Efficacy of Different LOAD-Intensity and Time-Under-Tension Exercise Interventions for Achilles Tendinopathy (The LOADIT Trial): A Randomised Pilot Trial

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Abstract

Background: One potential reason for disparate outcomes of exercise for Achilles tendinopathy is poor knowledge about whether exercise parameters (i.e. different exercise doses) influence outcome. Whether parameters that are important for tendon adaptation influence clinical outcomes in Achilles tendinopathy has not been investigated. Therefore, this research aimed to assess the feasibility of conducting a definitive randomised trial to investigate the efficacy of different load-intensity and time-under-tension exercise parameters for Achilles tendinopathy.

Methods: A factorial four-arm, randomised trial. Forty-eight male participants (18-70 years old) with mid-portion Achilles tendinopathy (≥ 3 months) were recruited. Participants were randomly allocated to high (6 repetition maximum) or low intensity (18 repetition maximum) exercise, performed with either high (6 seconds per cycle) or low (2 seconds per cycle) time-under-tension. Participants performed 12-weeks of standing and seated calf raise exercises three times per week in a gym setting using a Smith machine. One session per week was supervised (via teleconference). Primary feasibility outcomes (recruitment and retention rate, exercise adherence and fidelity [i.e. time-under-tension, volume, load intensity], incidence of adverse events, health care use and productivity cost) were collected weekly. Means and standard deviations were determined for parametric data, medians and interquartile range for non-parametric continuous data, and frequency counts for discrete data.

Results: Total recruitment (76%) and retention (90%) rates were high. Exercise adherence ranged from 45 to 63% and fidelity ranged from 8 to 83% across the groups. Thirty-one participants reported 64 adverse events over the 3 months. Twenty-one participants (70%) reported mild events. Participants reported reduced presenteeism more than absenteeism.

Conclusions: A definitive randomised trial is feasible. The proposed trial design and interventions demonstrated acceptable recruitment and retention rates and safety profile. However, exercise fidelity and adherence to the gym-based intervention was not acceptable. Strategies to improve intervention adherence and fidelity should be considered in future trials.

Trial registration: Australian New Zealand Clinical Trials Registry, ACTRN12618001315202. Registered retrospectively on August 6th, 2018.

Background

Mid-portion Achilles tendinopathy is a common musculoskeletal condition characterised by localised Achilles tendon load-related pain and dysfunction [1]. The pain mechanisms in tendinopathy are not clear but are thought to involve local nociception mediated by changes within the tenocytes [2]. The etiology of tendinopathy is complex and multifactorial [3], but imbalance between the load demands placed on the tendon and its capacity to remodel is considered a major factor [4]. Both athletes and sedentary people can be affected, and many suffer profound and longstanding impairment of activities such as walking and running [5, 6].

Exercise-based treatments that restore the load capacity of the tendon have become the focus of management for Achilles tendinopathy and are recommended in systematic reviews and clinical practice guidelines [7-9]. Despite being a first-line recommended treatment, the benefit from exercise is variable [10]. A recent longitudinal study found 60% had continued pain and disability after 5 years despite exercise interventions, and 48% sought additional treatment including injections and surgery [11]. One potential reason for disparate outcomes of exercise for Achilles tendinopathy is poor knowledge about whether exercise parameters (i.e. different exercise doses) influence outcome. Exploration of exercise dose-response in Achilles tendinopathy is warranted. Knowing whether certain exercise parameters improve outcomes for Achilles tendinopathy management will assist in developing more effective exercise approaches [12].

Many parameters can be influenced in exercise prescription, including load-intensity (e.g. repetition maximum [RM], maximal voluntary contraction), volume (repetitions and sets), and time under tension per contraction [13]. A systematic review investigating exercise response (i.e. adaptative outcomes such as tendon stiffness) in healthy Achilles and patellar tendons concluded that load-intensity is a key determinant of tendon tissue adaptation to load, and the type of contraction (e.g. eccentric versus concentric) did not influence adaptation [14]. Load-intensity results in greater tendon tissue strain which deforms tendon cells and triggers anabolic cell signalling [15]. There is also evidence that longer duration contractions at the same intensity result in greater Achilles tendon adaptation [16], most likely because there is time-dependent transmission of external load to the tendon cytoskeleton and cells. Whether parameters that are important for tendon adaptation such as load-intensity and duration of contraction (or time-under-tension) influence clinical outcomes in Achilles tendinopathy has not been investigated.

Aims

The primary aim of this study was to determine the feasibility of conducting a definitive randomised trial to determine the efficacy of different load-intensity and time-under-tension exercise parameters for Achilles tendinopathy. The key outcomes were (i) rate of participant recruitment, conversion, and retention, (ii) ability to perform the interventions per-protocol (adequate exercise fidelity and adherence based on weekly videoconference assessment), (iii) incidence and type of adverse events, (iv) use of rescue medication and co-interventions, and (v) feasibility of future economic evaluation. The secondary aim was to provide estimates of the variability of key outcomes (pain and disability, participant perception of change, satisfaction, health-related quality of life, physical activity, psychological measures, plantarflexor function) to enable estimation of the sample size for a future definitive trial.

Methods

Design

LOADIT (LOAD- Intensity and Time-under-tension) is a four-arm, factorial randomised pilot trial. The two factors, each with two levels, are load-intensity (determined by RM, the maximum mass that can be lifted for a given number of repetitions) and time-under-tension (determined by seconds). Participants were

randomly allocated into one of four groups: 6 RM with two second repetitions; 6 RM with 6 second repetitions; 18 RM with two second repetitions; or 18 RM with 6 second repetitions group (Figure 1). The methods are described in the published protocol [17]. The study was reported in accordance with the CONSORT extension for randomised pilot and feasibility trials [18] and the TIDieR guide [19]. The protocol was registered (August 2018; ACTRN 12618001315202. The trial was approved by the Human Research Ethics Committee at Monash University (ethics number 2018-1366-20711).

Figure 1. Trial profile. Abbreviation: HL, High load; HT, High time-under-tension; LL, Low load; LT, Low time-under-tension; VISA-A, Victorian Institute of Sports Assessment – Achilles; EQ-5D-5L, Health-related Quality of Life; WPAI, Work Productivity and Activity Impairment; PIC, Patient Impression of Change; PCS, Pain Catastrophising Scale; PAR, Physical Activity Recall questionnaire; PASS, Patient-Acceptable Symptom State instrument for satisfaction; MVIC, Maximal Voluntary Isometric Contraction; FM10%, Force match at 10%; RTD, Rate of Torque Development; RM, repetition maximum.

Study population

Participants were included if they were male, aged between 18 to 70 years with a history of mid-portion Achilles tendon pain in either or both legs for ≥ 12 weeks, and scored ≤ 75 on the Victorian Institute of Sports Assessment – Achilles questionnaire (VISA-A). Men were the focus because of evidence that tendon adaptation to exercise (and therefore possibly clinical outcomes) may be confounded by sex [20]. The clinical diagnosis was based on the clinical presentation, physical examination and ultrasound imaging done by practicing physiotherapist (FH). Exclusion included a history of Achilles tendon rupture, surgery in the symptomatic lower limb(s) or any health conditions that may interfere with the execution of the exercise interventions. Participants were also excluded if they had had an injection or received strength exercise treatment for their Achilles tendon pain within the last 3 months.

Recruitment and setting

Participants were recruited via social media (i.e. Facebook, Twitter), and by posting study information on relevant internet websites (e.g. sports clubs and forums), as well as referral from health professionals in Melbourne. All screening assessments and data collection were conducted at a single centre (Monash University, Melbourne, Victoria, Australia) between July 2018 and May 2019. Responders to the advertisements were asked to provide their contact number. They were contacted and screened via the telephone by research assistants who also provided trial information. Those who confirmed interest in the study (either at the time of the telephone call or by re-initiating contact with the researcher after the initial call) were invited to attend a screening visit to confirm their eligibility. All participants provided oral and written informed consent before joining the trial.

Randomisation and blinding

A randomisation sequence with permuted blocks of variable size was created using an online randomisation service (Sealed Envelope Ltd, London) and then concealed in opaque sealed envelopes by

a researcher who was not in contact with participants (TH). The treating physiotherapists and participants were not blinded. Each participant received a scripted explanation of the trial which included that there is uncertainty about whether any of the exercise interventions would be superior. The participants were assigned to intervention by the same investigator (PM). The investigator (FH) who administered and collected the secondary outcomes and the statistician were blinded to group allocation.

Exercise interventions

Participants performed four sets of unilateral standing and seated isotonic calf raise exercise to load the ankle plantarflexor complex (both sides, one leg at a time), three times per week for 12 weeks, with standardised rest times (90 seconds between sets). The 12-week endpoint was chosen because it has been shown to be a sufficient timeframe for exercise to have a clinically meaningful effect on Achilles tendinopathy pain and function [21]. Both isotonic exercises were performed in a Smith machine at a local gymnasium (gym membership was provided free of charge to participants, if required). A practicing physiotherapist monitored one session per week (via teleconferencing software [Zoom®]) and provided exercise progression and technique feedback. During this session, exercise adherence and fidelity (prior to providing feedback), adverse events, use of co-interventions, and productivity data were collected. Participants were taught calf raise exercise technique [17] using parameters specific to their group allocation (Table 1) and the exercises were externally paced using a metronome (via smartphone application). Participants were instructed to exercise to volitional failure and how to progress and regress exercise based on difficulty with the exercise and pain experienced. After the baseline testing of the repetition maximum, exercise intensity was adjusted down by 10% in all groups to reduce the risk of muscle soreness related to commencement of unaccustomed exercise. Further exercise details are provided in additional file 1 and the protocol [17].

Table 1. Calf exercise dosage for each group.

Participants were provided with education related to tendon pain mechanisms and acceptable levels of pain during exercise and activity. Participants were advised to consume up to four g/day pain-relieving medication [22] (i.e. paracetamol), if required. Participants received advice to gradually increase walking, running and sports activity if Achilles tendon pain during these activities was not beyond level 5 out of 10 on an 11-point numerical pain rating scale (NPRS) 0= no pain, 10 = worst pain imaginable) [23]. They were also advised it was acceptable for pain after sport activities to temporarily increase as long as it returned to baseline levels on a tendon loading test such as single-leg submaximal hop or single leg calf raise, within approximately 24 hours.

Outcome measures

Primary outcomes

Rate of conversion, recruitment, and retention

The conversion rate was the proportion of people who consented divided by those who met the criteria. The recruitment rate was the number of participants recruited per month. Retention was the proportion of recruited participants who completed the 12-week outcome assessment. The conversion and retention success criteria were $\geq 20\%$ and 80% respectively.

Exercise adherence and fidelity

Incidence of adverse events

An adverse event was defined as any unintended symptom associated with the study which may or may not be related to the intervention [24]. The frequency (number of participants and number of cases), nature (e.g. sprained ankle, a muscle tear or tendon pain worsening), and severity (mild [< 48 hours], moderate [up to 7 days], or severe [> 7 days or requiring medical attention]) were recorded at the weekly videoconference session. Individuals experiencing adverse events were managed by the research team or triaged to an appropriate medical facility.

Use of co-interventions

The frequency of the use of paracetamol medication and other co-interventions was recorded.

Feasibility of future economic evaluation

These costs were divided into the following:

- The direct intervention costs: This included the gym membership (estimated 15 AUD per week), physiotherapy treatment and participant screening time (estimated rate 150 AUD per hour). Other direct cost for co-interventions were calculated based on number of days the co-intervention $\times$ market price or by estimating the once off cost of the health product.
- The indirect cost or productivity cost included the absenteeism (time loss from work due to Achilles tendinopathy) and presenteeism (productivity loss while at work due to Achilles tendinopathy) were assessed using the Health-related work productivity questionnaire (WPAI) [25]. Absenteeism cost was calculated by multiplying this percentage score $\times$ the average wage rate in Australia (estimated at 45 AUD per hour) according to Australian Bureau of Statistics figures [26]. The costs of productivity loss due to presenteeism were calculated by multiplying the percentage of rating scale indicating the degree of health problem affected productivity while working score $\times$ number of hours actually worked per week $\times$ 45 AUD.

Secondary outcomes

Patient-reported outcomes

Nine patient-reported outcomes were included: (i) The severity of pain and disability were assessed using the VISA-A [27] and a modified version intended for non-athletes [28]; (ii) The worst pain level experienced

in the last week with an NPRS (11- point scale, 0 = no pain, 10 = worst imaginable pain); (iii) Patient Impression of Change (PIC) which is a 7-point Likert scale including two questions; 1) “How would you describe your Achilles tendon pain now, compared to before you began the treatment?” and 2) “How would you describe your ability to perform physical activities (such as walking, running, housework) now, compared to before you began the treatment?” [29]; (iv) Patient-Acceptable Symptom State instrument [30] which involved a yes or no response to two questions: “Currently are you satisfied with your condition?”, and “Would you recommend this treatment to another person who has Achilles pain?”; (v) Health-related quality of life was measured using the 5-level EQ-5D version (EQ 5D 5L index value and overall health state [VAS]); (vi) Physical activity using 7-day Recall Physical Activity Questionnaire [31]; (vii) Fear of movement or re-injury: Kinesiophobia was measured with the Tampa Scale for Kinesiophobia (TSK) [32]; (viii) Pain catastrophising was measured using the Pain Catastrophising Scale (PCS) [33], in addition to

the painDETECT questionnaire (at baseline testing only) which was implemented to screen for neuropathic pain [34].

Plantarflexor strength tests

A custom-built ankle dynamometer (participants seated with 50° knee flexion) was used to assess plantarflexor torque during maximal voluntary isometric contraction (MVIC), rate of torque development (RTD) and force matching (see additional file 2 for details). Force matching involved maintaining ankle plantarflexor force equivalent to 10% of their MVIC with visual feedback on a screen 1.5 meters in front of them.

Sample size

We made a pragmatic decision that we would be able to achieve our feasibility aim by recruiting 48 participants to be randomised into one of four factorial arms ($n = 12$ per trial arm as a rule of thumb recommended by Julious) [35].

Data management and analysis

Entered data were checked for accuracy by two study investigators (FH, PM). Statistical analysis was undertaken on coded data (group allocation concealed). Data from the most painful side were analysed for people with bilateral Achilles pain. SPSS (version 25, IBM Corp., Armonk, NY, USA) was used for statistical analysis. Means and standard deviations were determined for parametric data, medians and interquartile range for non-parametric continuous data, and frequency counts for discrete data. Mean difference (MD) and standard mean difference (SMD = MD/pooled standard deviation) from baseline to 6 and 12 weeks and 95% confidence intervals were calculated (RevMan, version 5.4, The Nordic Cochrane Centre, Copenhagen, DK) for all secondary outcomes. The SMD's were interpreted as very large when ≥ 1.2 , moderate when ≥ 0.6 , and small when ≥ 0.2 [36]. The PIC 7-point Likert scale was dichotomised for analyses (“very much improved” and “improved” represents treatment effectiveness). The MVIC torque

data (Nm) were extracted directly from PowerLab (AD Instruments Corp, Dunedin, NZ) whereas RTD data (Nm/s) and force match data were exported to Excel (Microsoft Corporation, Redmond, WA). The peak RTD (0-50 Nm scale window) was analysed using a custom-written software program (rehabtools.org, Sunshine Coast, Australia). The coefficient of variation of torque for the 15 second sampling window was used to represent fluctuations in force-matching (ratio of standard deviation to the mean torque). Patterns of missing data were analysed using Little's Missing Completely at Random test [37]. Data substitution was not applied for missing data given this was a feasibility study with a small sample. However, an effort was made to collect the patient-reported outcomes data especially for those who discontinued the intervention.

Results

The sample consisted of 48 men, aged 20 to 65 years (mean age 43.2 ± 10.4 years). The duration of symptoms ranged from 3 to 240 months (two outliers of 240 months, median = 24). The BMI ranged from 20 to 45 kg/m². None of the participants reported neuropathic pain (Table 2). From 1,043 initial contacts, 86 people were screened in-person, 63 were eligible and 48 consented (Figure 2).

Table 2. Participant characteristics at baseline. Values are mean (SD) unless otherwise noted.

Figure 2. The CONSORT flow diagram of participants through the study.

Primary outcomes

Rate of conversion, recruitment, and retention

Both conversion and retention rate were acceptable. The conversion rate was 76% (48/63) (Figure 2). The recruitment rate ranged from 3 to 20 per month over the 6-months recruitment window (Figure 3) because the Facebook strategy was intermittent (i.e. stopped for 4 months during holiday periods). Forty-one (85%) participants were recruited via Facebook (total spend \$9,052.91 AUD; average spend of \$221 AUD per person recruited) and the remaining (7 [15%]) via clinical networks and the community.

Five participants did not complete the study (Figure 2) giving a retention rate of 90% (43/48). Four participants dropped out because of the burden of the intervention, and one participant dropped out due to severe back pain. Between 86 and 98% of outcome data were collected at each timepoint.

Figure 3. Monthly and cumulative recruitment to the feasibility trial.

Exercise adherence and fidelity

Exercise adherence and fidelity data are presented in Table 3. The proportion of adherence to the supervised sessions was 71 to 92% and total adherence was 49 to 68% (1-2 sessions completed out of 3 per week). Fidelity varied substantially between criteria, with highest fidelity (58 to 83%) seen for the

volume criterion. The time-under-tension criterion averaged < 66% across all groups. Fidelity was lower for high-intensity groups (Figure 4). In general, the success rate (66%) was not reached for both adherence and fidelity outcome.

Figure 4. Exercise fidelity of the individual exercise dose parameters for each participant per group.

Incidence of adverse events

There were between six and eight participants per group who experienced an adverse event and a total of 64 reported adverse events over the 3 months (Table 3). Twenty-one participants (70%) reported mild adverse events that included Achilles pain, headache, and pain in other areas [shoulder, wrist, back]). Eight participants (17%) reported moderate adverse events (included back, anterior knee and shin pain) that occurred more frequently in the high-intensity groups (21% versus 13%). There was only one serious adverse event that was not related to the interventions (back pain that required surgery).

Use of co-interventions

There were similar rates of co-intervention use between groups (Table 3). Common co-interventions included myotherapy, acupuncture, and topical non-steroidal anti-inflammatory agents (i.e. diclofenac gel). Four to six participants in each group reported using paracetamol for their associated pain, during the 12 weeks of intervention.

Table 3. Feasibility outcomes. Values are n (%) unless otherwise noted.

Feasibility of future economic evaluation

Over the three-month study period, the direct cost was 1,050 AUD and indirect cost was 37 AUD per participant. This included costs associated with participants who withdrew or missed sessions. The three months gym membership cost was 180 AUD per participant. Average presenteeism was valued at 412 AUD per participant over the three-month study period. Only one participant reported absenteeism (8 hours) due to their Achilles tendinopathy, which equated to a cost of 765 AUD.

Secondary outcomes

Patient-reported outcomes

All groups displayed improvement in self-reported outcome measures during the study (Table 4). At 12 weeks, the mean improvement in VISA-A scores was between 26 to 40 points. The worst pain over the last

week decreased by an average of 3 to 4 points. More than 75% of participants reported an improvement in pain and function and satisfaction with condition post-intervention.

Table 4. Patient-reported outcomes with effect estimates. Values are mean (SD) unless otherwise noted.

Plantarflexor strength tests

All groups displayed improvement in all strength tests (Table 5). The magnitude of mass lifted increased by about 25% in seated and 10% in the standing positions (Figure 5).

Table 5. Performance outcomes with effect size estimates and mean difference (mean $\pm$ SD)

Figure 5. Overall absolute mass lifted during the intervention.

Discussion

This pilot randomised trial has demonstrated that the interventions are safe (only one unrelated serious adverse event), and the rate of conversion, recruitment, and retention were acceptable. Adherence to the gym-based intervention was acceptable for the weekly videoconference supervised sessions but not for the two non-supervised sessions. Exercise fidelity varied substantially between criteria and was unsatisfactory for the time-under-tension criterion across all groups. Prior to progressing to a full-scale trial, further work is necessary to identify and trial strategies to improve exercise adherence and fidelity. The major cost appeared to be related to provision of the intervention. Unlike other chronic pain conditions [38], the amount of time lost from work and productivity loss at work related to this condition was minimal, which raises the question whether economic evaluation is warranted in a full-scale trial.

Our interventions have similar characteristics to the ‘heavy slow resistance training’ intervention utilised by Beyer et al. [39]. Heavy slow resistance involves three sessions of gym-based calf loading exercise per week. There were, however, differences in reported exercise adherence between our pilot trial (49 to 68%) and the Beyer et al. trial (92% for heavy slow resistance). Discrepant adherence rates may be explained by methodological differences between the trials. First, Beyer et al. prescribed three 2-legged exercises (three exercises in total) which would have been less time consuming than the four exercise (2 on each limb) in our study. Second, the socio-geographical environment (Copenhagen versus Melbourne) may have influenced adherence (e.g. commute time to the gym or traffic congestion favouring Copenhagen). Third, the adherence data was recorded more frequently in our study (weekly by our physiotherapists from patient report during the teleconference sessions versus a single supervised session plus patient diaries in the Beyer study) which may have influenced accuracy by reduced recall bias [39]. Future studies could benefit from better understanding barriers to patients’ exercise adherence, in order to identify and implement strategies to improve adherence across all trial groups, such as more supervised exercise sessions, either synchronously or asynchronously (e.g. via patients self-recording exercise sessions).

Exercise fidelity was important for ensuring that the exercise groups varied in the exercise parameters that were being compared including volume, intensity and time-under-tension. There was varied fidelity rate across all the trial groups with the lowest fidelity seen for the time-under-tension criterion (25 to 42%). Adequate time-under-tension was achieved if calf raise tempo was judged by the telerehabilitation rater (physiotherapist) to be in time with metronome (auditory cue) during the videoconference sessions. Errors related to poor internet connection and delayed or freezing video that may impact the rating, were reduced by re-rating any trials in which this was perceived by the rater. This criterion may have been too stringent because the overall time-under-tension may have been satisfactory even if there were timing violations for some of the repetitions. In future trials comparing different levels of time-under-tension, we recommend comparing total time-under-tension per set. Although they did not assess time-under-tension, Sancho et al. recently reported exercise (calf raises and hopping) fidelity ranging from 22 to 64% for volume and load-intensity [40].

High-intensity groups had lower fidelity compared to low-intensity groups. Fidelity strategies may need to be targeted towards the high-intensity groups as they seem to have more difficulty performing the required load-intensity. This could be a practical issue i.e. participants lifting heavy weight, or fear issues.

At 12 weeks, there was an improvement in patient-reported pain and function scores measured with the VISA-A questionnaire, ranging from 26 to 40 points. In a recent systematic review of 31 studies among individuals with Achilles tendinopathy undergoing a calf muscle loading program mean (SD) change in patient-reported pain and function (measured using the VISA-A questionnaire) was 21.1 (6.6) points [10]. Our findings are one to three standard deviations above this pooled mean. A clinically meaningful change is suggested to be 10-points [28, 39, 41] and this is also the Cochrane collaboration recommended minimal clinically important difference for a 100-point function scale [42]. However, our study did not include a control group, so the influence of natural history or placebo is not known. Other secondary outcomes also changed favourably in all groups. The improvements were likely to be clinically meaningful as the estimated effect size were moderate to large ≥ 0.6 .

Variability of the VISA-A outcome in our data can be used to estimate the sample size for a future full-scale randomised controlled trial. One hundred and fourteen participants (i.e. 57 per group) would provide power of over 80% to detect an effect size of 10-points on the VISA-A questionnaire [28, 39, 41] with the significance level set at $p < 0.05$. A pooled standard deviation of 17.2 was derived from the 4 arms in this pilot study. This calculation accounts for a 10% drop-out rate.

Conclusions

The results of this study suggest that high and low-intensity and time-under-tension loading protocols are feasible and safe for individuals with mid-portion Achilles tendinopathy. Future trials should consider strategies to optimise exercise adherence and fidelity.

Abbreviations

RM: repetition maximum; VISA-A: Victorian Institute of Sports Assessment – Achilles questionnaire; MVIC: Maximal Voluntary Isometric Contraction; RTD: Rate of Torque Development; NPRS: Numerical Pain Rating Scale; PIC: Patient Impression of Change; WPAI: Work Productivity and Activity Impairment Questionnaire.

Declarations

Ethics approval and consent to participate

All experimental procedures have been approved by the Human Research Ethics Committee at Monash University (ethics number 2018-1366-20711) for study protocol version 3 dated 10/07/2018 and all supporting documents. Any significant modification to the study protocol will require a formal amendment. written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

PM is a member of the editorial board (Associate Editor) of this journal. Peter Schoch is a Faculty member of the McKenzie Institute Australia and McKenzie Institute International and receives payment for teaching post graduate courses in the McKenzie Method of Mechanical Diagnosis and Therapy. He has no direct affiliation with the International Mechanical Diagnosis and Therapy Research Foundation. FH, TH, SEM and BV declare that they have no competing interests.

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Authors' contributions

All authors (FH, TH, SEM, BV, PS and PM) contributed to the conception, design of the trial and interpretation the data. FH and PM conducted the data collection. FH and TH completed the data analysis. PM contributed to training and supervision of the physiotherapists involved on the trial. FH drafted the manuscript and all co-authors provided critical revisions to the clinical and intellectual content. All authors have read and approved the manuscript.

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Clinical messages

- Conducting a definitive randomised trial to determine the efficacy of different load-intensity and time-under-tension exercise parameters for Achilles tendinopathy is feasible.
- Strategies designed to improve exercise adherence and fidelity are necessary prior to progressing to a full-scale trial.
- The findings provide important preliminary information regarding treatment effect sizes of the interventions described.

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Tables

Table 1 Calf exercise dosage for each group.

	High Load		Low Load	
	with High TUT (Group 1)	with Low TUT (Group 2)	with High TUT (Group 3)	with Low TUT (Group 4)
Load intensity	6 RM	6 RM	18 RM	18 RM
Repetition	6	6	18	18
Sets	4	4	4	4
Contraction time/rep	3s concentric	1s concentric	3s concentric	1s concentric
	3s eccentric	1s eccentric	3s eccentric	1s eccentric
Rest in between reps	No	No	No	No
Contraction time per set	36 s	12 s	108 s	36 s
Total contraction time	288 s	96 s	864 s	288 s
Volitional muscular failure	Yes	Yes	Yes	Yes
Range of motion	0° to 15° DF	0° to 15° DF	0° to 15° DF	0° to 15° DF
	0° to 50° PF	0° to 50° PF	0° to 50° PF	0° to 50° PF

Abbreviations: TUT, time-under-tension. RM, repetition maximum. TUT, time-under-tension. DF, dorsiflexion; PF, planter flexion. S, seconds

Table 2. Participant characteristics at baseline for each group. Values are mean (SD) unless otherwise noted.

	High Load		Low Load	
	with High TUT (n=12)	with Low TUT (n=12)	with High TUT (n=12)	with Low TUT (n=12)
Age, years	42.0 (11.4)	43.0 (11.3)	41.6 (7.2)	46.3 (11.9)
Height, cm	177.8 (6.2)	176.6 (10.3)	178.1 (8.2)	175.0 (8.2)
Mass, kg	89.0 (17.9)	97.0 (18.1)	84.6 (17.1)	94.5 (13.7)
Body mass index, kg/m²	28.0 (4.6)	31.1 (5.3)	26.6 (4.4)	30.6 (6.4)
<i>Employment*</i>				
<i>Full-time</i>	10 (83)	8 (67)	10 (83)	9 (75)
<i>Part-time</i>	0	1 (8)	0	1 (8)
<i>Casual</i>	1 (8)	1 (8)	0	1 (8)
<i>Self-employed</i>	0	2 (17)	1 (8)	1 (8)
<i>Student</i>	1 (8)	0	1 (8)	0
Duration of symptoms, monthst	11.0 (39)	54.0 (83)	18.0 (30)	12.0 (36)
Dominant side, - right*	11 (92)	11 (92)	8 (67)	10 (83)
Presentation, unilateral/ bilateral *	7 (58) / 5 (42)	6 (50) / 6 (50)	4 (33) / 8 (67)	6 (50) / 6 (50)
Achilles tendon AP diameter, mm¶	6.9 (1.3)	7.8 (1.9)	7.3 (2.2)	8.5 (3.1)
Prior exercise treatment, yes *	3 (25)	4 (33)	6 (50)	8 (67)
Classified Achilles pain quality ^*	7 (58)	10 (83)	9 (75)	9 (75)
<i>Intensity of Achilles pain *</i>				
<i>Mild</i>	3 (25)	3 (25)	2 (17)	4 (33)
<i>Moderate</i>	9 (75)	5 (42)	8 (66)	4 (33)
<i>Severe</i>	0	4 (33)	2 (17)	4 (33)
VISA–A	55.3 (13.4)	44.8 (18.1)	46.0 (15.8)	54.7 (9.8)
Pain Detect	10.0 (5.2)	12.2 (6.1)	10.0 (6.0)	10.0 (5.0)

Table 3. Feasibility outcomes. Values are n (%) unless otherwise noted.

	High Load		Low Load	
	with High TUT	with Low TUT	with High TUT	with Low TUT
<i>Session time duration in minutes*</i>	43.4 (12.2)	39.0 (6.1)	53.0 (7.3)	37.1 (7.0)
Adherence†				
<i>Number of zoom sessions completed / 12</i>	11 (92)	9 (71)	11 (92)	10 (79)
<i>Number of home sessions completed / 36</i>	21 (58)	18 (49)	21 (58)	25 (68)
Fidelity of exercise dose parameters in seated				
<i>Time-under-tension</i>	5 (42)	5 (42)	6 (50)	7 (58)
<i>Volume</i>	7 (58)	8 (67)	8 (67)	10 (83)
<i>Load intensity</i>	6 (50)	1 (8)	8 (67)	8 (67)
Fidelity of exercise dose parameters in standing				
<i>Time-under-tension</i>	5 (42)	3 (25)	6 (50)	6 (50)
<i>Volume</i>	7 (58)	7 (58)	8 (67)	7 (58)
<i>Load intensity</i>	5 (42)	4 (33)	9 (75)	7 (58)
No. of participants who reporting adverse event	8 (67)	8 (67)	8 (67)	6 (50)
Severity of adverse events ¶				
<i>Mild</i>	4 (33)	6 (50)	8 (67)	3 (25)
<i>Moderate</i>	3 (25)	2 (17)	0	3 (25)
<i>Severe</i>	1 (8)	0	0	0
Achilles related adverse events	3 (25)	4 (33)	4 (33)	4 (33)
Severity of Achilles related adverse events				
<i>Mild</i>	3 (25)	4 (33)	4 (33)	3 (25)
<i>Moderate</i>	0	0	0	0
<i>Severe</i>	0	0	0	0
No. of participants who used co-interventions	3 (25)	2 (17)	2 (17)	4 (33)

No. of participants using paracetamol	4 (33)	5 (42)	4 (33)	6 (50)
Total paracetamol tablets used ¶¶	16 (33)	31 (33)	33 (25)	17 (25)

Abbreviations: TUT, time-under-tension. * Mean (SD); †Median (percentage); Mild: some discomfort noted but without disruption of daily life that goes within 24-28 hrs ; Moderate: discomfort enough to affect/reduce normal activity that goes within 3-5days ; Severe: complete inability to perform daily activities and lead a normal life and that requires medical intervention; tablet dose= 500mg;

Table 4. Patient-reported outcomes with effect estimates. Values are mean (SD) unless otherwise noted.

	High Load		Low Load	
	with High TUT	with Low TUT	with High TUT	with Low TUT
Self-reported measures				
Severity of pain using VISA-A § / 100				
Baseline	55.3 (13.4)	44.8 (18.1)	46.0 (15.8)	54.7 (9.8)
Week-6	69.3 (14.8)	65.2 (16.7)	63.2 (16.8)	68.5 (14.0)
Week-12	81.5 (11.2)	80.7 (17.5)	86.3 (9.0)	83.8 (13.0)
Mean Difference at 6-weeks, [95 %CI]	14.0 [2,26]	20.4 [6,35]	17.2 [4,30]	13.8 [4,23]
Mean Difference at 12-weeks, [95 %CI]	26.2 [16,37]	35.9 [21,51]	40.3 [30,51]	29.1 [20,38]
SMD baseline-week 6	0.9	1.0	0.9	1.0
SMD baseline-week 12	1.5	1.4	1.7	1.6
Worst pain using Numerical Pain Rating Scale / 10**				
Baseline	5.0 (2.2)	4.8 (3.2)	4.7 (3.0)	5.0 (3.0)
Week-6	2.4 (2.5)	2.2 (1.0)	3.1 (2.2)	3.3 (2.2)
Week-12	3.4 (2.7)	2.3 (2.0)	2.1 (2.3)	2.3 (1.8)
Mean Difference at 6-weeks, [95 %CI]	-2.6 [-5,-1]	-2.6 [-5,-1]	-1.6 [-4,1]	-1.7 [-4,0.4]
Mean Difference at 12-weeks, [95 %CI]	-1.6 [-4,1]	-2.5 [-5,-0.3]	-2.6 [-5,-0.5]	-2.7 [-5,-1]
SMD baseline-week 6	-1.0	-1.0	-0.6	-0.7
SMD baseline-week 12	-0.6	-0.9	-0.9	-1.0
EQ-5D-5L, Index ††/ 1				
Baseline	0.71 (0.10)	0.71 (0.17)	0.72 (0.10)	0.74 (0.10)
Week-6	0.79 (0.09)	0.76 (0.16)	0.76 (0.10)	0.78 (0.14)
Week-12	0.84 (0.11)	0.88 (0.14)	0.84 (0.11)	0.87 (0.12)
Mean Difference at 6-weeks, [95 %CI]	0.08 [0,0.16]	0.05 [-0.16,0]	0.04 [-0.12,0]	0.03 [-0.13,0]
Mean Difference at 12-weeks, [95 %CI]	0.13 [0.04,0.22]	0.17 [0.09,0.25]	0.12 [0.04,0.20]	0.13 [0.05,0.21]
SMD baseline-week 6	0.9	0.3	0.4	0.3

SMD baseline-week 12	1.2	1.0	1.0	1.0
EQ-5D-5L, VAS ‡‡ / 100				
Baseline	67.8 (15.2)	70.2 (17.8)	72.8 (16.6)	69.6 (12.0)
Week-6	82.2 (8.5)	75.3 (9.4)	80.0 (8.3)	75.7 (13.6)
Week-12	83.4 (13.2)	82.6 (15.5)	82.3 (10.3)	74.0 (11.5)
Mean Difference at 6-weeks, [95 %CI]	14.4 [4,24]	5.1 [-7,17]	7.2 [-3,18]	6.1 [-4,17]
Mean Difference at 12-weeks, [95 %CI]	15.6 [4,28]	12.4 [-2,26]	9.5 [-2,21]	4.4 [-5,14]
SMD baseline-week 6	1.0	0.4	0.6	0.5
SMD baseline-week 12	1.0	0.7	0.7	0.4
7-Day Activity Recall §§				
Baseline	1041 (170)	1322 (257)	1017 (200)	1303 (296)
Week-6	1071 (241)	1311 (237)	997 (194)	1229 (256)
Week-12	837 (555)	1314 (211)	1046 (175)	1275 (285)
Mean Difference at 6-weeks, [95 %CI]	29 [-149,207]	-10 [-216,197]	-39 [-196,118]	75 [-296,146]
Mean Difference at 12-weeks, [95 %CI]	-204 [-579,171]	-7 [-203,189]	29 [-121,179]	-28 [-260,204]
SMD baseline-week 6	0.1	0	0	-0.3
SMD baseline-week 12	-0.5	0	0.2	0
Tampa Scale for Kinesiophobia ¶/ 68				
Baseline	39.8 (8.7)	39.7 (3.6)	37.2 (4.9)	35.1 (12.5)
Week-6	34.5 (8.3)	35.0 (6.1)	34.9 (4.1)	30.8 (6.8)
Week-12	30.2 (6.4)	29.3 (6.1)	32.3 (6.4)	27.2 (4.5)
Mean Difference at 6-weeks, [95 %CI]	-5.3[-13,2]	-4.7[-9,-0.4]	-2.3[-6,1]	-4.3[-12,4]
Mean Difference at 12-weeks, [95 %CI]	-9.6[-16,-4]	-10.4[-15,-6]	-4.9[-9,-0.3]	-7.9[-15,-0.3]
SMD baseline-week 6	-0.6	-0.9	-0.5	-0.4
SMD baseline-week 12	-1.1	-1.5	-0.8	-0.8
Pain Catastrophising Scale ¶¶/ 52				

Baseline	12.8 (6.4)	17.3 (16.5)	9.4 (7.7)	11.4 (11.3)
Week-6	6.9 (3.2)	8.0 (7.0)	7.3 (5.9)	6.1 (5.4)
Week-12	4.3 (4.2)	5.6 (6.2)	5.3 (5.9)	2.7 (2.1)
Mean Difference at 6-weeks, [95 %CI]	-6.1[-10,-2]	-9.3[-20,1]	-2.1[-8,3]	-5.3[-12,2]
Mean Difference at 12-weeks, [95 %CI]	-8.5[-13,-4]	-11.7[-22,-2]	-4.1[-10,2]	-8.7[-15,-2]
SMD baseline-week 6	-1.0	-0.7	-0.3	-0.6
SMD baseline-week 12	-1.2	-0.9	-0.6	-1.0
Patient Impression of Change for pain ^{^*}				
Week-6 (improve)	8 (67)	9 (82)	5 (42)	8 (67)
Week-12 (improve)	7 (78)	10 (100)	10 (91)	9 (82)
Patient Impression of Change for function ^{^*}				
Week-6 (improve)	7 (58)	8 (73)	4 (33)	9 (75)
Week-12 (improve)	7 (78)	10 (100)	10 (91)	9 (100)
Patient-Acceptable Symptom State instrument for satisfaction [*]				
Week-6 (50% improve)	5 (42)	1 (10)	4 (33)	5 (42)
Week-6 (100% improve)	7 (58)	9 (90)	8 (67)	7 (58)
Week-12 (50% improve)	2 (22)	0	2 (18)	2 (17)
Week-12 (100% improve)	7 (78)	10 (100)	9 (82)	10 (83)

Abbreviations: §Scores on the VISA-A range from 0 (worst Achilles symptoms) to 100 (no Achilles tendinopathy). ** worst pain during the week scored on the NPRS range from 0 (no pain) to 10 (worst pain imaginable). ††Scores on the EQ-5D-5L Index Value range from <0 (worse than dead) to 0 (dead) to 1 (full health). ‡‡Scores on the EQ-5D-5L VAS range from 0 (worst imaginable health state) to 100 (best imaginable health state). §§Scores on the PAR are represented as daily energy expenditure (kilocalories per day). Tampa score ranges from 17 (no fear of movement) to 68 (greater fear of movement). Scores on CPS range from 0 (no pain) to 52 (higher levels of pain catastrophising). ^ dichotomised scores to “improved” and “not improved”. *n (%).

Table 5. Performance outcomes with effect size estimates and mean difference (mean ± SD)

	High Load		Low Load	
	with High TUT	with Low TUT	with High TUT	with Low TUT
Ankle plantarflexion torque (Nm)				
Baseline	188.4 (43.1)	194.9 (60.8)	188.6 (53.8)	188.5 (66.2)
Week-12	225.8 (32.9)	220.0 (42.8)	204.9 (58.0)	206.8 (40.0)
Mean Difference, [95 %CI]	37.4 [4,71]	25.1 [-18,69]	16.3 [-28,62]	18.3 [-26,63]
SMD baseline-week 12	0.9	0.5	0.3	0.3
Ankle plantarflexion rated of torque development (Nm/s)				
Baseline	644.5 (235.3)	637.4 (326.6)	635.9 (215.8)	557.1 (197.5)
Week-12	850.4 (174.4)	738.9 (189.0)	699.9 (183.4)	668.6 (170.4)
Mean Difference, [95 %CI]	205.5 [26,385]	101.5 [-117,320]	64.0 [-96,224]	111.5 [-39,261]
SMD baseline-week 12	0.9	0.4	0.3	0.6
Plantarflexor coefficient of variation of torque				
Baseline	1.9 (0.8)	1.9 (0.4)	2.3 (1.0)	2.2 (1.0)
Week-12	1.6 (0.2)	1.6 (0.9)	1.9 (1.0)	1.7 (1.0)
Mean Difference, [95 %CI]	-0.3 [-0.8,0.2]	-0.3 [-0.9,0.3]	-0.4 [-1,0.3]	-0.5 [-1,0.3]
SMD baseline-week 12	-0.4	-0.4	-0.4	-0.5
Mass lifted in seated (kg)				
Baseline	54.5 (20.2)	38.3 (23.4)	45.8 (10.2)	56.3 (17.2)
Week-12	77.5 (41.8)	64.0 (19.1)	70.8 (25.0)	79.4 (26.0)
Mean Difference, [95 %CI]	23.0 [- 8,54]	25.7 [8,44]	24.0 [9,40]	23.1 [5,42]
SMD baseline-week 12	0.7	1.0	1.2	1.0
Mass lifted in standing (kg)				
Baseline	13.1 (8.7)	11.2 (14.0)	9.5 (7.1)	8.3 (9.5)
Week-12	27.4 (14.1)	18.0 (12.0)	16.2 (11.4)	22.1 (23.3)
Mean Difference, [95 %CI]	14.3 [3, 26]	6.8 [- 4,18]	6.7 [- 1,14]	13.8 [- 1,29]
SMD baseline-week 12	1.1	0.5	0.7	0.8

Figures

Figure 1

Trial profile.

Figure 2

The CONSORT flow diagram of participants through the study.

Figure 3

Monthly and cumulative recruitment to the feasibility trial.

Figure 4

Exercise fidelity of the individual exercise dose parameters for each participant per group.

Figure 5

Overall absolute mass lifted during the intervention.

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