoration of function in those with Achilles tendinopathy and immediate analgesia is not the only reason to provide an exercise to a patient with Achilles tendinopathy. If exercise is truly going to be used as medicine then studies should seek to identify what exercise suits which patient, and with what dosage and progression. This requires adequate description of participants to identify sub-groups of responders and non-responders to aid clinical interpretation [31].

**Legend for Tables and Figures**

**Table 1: Baseline Data.**

**Legend:** EXT= extension, FLX= flexion, BMI= body mass index, VISA-A= Victorian Institute of Sport Assessment- Achilles [1]data are presented as number, [2]data are presented as mean (SD)

**Table 2: Within-group differences of pain with isometric plantar flexion.**

**Legend:** * Significance of $p<0.05$

**Table 3: Generalised estimating equation of absolute change in pain with isometric plantar flexion.**

**Legend:** β= beta, SE= standard error, 95%CI= 95% confidence interval

[a] Knee flexion set to 0, [b]Isometric plantar flexion in knee flexion first set to 0

* Significance of $p<0.05$

**Table 4: Generalised estimating equation of relative change in pain with isometric plantar flexion .**

**Legend:** β= beta, SE= standard error, 95%CI= 95% confidence interval,

[a] Knee flexion set to 0, [b]Isometric plantar flexion in knee flexion first set to 0,

* Significance of $p<0.05$

**Figure 1: EXT and FLX Isometric Exercise Position(s)**

Legend: EXT – the knee joint positioned in terminal extension and secured with non-elastic strapping. FLX – the knee joint positioned at 80 degrees of flexion and secured against the thigh stabilizer with non-elastic strapping.

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