REVIEW

Chronic tendinopathy: effectiveness of eccentric exercise

Brett L Woodley, Richard J Newsham-West, G David Baxter

Br J Sports Med 2007;**41**:188–199. doi: 10.1136/bjsm.2006.029769

See end of article for authors' affiliations

Correspondence to: Brett Woodley, c/o Centre for Physiotherapy Research, School of Physiotherapy, University of Otago, Dunedin, New Zealand; brettandsteph@xtra.co.nz

Accepted 10 October 2006
Published Online First 24 October 2006

Objectives: To determine the effectiveness of eccentric exercise (EE) programmes in the treatment of common tendinopathies.

Data sources: Relevant randomised controlled trials (RCTs) were sourced using the OVID website databases: MEDLINE (1966–Jan 2006), CINAHL (1982–Jan 2006), AMED (1985–Jan 2006), EMBASE (1988–Jan 2006), and all EBM reviews – Cochrane DSR, ACP Journal Club, DARE, and CCTR (Jan 2006). The Physiotherapy Evidence Database (PEDro) was also searched using the keyword: eccentric.

Review methods: The PEDro and van Tulder scales were employed to assess methodological quality. Levels of evidence were then obtained according to predefined thresholds: *Strong*–consistent findings among multiple high-quality RCTs. *Moderate*–consistent findings among multiple low-quality RCTs and/or clinically controlled trials (CCTs) and/or one high-quality RCT. *Limited*–one low-quality RCT and/or CCT. *Conflicting*–inconsistent findings among multiple trials (RCTs and/or CCTs). *No evidence*–no RCTs or CCTs.

Results: Twenty relevant studies were sourced, 11 of which met the inclusion criteria. These included studies of Achilles tendinopathy (AT), patella tendinopathy (PT) and tendinopathy of the common wrist extensor tendon of the lateral elbow (LET). Limited levels of evidence exist to suggest that EE has a positive effect on clinical outcomes such as pain, function and patient satisfaction/return to work when compared to various control interventions such as concentric exercise (CE), stretching, splinting, frictions and ultrasound. Levels of evidence were found to be variable across the tendinopathies investigated.

Conclusions: This review demonstrates the dearth of high-quality research in support of the clinical effectiveness of EE over other treatments in the management of tendinopathies. Further adequately powered studies that include appropriate randomisation procedures, standardised outcome measures and long-term follow-up are required.

Tendinopathy is the preferred term used to describe various tendon pathologies, including paratendinitis, tendinitis and tendinosis in the absence of biopsy-proven histopathologic evidence.[1] Tendinopathy of the Achilles tendon (AT) alone has been reported to constitute 7–9% of total injuries in top-level runners.[2] Other tendinopathies are also prevalent:1–2% of the general population have been reported as experiencing tendinopathy in the common wrist extensor origin of the lateral elbow (LET),[3] and 20% of all knee injuries (n = 266) assessed in a sports clinic setting over six months were diagnosed as patella tendinopathy (PT).[4] Other common sites of tendinopathy include the proximal hamstring insertion, the rotator cuff tendons, and the wrist flexor tendon insertion at the medial elbow.[5] Considering the prevalence of these tendinopathies, the determination of modalities effective in treating tendon pathology remains important.[3 6]

Various modalities have been recommended as appropriate treatment options for tendinopathy, depending upon the phase of presentation. In the acute phase of treatment, reduction of risk factors such as training errors,[6] flexibility issues[6–10] and biomechanical abnormalities,[6 8 11]along with symptom reduction using relative rest,[9 10 12] ice,[7 8 10] and physical modalities such as ultrasound and laser have been suggested.[6–10] In chronic, long-standing cases, a complete rehabilitation programme incorporating strengthening,[6 7 9 11–19] flexibility,[6] proprioception,[6] massage[9 11 12] and endurance[6] has been recommended. Eccentric exercise (EE) strengthening programmes have been emphasised recently as a key element of strength training in rehabilitation,[6–9 11–13 15 17–24] in part due to literature supporting their use in the treatment of AT.[25–27] In more recent, non-systematic reviews, EE has been recommended as a treatment modality for other tendinopathies such as PT and LET.[6 19 28]

It has been proposed that EE may counteract the failed healing response which apparently underlies tendinopathy, by promoting collagen fibre cross-linkage formation within the tendon, thereby facilitating tendon remodelling.[19 21] However, as the basic pathophysiology of tendinopathy is still poorly understood, the mechanisms by which EE may help resolve tendinopathy remain hard to determine. Beyond this, it is essential that the clinical effectiveness of physical modalities such as EE is established as a matter of priority.

To date no systematic review has investigated EE and its effectiveness in tendinopathy rehabilitation. Therefore, this systematic review was undertaken to evaluate the current evidence for the effectiveness of EE programmes in the treatment of common tendinopathies.

METHODOLOGY

Aim

The aim of this systematic review was to evaluate the evidence for the effectiveness of EE programmes in the treatment of common tendinopathies.

Search strategy

The following databases were searched using the OVID website:[29] MEDLINE (1966–Jan 2006), CINAHL (1982–Jan 2006), AMED (1985–Jan 2006), EMBASE (1988–Jan 2006), and all EBM reviews – Cochrane DSR, ACP Journal Club, DARE, and CCTR (Jan 2006). A defined search strategy was

Abbreviations: AT, achilles tendinopathy; CCT, clinically controlled trial; CE, concentric exercise; EE, eccentric exercise; FAOS, foot and ankle outcome score; LET, lateral elbow; PED, physiotherapy evidence database; PT, patella tendinopathy; RCT, randomised controlled trial; RR, relative risk; VAS, visual analogue scale WMD, weighted mean difference

implemented incorporating the first two phases of a highly sensitive search strategy for OVID MEDLINE.[30] Keywords used in the initial phase of the search included: tend*, eccentric*, Achill*, patell*, epicondyl*, tennis elbow, and rotator cuff (table 1). The Physiotherapy Evidence Database (PEDro)[31] was also searched using the keyword: eccentric; and a hand search of three prominent sports medicine journals was undertaken: the British Journal of Sports Medicine (1995–Jan 2006), the American Journal of Sports Medicine (1995–Jan 2006) and the online resource of the Scandinavian Journal of Medicine and Science in Sports (2000–Jan 2006).

Inclusion and exclusion criteria

Randomised controlled trials investigating the use of EE to treat tendinopathy of the Achilles tendon, patella tendon, common wrist extensor tendon origin, or rotator cuff tendons were included. Other less common tendinopathies fell outside the scope of this review. Studies where at least one treatment group received an EE programme as the mainstay of treatment were included. Study participants must have been diagnosed clinically with tendinopathy of the studied tendon. Both mid-portion and insertional tendinopathies were included.

There were no restrictions placed on age, gender or activity level of the study participants, and non-English studies were eligible for inclusion. Co-interventions were allowed alongside EE in the intervention group as long as they were standardised. Studies that included participants who had previously ruptured, or had undergone surgery of, the involved tendon were excluded as were studies that compared two different types of EE programmes without a control group.

Outcome measures

The clinical outcome measures of interest in this review were pain, function and patient satisfaction/return to activity.

Pain has been defined by the International Association for the Study of Pain (IASP) as ''an unpleasant sensory and emotional experience associated with actual or potential tissue damage and described in terms of such damage''.[32] All pain scales were included in the review, but with conclusions based on the reliability and validity of pain scale used. A recent review of pain measurement methods recommended the visual analogue scale (VAS)[33] and the McGill Pain Questionnaire[34] as the most reliable and sensitive tools for pain measurement.[35]

Function may be defined as an activity that is natural to, or the purpose of, a person or thing.[36] Functional assessment has also been defined as ''any systematic attempt to measure objectively the level at which a person is functioning, in any of a variety of areas such as physical health, quality of self-maintenance, quality of role activity, intellectual status, social activity, attitude towards the world and self, and emotional status''.[37]

Therefore, outcomes that objectively measured any part of function were included in the review: e.g. strength, or range of movement.

The third outcome measure of interest was patient satisfaction/return to sport/return to activity, which are now accepted widely as a necessary part of outcome assessment;[38] for the purposes of this review these were analysed together as one dichotomous outcome.

Studies that reported at least one of these three clinically orientated outcomes were included in the systematic review.

Quality assessment

The PEDro[31] and van Tulder[39] scales were used to assess methodological quality.

The PEDro scale is based on the Delphi list,[40] and its reliability has been reported as being ''fair'' to ''good'' in a recent assessment;[41] Maher *et al* (2003) therefore concluded that the PEDro scale had sufficient reliability for its use in systematic reviews of physiotherapy randomised controlled trials (RCTs). The PEDro scale consists of 11 criteria, of which the first is not included in the final internal validity score. The answer to each criterion is a simple yes/no and the score is expressed as a mark out of 10. To achieve a 'yes', it must be explicitly clear upon reading the article that the criterion has been satisfied.

The van Tulder scale is the methodological quality scale utilised in the updated guidelines for systematic reviews of the Cochrane Collaboration back review group.[39] The internal validity portion of this scale consists of 11 criteria and the answer to each may be yes/no/don't know. In the case of a 'don't know', the authors were contacted to help clarify the answer. If there was no reply or it remained unclear, the answer stayed as a 'don't' know'.

Three assessors (BW, DB and RNW) independently reviewed the included articles and a consensus was reached to determine the final quality scores. The PEDro scores for articles found in the PEDro database were subsequently compared to those available on the website.

Methodological scores were calculated for each study and the two scales were then compared to determine whether these were consistent measures of quality. The studies were then rated as high or low quality based on definitions used in a previous systematic review using the van Tulder scale.[42] A *high-quality* study was defined as satisfying six or more of the 11

Table 1 Predefined search strategy used for OVID databases

Phase 1	Phase 2	Phase 3
1. Tend$.mp.	15. randomized controlled trial.pt.	24. clinical trial.pt.
2. Soft Tissue injuries/	16. controlled clinical trial.pt.	25. exp Clinical Trials/
3. Tendon Injuries/	17. Randomized Controlled Trials/	26. (clinic adj25 trial$).tw.
4. Achill$.mp.	18. Random Allocation/	27. ((singl$ or doubl$ or trebl$ or tripl$) adj (mask$ or blind$)).tw.
5. Patell$.mp.	19. Double-Blind Method/	28. Placebos/
6. epicondyl$.mp.	20. Single-Blind Method/	29. placebo$.tw.
7. tennis elbow.mp.	21. or/15–20	30. random$.tw.
8. rotator cuff.mp.	22. Animal/ not Human/	31. Research Design/
9. (jumper$ adj knee).mp.	23. 21 not 22	32. (latin adj square).tw.
10. or/1–9		33. or/24–32
11. exercise programme.mp		34. 33 not 22
12. eccentric$.mp.		35. 34 not 23
13. or/11–12		36. and/14,23
14. and/10,13		37. and/14,35
		38. or/36–37

quality criteria in the van Tulder scale, and six or more of the 10 criteria in the PEDro scale. Studies that did not meet this level were rated as *low quality*.

Levels of evidence were then determined using the following criteria:[39] *Strong*–consistent findings among multiple high-quality RCTs. *Moderate*–consistent findings among multiple low-quality RCTs and/or clinically controlled trials (CCTs) and/or one high-quality RCT. *Limited*–one low-quality RCT and/or CCT. *Conflicting*–inconsistent findings among multiple trials (RCTs and/or CCTs). *No evidence from trials*–no RCTs or CCTs.

Data management and statistical analysis

Where possible, the mean differences between pre-treatment scores and post-treatment scores were calculated for continuous data sets: a standard deviation was then obtained for the mean differences assuming a covariance of zero. For dichotomous data, the numbers of events in each group were extracted along with the groups' sample sizes. If a study reported data that were not adequate for inclusion in the analysis, all efforts were made to obtain it from the relevant author. Values were then entered for analysis into Review Manager 4.2.8 software,[43] which is commonly used for meta-analysis of data in Cochrane Collaboration systematic reviews.

The results are expressed as a weighted mean difference (WMD) or relative risk (RR) and 95% confidence intervals (CI), depending on the type of data entered, and are based on the random effects model. The statistical significance level was set at $p = 0.05$ for all results. Sample size calculations were obtained using an online calculator,[44] in collaboration with a biostatistician.

RESULTS

Selection of studies

The initial search resulted in 450 titles from the included databases (fig 1); of these, 252 were discarded as duplicate references, leaving a total of 198. The hand search of three sports journals resulted in no further inclusions. Of these 198 articles, 185 were excluded based on the title and/or abstract: eight were reviews, four did not have EE as a treatment group and 173 did not investigate tendinopathy, leaving 13 potential articles.[27 45–56] The articles' reference lists were then checked for additional studies and a further seven potential articles were found.[57–63] At this stage a second eligibility screening was done on the 20 articles and a further nine were excluded: three were not randomised,[47 48 64] two included treatment and control groups that both received EE programmes,[49 56] one did not report any of the included primary outcome measures adequately[58] and three investigated strength programmes other that eccentric training.[58 60–62] Thus, a total of 11 articles were included in the current review.

Description of studies

The characteristics of each included study can be found in table 2. In total, 443 tendons from 250 males and 172 females were included in the 11 trials. Seven studies reported drop outs,[45 46 50 52 54 55 63] with a mean percentage drop out rate of 12.5% (range 6.5–17.4%). All studies gave descriptive statistics on age of subjects with an overall mean of 36.5 years. The duration of symptoms were reported in nine studies with a mean of 19.7 months. Four studies investigated subjects diagnosed with AT,[27 50 52 59] four investigated subjects with PT[45 53 55 57] and the remaining three investigated subjects with LET.[46 54 63] Randomised studies investigating the effect of EE on rotator cuff or other less common tendinopathies were not found.

Studies included interventions of EE programmes of varying lengths: a 12-week exercise programme was undertaken in eight studies,[27 45 50 52 54 55 57 59] while two other studies implemented a four-week programme[53 63] and one study implemented a six-week programme.[46] Comparison groups included concentric exercise (CE) programmes,[27 45 46 52 57 59] stretching,[46 54] ultrasound,[53 63] frictions,[53] splints,[50] or normal training.[55] The length of follow-up varied from six weeks[46] to one year.[50 52 54] The most common follow-up time point was immediately after the conclusion of treatment at 12 weeks.[27 45 55 57 59]

Various outcome measures were used in the included studies. The most common was patient satisfaction or return to activity outcomes, with seven of the 11 studies reporting this outcome.[27 45 52 54 57 59 63] Six studies used a pain VAS as their pain outcome measure;[27 45 46 52 54 57] however, three of these studies[27 54 57] failed to report the VAS data in sufficient detail to be used in statistical analysis. Other studies utilised either a ten-point numerical rating scale[59] or a five-point ordinal rating scale.[53] Functional outcome measurement varied significantly amongst the trials with no consistency between studies: measures included Victorian Institute of Sport Assessment (VISA)[66 67] scores,[45 55] muscle strength,[54] disabilities of the arm, shoulder and hand (DASH)[68] scores,[46] Foot and Ankle Outcome (FAOS)[69] scores,[50] Ko[70] scores,[63] and peak muscle torque values.[57]

Methodological quality

The internal validity scores for the included studies are shown in figs 2 and 3. The median score for methodological quality of the included studies was 7 out of 11 for the van Tulder score (range of 5 to 9), and 6 out of 10 for the PEDro score (range of 5 to 8). Using the cut-off point of 6 in both scales for high-quality studies, six studies attained a high-quality rating.[46 50 52 55 57 63]

The PEDro scale results showed that in all studies subjects were randomly allocated to groups (criteria 2), and between group statistical comparisons were reported for at least one key outcome (criteria 10). The van Tulder scale scores showed the timing of outcome assessment was identical for all intervention groups for all important outcomes (criteria J), and high levels of allocation concealment (criteria B) and drop-out rate description (criteria I) were achieved throughout the studies (92%).

The most common methodological failings of the studies under the van Tulder rating were inadequate therapist (100%), subject (92%) and assessor (67%) blinding, and a lack of intention-to-treat analysis (58%). The PEDro scale showed a similar pattern with inadequate therapist (100%), subject (92%) and assessor (58%) blinding, and a lack of intention-to-treat analysis (50%) being commonly reported problems.

The PEDro values were compared to the online scores available and were found to fall within one point of each other. The quality rating of only one study would have changed from high to low quality if online scores were used.[52] Upon further deliberation it was decided that the score for this study should remain at 6/10 as we felt the measurement of at least one key outcome was obtained from more than 85% of the subjects initially allocated to groups.

Outcome measures

Summary statistics for the included studies can be found in table 3. Comparisons between tendinopathies for the outcome measures of pain and satisfaction/return to activity are shown in figs 4 and 5.

Pain

Only three studies using the pain VAS as an outcome measure were able to be included in data analysis;[45 46 52] no pooling of data was achievable due to the low number of studies.

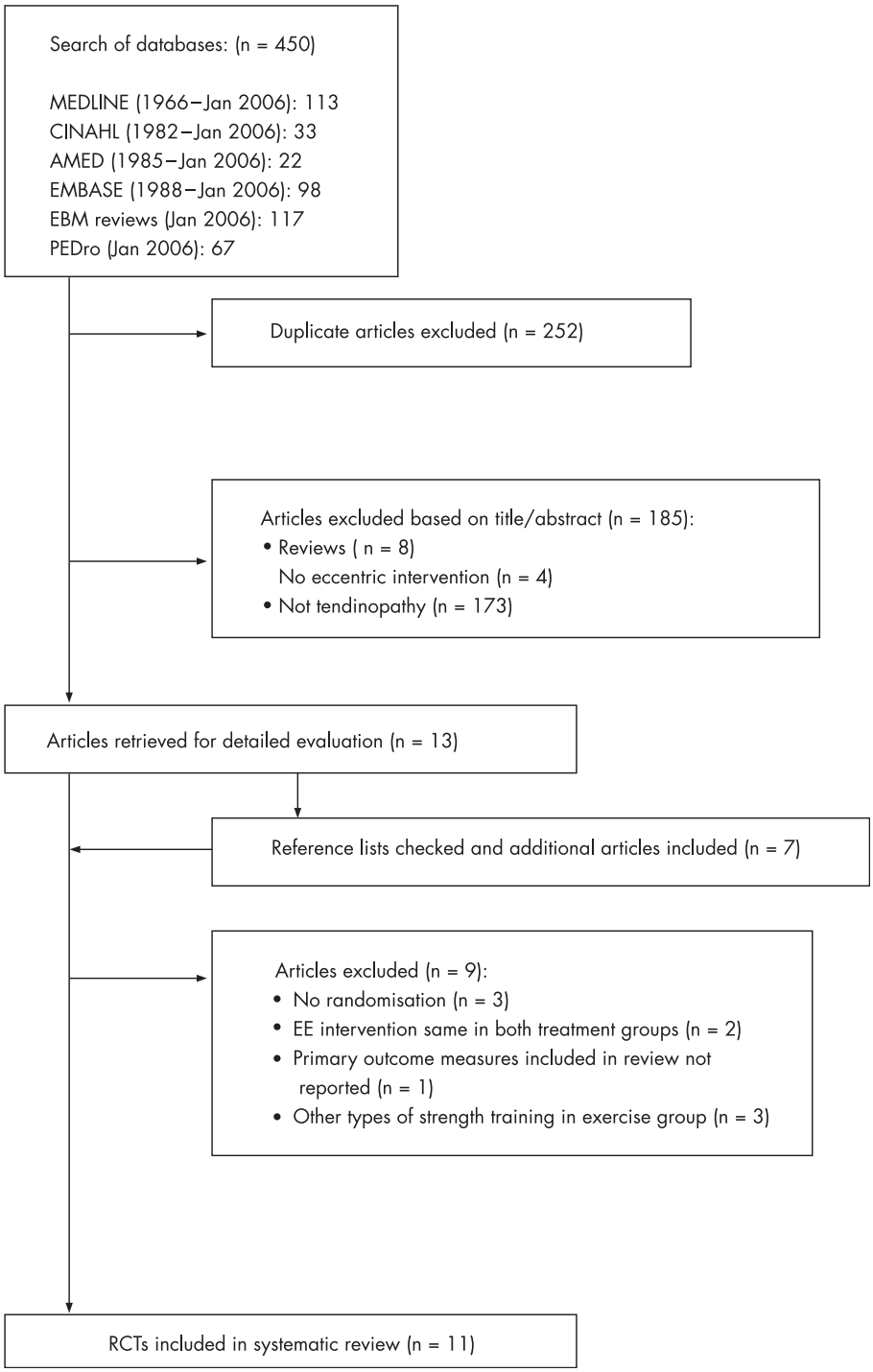

Figure 1 Study selection process. Flow-diagram based on the QUOROM guidelines.[65] RCT, randomised controlled trial; EE, eccentric exercise.

Silbernagel *et al*[52] found an 18 mm (95% CI −3.68 to 39.68) difference in VAS favouring EE to CE intervention at the 12-week stage of rehabilitation in AT; however, this was not statistically significant (p = 0.10). In PT, Jonsson *et al*[45] found a WMD of 44.8 mm (95% CI 20.09 to 69.51) between the eccentric and concentric exercise groups at 12 weeks. This result was statistically significant (p = 0.0004) but the study was found to be of low methodological quality. Martinez-Silvestrini *et al*[46] studied three different interventions for LET: eccentric, concentric and stretching groups. The WMD for pain VAS comparing eccentric to concentric was 8.00 (95% CI −8.02, to 24.02), and for eccentric compared to a stretching group was −1.00 (95% CI −16.46 to 14.46). Overall, this study showed no statistically significant differences between EE and any comparison group. Stasinopoulos *et al*[53] investigated PT and used a scale dividing subjects into two groups, either 'much better/no pain' or 'worse/no change/slightly better';[53] they found a RR of 21 (95% CI 1.40 to 315.98) at 16 weeks comparing EE to ultrasound, and a RR of 5 (95% CI 1.45 to 17.27) at 16 weeks comparing EE to frictions. Although these results were statistically significant in favour of EE (p = 0.03 and 0.01 respectively), the pain scale had not been validated and the study was of low methodological quality. Roos *et al*[50] used the FAOS[69] pain sub-score to determine a change in pain

Table 2 Characteristics of included studies

Study ID	Type of study	Participants' characteristics	Interventions	Outcomes
Cannell 2001[57]	RCT	Participants: 19 subjects involved in various sports.	Ice, AIs and rest for the first two weeks of the study; then 12-week intervention.	Length of follow-up: no follow-up past intervention
	Method of randomisation: sealed envelope draw.	EE = 10: 7 male, 3 female, Age = 26 (23–29) years, DOS = 3.1 (1.6–4.6) mths.	EE group: 3 sets of 20 drop-squats 1/day, 5 days/week. Load increase over 4 levels and dependent on body weight. Activity level could increase over this period.	Outcomes assessed:
	2 groups: drop-squats (EE) or leg extension/ curl exercises (CE).	CE = 9: 6 male, 3 female, Age = 26 (19–33) years, DOS = 4.2 (2.3–6.1) mths.	CE group: 3 sets of 10 lifts of each exercise, 1/day, 5 days/week. Weights increased as per table over 4 levels. Activity increased over this period as able.	Pain: VAS Return to sport: reported at the 12-week stage –y/n Muscle strength: quads and hamstrings moments of force 30˚/sec on both legs.
Jonsson 2005[45]	RCT	Participants: 15 patients active in various sports.	12-week intervention.	Length of follow-up: 32.6 months.
	Method of randomisation: not stated.	EE = 10: 7 male, 1 female. Age = 25.7 ± 9.9 years, DOS = 15.4 ± 6 mths.	No sports-specific training for 6 weeks. Given by same physiotherapist. Both groups performed exercise on decline board. Training was meant to be painful. Load increased to attain this.	Outcomes assessed:
	2 groups: EE and CE.	CE = 9: 6 male, 1 female, Age = 24.1 ± 6.1 years, DOS = 19.6 ± 20.3 mths.	EE group: exercises done 2 times a day, 7 days/week. 3×15 reps. Concentric activity done by uninjured leg.	Pain: VAS
			CE group: a/a, eccentric activity avoided as much as possible.	Function: VISA score for knee function. Patient satisfaction: satisfied/not satisfied.
Mafi 2001[27]	RCT	Participants: 44 patients referred as potential surgical candidates: 24 male, 20 female.	12-week intervention.	Length of follow-up: no follow-up past intervention.
	Method of randomisation: envelope.	EE = 22, Age = 48.1 ± 9.5 years, DOS = 18 (3–120) mths.	EE group: exercises done 2 times a day, 7 days/week. Two exercises used short and long calf muscle loading. Each 3×15 reps. Concentric activity done by uninjured leg. Increased load when exercise became pain free.	Outcomes assessed:
	2 groups: EE and CE.	CE = 22, Age = 48.4 ± 8.3 years, DOS = 23 (5–120) mths.	CE group: various concentric exercises used, from calf raises to side jumps.	Pain: VAS Patient satisfaction: satisfied/not satisfied.
Martinez-Silvestrini 2005[46]	RCT	Participants: 94 subjects: 50 male, 44 female.	6-week intervention.	Length of follow-up: no follow-up past intervention.
	Method of randomisation: not stated.	DOS: >3 mths.	Stretching group: 2 times/day 3 repetitions held for 30 secs, 30 sec rest between.	Outcomes assessed:
	3 groups: stretching, EE + stretching, CE + stretching.	Age:	EE group: eccentric resistance band exercises, avoiding concentric activity. 3 sets of 10 reps 1 time/day 2, 5 minutes of rest between sets.	Grip strength: pain free.
		St = 43.1 years.	CE group: a/a but eccentric load avoided during exercise.	Patient-rated forearm evaluation questionnaire.
		EE + St = 46.6 years.	Advice on ice massage and strap use was also given to all patients.	DASH
		CE + St = 47.0 years.		SF–36. Pain: VAS Patient satisfaction: 5 point scale.
Neisen-Vertommen 1992[59]	RCT.	Participants: 17 non-competitive recreational athletes	12-week intervention.	Length of follow-up: no follow-up past intervention.
	Method of randomisation: not stated.	EE = 8	5 sets of 10 reps, in a pain free ROM, 1 time/day 6/week.	Outcomes assessed:
	2 groups: EE and CE.	4 male, Age = 39.5 ± 3.2 years, DOS: 3.7 ± 1.1 mths.		
		4 female, Age = 31 ± 2.6 years, DOS: 3.7 ± 0.9 mths.	EE group: protocol outlined in another journal article, raised step exercise, eccentric only.	Concentric and eccentric plantarflexor average and peak torque, 30˚/sec and 50˚/sec.
		CE = 9	CE group: progressive concentric exercise programme on universal gym.	Pain: scale from 1–10.
		6 male, Age = 37.33 ± 1.7 3 female, Age = 28.66 ± 3.2 years.	Each group progressed weight as able.	Return to activity: scale from 1–10; 10 denoted full activity of pre-injured level.
Roos 2004[50]	RCT.	Participants: 44: 21 male, 23 female. Age = mean 45 years. DOS: 5.5 (1–180) mths.	12-week intervention.	Length of follow-up: 1 year.

Table 2 Continued

Study ID	Type of study	Participants' characteristics	Interventions	Outcomes
	Method of randomisation: envelope.			
		EE = 16	EE group: as described by Alfredson *et al* 1998. Straight and bend knee exercises. Day 1–2 1×15; day 3–4 2×15; day 5–7 3×15; then 3×15 from then on. Load added as tolerated.	Outcomes assessed:
	3 groups: EE, night splint or combination of both.	EE + Sp = 15	Night splint group: anterior night splint, night-time use only.	FAOS
		Sp = 13	Combination group: a/a.	Return to sport: y/n.
Selvanetti 2003[63]	RCT	Participants: 60 patients.	20–30 sessions.	Length of follow-up: mean 11 months.
	Method of randomisation: envelope numbered and sealed.	EE = 31: 17 males, 14 female, Age = 41.3 (33–54) years, DOS = 6.6 (2–10) mths.	EE group: 3 mins warm-up, 4 PNF contract relax (10 sec contract, 2 sec rest, 30 sec stretch), 3 sets of 10 reps ecc. Exercises with theraband, 30 secs rest between sets, PNF stretches times 4 again then ice for 15 minutes.	Outcomes assessed:
	2 groups: sham ultrasound and counselling, and EE, contract-relax stretching and counselling.	US = 29: 15 males, 14 female, Age = 40.5 (32–52) years, DOS = 6.8 (3–11) mths.	US group: placebo US (20 sessions, 5/week).	Pain: VAS scale, but 0 = severe, 10 = no pain.
				Patient satisfaction: subjective general enhancement; 0–100%
Silbernagel 2001[52]	RCT.	Participants: 40 (57 involved tendons) patients.	12-week intervention.	Length of follow-up: 6 months.
		EE = 30 tendons, 17 male, 5 female, Age = 47 ± 14.7 years, DOS = 20 ± 25.4 mths.		One-year follow-up for summary of questions to patient.
	Method of randomisation: not stated.		EE group: extensive exercise programme split into 3 phases, including ROM exercises, concentric exercises and eccentric exercises. Pain allowed to reach 5 on VAS, no morning stiffness following, and decrease in VAS pain by morning.	
	2 groups: EE and CE.	CE = 27 tendons, 14 male, 4 female, Age = 41 ± 10.2 years, DOS = 41 ± 55.9 mths.	CE group: a/a minus the eccentric exercises. Frequency of all exercises in all groups varied from week to week.	Outcomes assessed:
				Pain: VAS Function: plantarflexion, jumping test, toe raising test. Patient satisfaction: y/n.
Stasinopoulos 2004[53]	RCT.	Participants: 30 patients, DOS = minimum 3 mths.	4-week intervention.	Length of follow-up: 3 months.
	Method of randomisation: drawing lots.	EE = 10: 7 male, 3 female, Age = 28.12 ± 2.03 years.	All patients received 3 treatments per week.	Outcomes assessed:
	3 groups: EE, pulsed US, and frictions (F).	US = 10: 6 males, 4 female, Age = 29.17 ± 3.76 years.	EE group: static stretching exercises, 3 sets of 15 unilateral eccentric squats, load increased as able, 2 minute rest between sets.	Pain status: worse, no change, somewhat better, much better, no pain.
		F = 10: 5 male, 5 female, Age = 26.24 ± 4.17 years.	US group: local pulsed US 0.4–0.8 W/cm^2 ratio1:4, 2 ms pulse duration, frequency 1 MHz. -10 minutes. Friction group: Cyriax and Cyriax technique for 10 minutes.	
Svernlov 2001[54]	RCT.	Participants: pilot study: 30 patients.	12-week intervention.	Length of follow-up: 12 months for pilot, after 3 months training in clinical study.
	Method of randomisation: not stated.	EE = 15: 13 male, 2 female, Age = 42.1 years, DOS = 10.7 (3–24) mths.	EE group: warm-up ex. 2–3 mins, static stretch 3–5 times (15–30 secs), eccentric exercises, 3 sets of 5 with dumb-bell 10 sec duration, static stretch as before, performed 1 time/day.	Outcomes assessed:
	2 groups: EE and St. Both with use of brace.	St = 15: 6 male, 9 female, Age = 43 years, DOS = 8.4 (3–20) mths.	Stretching group: 10 secs of contractions of muscle, relaxation 2 secs, stretching 15–20 secs, repeated 3–5 times twice daily.	Pain: VAS
				Strength testing: using strain gauge device. Patient satisfaction: y/n.
Visnes 2005[55]	RCT.	Participants: 29 male and female elite volleyball players (12 with bilateral symptoms) in Norway.	12-week intervention.	Length of Follow-up: 6 months after end of intervention.

Table 2 Continued

Study ID	Type of study	Participants' characteristics	Interventions	Outcomes
	Method of randomisation: by statistician who was blinded to player identity.	EE = 13: 8 male, 5 female, Age = 26.8 ± 4.6 years, DOS = 67 ± 44 mths	EE group: twice daily, 3 sets of 15 reps, done without warming up. Decline squat exercise, eccentric loading only on affected leg, recommended to have 5/10 pain upon exercising. Load was increased as pain decreased.	Outcomes assessed:
	2 groups: EE and control.	C = 16: 11 male, 5 female, Age = 26.4 ± 3.4 years, DOS = 79 ± 75 mths.	Control group: no intervention, trained as usual.	Function: VISA scores for knee function. Global evaluation score (pain and function) and jumping performance.

AI, anti-inflammatories; a/a, as above; C, control; CE, concentric exercise; DASH, disabilities of the arm, shoulder and hand; DOS, duration of symptoms; EE, eccentric exercise; F, frictions; FAOS, foot and ankle outcome score; RCT, randomised controlled trial; Sp, splint; St, stretching; US, ultrasound; VAS, visual analogue scale; VISA, Victorian Institute of Sport Assessment.

in AT and found no statistically significant differences at 12 weeks comparing EE to a control group (WMD 1.40; 95% CI −19.16 to 21.96) or EE to a splint group (WMD 14.00; 95% CI −6.56 to 34.56).

In summary, only two of the 11 included studies, both investigating PT, reported statistically significant results using a validated outcome measure of pain.[45 53] Due to the low methodological quality and heterogeneity of these two studies, only a limited level of evidence exists to suggest that EE is clinically effective in reducing pain in PT. Owing to small trial numbers and very large confidence intervals, there is no evidence available to suggest whether EE is effective in reducing pain in either AT or LET.

Function

Various measures of functional outcome were used to determine whether EE was effective in increasing function in tendinopathy, and due to this variation, pooling of data was not possible.

In AT, Roos *et al*[50] reported function at 12 weeks using the FAOS subscale of sport and recreation. The study compared EE to a control group (WMD 17.00; 95% CI −8.87 to 42.87) and EE to a splint group (WMD 20.00; 95% CI −5.87 to 45.87); both of these differences were not statistically significant. Other outcomes, including plantarflexion range of motion (WMD 2.00; 95% CI −3.36 to 7.36), a jumping test (WMD 0.00; 95% CI −4.89 to 4.89), and a toe raise test (WMD −2.00; 95% CI,

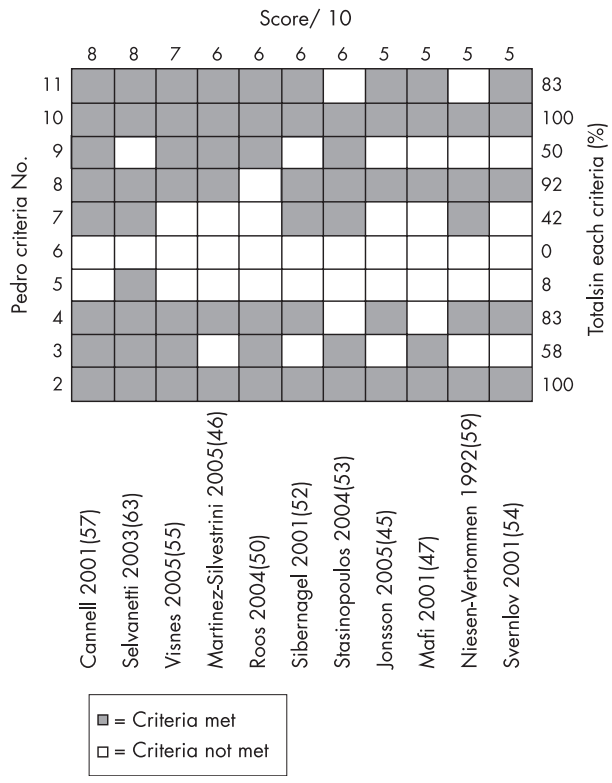

Figure 2 PEDro[31] scores for included studies. Studies are ordered by PEDro score. Criteria 1 omitted as not included in internal validity scores. ■ = criteria met; □ = criteria not met.

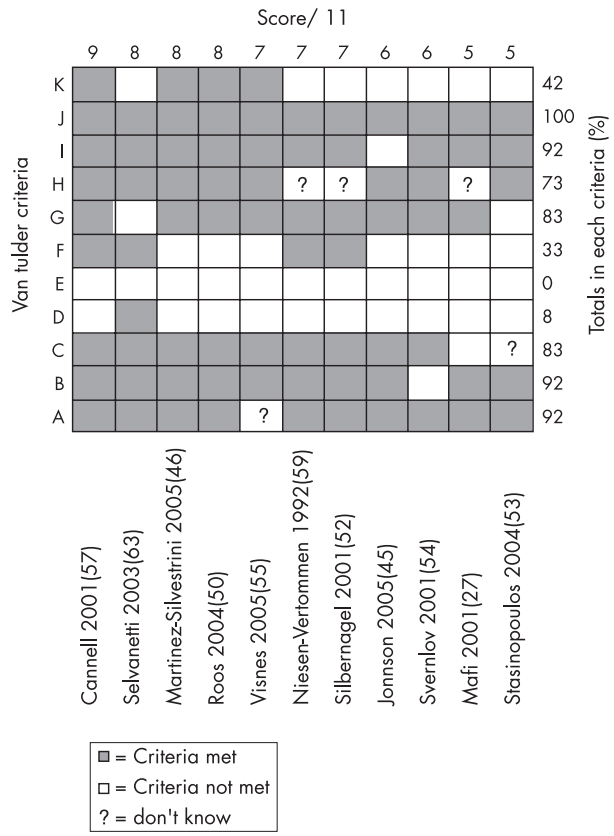

Figure 3 van Tulder[39] scores for included studies. Studies are ordered by van Tulder score. ■ = criteria met; □ = criteria not met; ? = don't know.

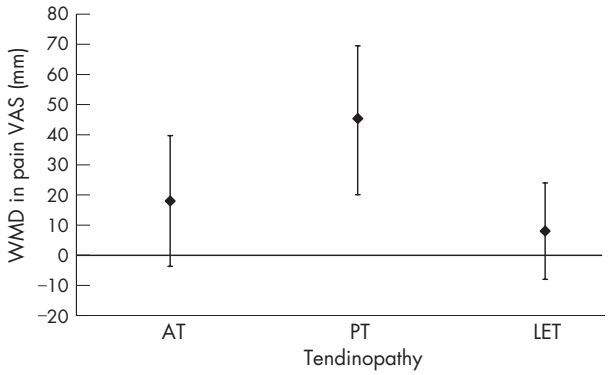

Figure 4 Summary of findings. Pain VAS changes in the treatment of three tendinopathies, EE compared to CE (WMD ± 95% CI are shown). AT, Achilles tendinopathy; CE, concentric exercise; CI, confidence interval; EE, eccentric exercise; LET, lateral elbow tendinopathy; mm, millimetres; PT, patellar tendinopathy; VAS, visual analogue scale; WMD, weighted mean difference.

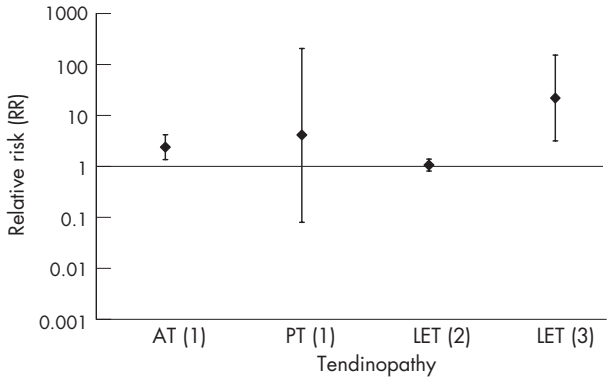

Figure 5 Summary of findings. RR of Satisfaction/Return to Activity in EE groups compared to controls (±95% CI): (1) eccentric vs concentric - 12 weeks; (2) eccentric vs st. >6 months; (3) eccentric vs US >6 months. AT, Achilles tendinopathy; CI, confidence interval; EE, eccentric exercise; LET, lateral elbow tendinopathy; mm, millimetres; PT, patellar tendinopathy; RR, relative risk; st, stretching; US, ultrasound; VAS, visual analogue scale.

−14.55 to 10.55), also failed to show statistically significant differences between EE and comparison groups.[52]

Two studies examined function in PT using the VISA[66 67] scale, a functional pain-rating scale specifically designed for AT and PT, and found quite different results.[45 55] Jonsson *et al*[45] showed that EE intervention increased VISA scores significantly compared to a CE programme (WMD 45.90; 95% CI 24.54 to 67.26); in contrast, Visnes *et al*[55] found a WMD of 0.10 (95% CI −14.38 to 14.58) comparing EE to a control of normal training in elite volleyball players. Cannell *et al*[57] also investigated PT, and measured hamstring and quadriceps moments as a functional outcome. No statistically significant difference was found between the two intervention groups for either hamstrings moment (WMD 5.00; 95% CI −133.98 to 143.98) (p = 0.94), or for quadriceps moment (WMD 106; 95% CI −73.74 to 285.74) (p = 0.25). Martinez-Silvestrini *et al*[46] used the DASH[68] functional outcome measure for LET and found no significant difference in function comparing EE to CE (WMD 0.00; 95% CI −9.76 to 9.76) (p = 1.00), and comparing EE to stretching (WMD −3.00; 95% CI −12.71 to 6.71) (p = 0.54). The same study also assessed grip strength as a functional measure, but again there were no statistically significant results. Selvanetti *et al*[63] also studied the common extensor tendon origin to determine the effect of EE compared to ultrasound, and found a significant difference in Ko[70] scores at 4 weeks (WMD 38.70; 95% CI 29.75 to 47.65; p<0.00001) and at 11 months (WMD 39.20; 95% CI 30.32 to 48.08; p<0.00001). This scale was taken from a previous study that investigated another type of treatment for LET, but had not been validated.[70]

No firm conclusions can be derived from these studies regarding the effect of EE on function due to the variety of outcome measurement used and the small number of available studies. The only two statistically significant results reported were either from a study of low quality,[45] or were obtained using a non-validated functional outcome measure.[63]

Patient satisfaction/return to activity

Patient satisfaction/return to activity was significantly different for AT (p = 0.003) when 12-week data were pooled from two studies (RR 2.38; 95% CI 1.36 to 4.18).[27 59] These studies, however, were both of low methodological quality. In contrast, a significant risk ratio in favour of EE was not found in a high-quality study measuring satisfaction after 12 months (RR 1.56; 95% CI 0.73 to 3.32) (p = 0.25).[52] Pooling of data was completed for satisfaction/return to activity at the 12-week stage of rehabilitation in PT for EE compared to CE (RR 4.17; 95% CI 0.08 to 206.41).[45 57] This result was more pronounced and statistically significant at a follow-up point of 32.6 months (mean) in another study (RR 17.27; 95% CI 1.15 to 260.07; p = 0.04), although this was of low quality.[45] In LET, satisfaction/return to activity for EE intervention compared to ultrasound was statistically significant at six months post-treatment (RR 21.97; 95% CI 3.17 to 152.20; p = 0.002),[63] whereas the RR for EE compared to stretching at the same time point was 1.06 (95% CI 0.81 to 1.39).[54]

In summary, moderate evidence exists to suggest satisfaction/return to activity is more likely with 12 weeks of EE therapy compared to CE intervention in AT, but this is based on small study numbers. There is also moderate evidence to suggest that EE therapy is associated with increased satisfaction/return to activity at six months post-treatment in LET when compared to ultrasound therapy. Only limited evidence exists to support the effectiveness of EE on satisfaction/return to activity in PT.

DISCUSSION

This systematic review was undertaken with the aim of determining the effectiveness of EE in the treatment of various common tendinopathies. Eleven RCTs met the inclusion criteria; they included studies of AT, PT and LET. RCTs investigating the effect of EE on rotator cuff tendinopathy were not found using the defined search strategy. Since the time of data analysis, a small non-randomised pilot study has been published investigating rotator cuff tendinopathy and the effect of EE therapy; however, it would not have satisfied the inclusion criteria used here, and would not, therefore, have affected the results of this review.[71]

Due to the lack of high-quality studies with clinically significant results, no strong conclusions could be made regarding the effectiveness of EE (compared to control interventions) in relieving pain, improving function or achieving patient satisfaction. A limited level of evidence exists suggesting EE reduces pain in PT at the 12-week stage of treatment when compared to CE. There is also limited evidence suggestive of an increase in function using EE compared to ultrasound in the treatment of LET, although the validity of the outcome measure used in this study is unclear.[63] Patient satisfaction/return to activity results were more positive for EE, with moderate evidence suggesting EE intervention may increase patient satisfaction/return to activity compared to CE

Table 3 Results of included studies for clinical outcome measures. Incomplete data were not included

Outcome measure	Study ID	Dx	Intervention	Wk	WMD (95% CI)	RR (95% CI)	p Value
Pain							
Pain VAS (100 mm)	Silbernagel 2001[52]	AT	EE vs CE	6	2.00 (−18.90, 22.90)		0.85
				12	18.00 (−3.68, 39.68)		0.10
				26	10.00 (−8.81, 28.81)		0.30
	Jonsson 2005[45]	PT	EE vs CE	12	44.80 (20.09, 69.51)		0.00004
	Martinez-Silvestrini 2005[46]	LET	EE+St vs CE+St	6	8.00 (−8.02, 24.02)		0.33
			EE+St vs St				
				6	−1.00 (−16.46, 14.46)		0.90
Decrease in pain (Yes/ No)*	Stasinopoulos 2004[53]	PT	EE vs US	4		8.00 (1.21, 52.69)	0.03
				8		21.00 (1.40, 315.98)	0.03
				16		21.00 (1.40, 315.98)	0.03
			EE vs F	4		4.00 (1.11, 14.35)	0.03
				8		5.00 (1.45, 17.27)	0.01
				16		5.00 (1.45, 17.27)	0.01
FAOS Pain Score (/ 100)	Roos 2004[50]	AT	EE vs EE+Sp	12	1.40 (−19.16, 21.96)		0.89
				52	4.00 (−15.01, 23.01)		0.68
			EE vs Sp	12	14.00 (−6.56, 37.94)		0.18
				52	4.00 (−14.11, 22.11)		0.67
Function							
FAOS Sport/Rec score (/100)	Roos 2004[50]	AT	EE vs EE+Sp	12	17.00 (−8.87, 42.87)		0.20
				52	10.00 (−17.94, 37.94)		0.48
			EE vs Sp	12	20.00 (−8.87, 45.87)		0.13
				52	8.00 (−17.89, 33.89)		0.54
Plantarflexion ( )	Silbernagel 2001[52]	AT	EE vs CE	12	2.00 (3.36, 7.36)		0.46
Jumping test (cm)	Silbernagel 2001[52]	AT	EE vs CE	12	0.00 (−4.89, 4.89)		1.00
Toe raise Test (n)	Silbernagel 2001[52]	AT	EE vs CE	12	−2.00 (−14.55, 10.55)		0.75
VISA scores (/100)	Jonsson 2005[45]	PT	EE vs CE	12	45.90 (24.54, 67.26)		<0.0001
	Visnes 2005[55]	PT	EE vs C	12	0.10 (−14.38, 14.58)		0.99
Hamstring moment (Nm)	Cannell 2001[57]	PT	EE vs CE	12	5.00 (−133.98, 143.98)		0.94
Quadriceps moment (Nm)	Cannell 2001[57]	PT	EE vs CE	12	106.00 (−73.74, 285.74)		0.25
DASH (/100)	Martinez-Silvestrini 2005[46]	LET	EE vs CE	6	0.00 (−9.76, 9.76)		1.00
			EE+St vs St	6	−3.00 (−12.71, 6.71)		0.54
Ko scores (/100) <0.00001	Selvanetti 2003[63]	LET	EE vs US	4	38.70 (29.75, 47.65)		
				48	39.20 (30.32, 48.08)		
<0.00001							
Grip strength (mmHg)	Martinez-Silvestrini 2005[46]	LET	EE vs CE	6	−3.00 (−13.10, 7.10)		0.56
			EE+St vs St	6	−4.00 (−12.50, 4.50)		0.36
Satisfaction/ Return to activity							
	Neisen-Vertommen 1992[59]	AT	EE vs CE	12		4.50 (0.63, 32.38)	0.14
	Mafi 2001[27]	AT	EE vs CE	12		2.25 (1.25, 4.05)	0.007
	Silbernagel 2001[52]	AT	EE vs CE	>26		1.56 (0.73, 3.32)	0.25
	Cannell 2001[57]	PT	EE vs CE	12		1.35 (0.81, 2.24)	0.25
	Jonsson 2005[45]	PT	EE vs CE	12		17.27 (1.15, 260.07)	0.04
				>26		17.27 (1.15, 260.07)	0.04
	Svernlov 2001[54]	LET	EE vs St	>26		1.06 (0.81, 1.39)	0.68
	Selvanetti 2003[63]	LET	EE vs US	>26		21.97 (3.17, 152.20)	0.002

AT, Achilles tendinopathy; C, control; CE, concentric exercise; CI, confidence interval; DASH, disabilities of the arm, shoulder and hand; DOS, duration of symptoms; Dx, diagnosis; F, frictions; FAOS, foot and ankle outcome score; EE, eccentric exercise; LET, lateral elbow tendinopathy; p, statistical significance; PT, patellar tendinopathy; RCT, randomised controlled trial; RR, relative risk; S, splint; St, stretching; US, ultrasound; VAS, visual analogue scale; VISA, Victorian Institute of Sport Assessment; WMD, weighted mean difference; Wk, week of data collection.
*Yes, much better /no pain; No, worse/no change/slightly better

in AT, as well as to support EE compared to ultrasound in LET; limited evidence exists supporting EE compared to CE in PT. Another systematic review known to have investigated the effect of different physical interventions in the treatment of LET came to similar conclusions regarding the effectiveness of exercise therapy.[72] This group found insufficient evidence to determine the effectiveness of exercise therapy in the treatment of LET but concluded that results from preliminary studies warranted further evaluation in this area. Other systematic reviews investigating exercise therapy in PT or AT were not found.

Overall, the methodological quality was considered high in only six studies of the 11 included in this review. It was assumed that the risk of misclassification was low, as reliable and valid measures of methodological quality were used.[39 41] The most common deficits in methodology were the lack of blinding of subjects, assessors and therapists. The blinding of subjects and therapists will always remain difficult when implementing exercise therapy interventions in research.[73] Liddle *et al* (2004) omitted the van Tulder item of 'blinding of care provider' in a systematic review of exercise and chronic low back pain as they felt the item was inapplicable to exercise

interventions. If this item was deleted in both methodological scores used in this review, quality ratings of all included studies would not have changed.

Treatment effects are found to be overestimated in low-quality systematic reviews where non-randomised studies such as prospective cohorts are included.[74 75] This may be due to non-randomisation and inadequate allocation concealment methods contained within these prospective studies.[74] For this reason, prospective, non-randomised studies were not included in this systematic review. However, many non-randomised trials have been undertaken to investigate the effectiveness of EE in common tendinopathies.[25 26 47 48 64 76 77] One non-randomised prospective study investigating AT compared EE to a surgical intervention and found a larger, significant treatment effect on pain VAS than reported here (WMD 25.8; 95% CI 11.36 to 40.24).[25] This result should be viewed with caution due to the low methodological quality of the study concerned.

Findings from this review are limited by the fact that included trials were based upon small sample sizes, and these numbers were often too small to reach adequate statistical power. Heterogeneity of the studies included in the review was considered another problem, with differences in study population, interventions, controls and outcome measures. Only a few studies reported similar outcomes, making the pooling of data impossible for the majority of outcome measures. The lack of long-term follow-up in research in this area is also an issue, as only three studies included a one-year outcome measurement.[50 52 54] This makes any potential longer-term clinical benefit of EE hard to determine.

The treatment regime most commonly used in the included studies was derived from an initial study of AT.[25] This comprised three sets of 15 repetitions, done twice daily, seven days a week for 12 weeks. Upon correspondence with one of the authors of this study, it was found that the regime was based on clinical experience, rather than derived from any empirical evidence; e.g. data from 'dose response'-type studies. However, the lack of understanding about the basic pathophysiology of tendinopathy makes determining the optimal dosage of intervention difficult. A recent review of EE in AT tried to address the issue of treatment dosage[21] and concluded that because the studies in this area have not used an underlying rationale to determine loading parameters, progressions and frequency of treatment, further research needs to be undertaken before an optimal dosage can be determined.

In summary, there is a dearth of high-quality research available to establish the effectiveness of EE therapy in the treatment of three common tendinopathies. Due to low sample numbers, large confidence intervals were present in many studies, making the majority of results inconclusive. Limited to moderate levels of evidence exist in a number of areas, thus warranting further research in this field. Although clinical benefits of EE could not be fully determined due to the lack of quality research with adequate follow-up, the overall trend suggested a positive effect of EE, with no study reporting adverse effects. However, a recent study suggests that sedentary subjects with AT may show less promising results with EE therapy compared to athletic subjects.[78] Further determination of variations between population sub-groups such as these will also require high-quality RCTs to be undertaken before any firm conclusions can be made.

Randomised controlled trials are commonly accepted as the 'gold standard' way to investigate the effectiveness of a particular healthcare intervention.[79] Thus, further RCTs in this area must be adequately powered and include appropriate randomisation procedures, standardised outcome measures and long-term follow-up. As a precursor to this, RCTs should be undertaken to determine the 'dose-response' effect of various EE programme durations and intensities. It is only then that the clinical benefit of EE in the treatment of tendinopathy may be fully elucidated compared to other treatment modalities. While clinicians may opt to continue to utilise EE programmes in the treatment of common tendinopathies, they should be aware of the lack of evidence for the superior effectiveness of this approach in comparison with other active modalities such as concentric exercise and stretching.

What is already known on this topic

- Tendinopathy is a non-inflammatory degenerative condition that may take 6–12 months to resolve with conservative intervention.
- The pathogenesis of tendinopathy remains unclear.
- EE programmes have been emphasised in recent literature as a key part of tendinopathy rehabilitation.

What this study adds

- There is a lack of evidence supporting the effectiveness of EE programmes over other active modalities such as CE and stretching.
- Further adequately powered RCTs with standardised outcome measures and long-term follow-up are required to ascertain the clinical benefits of EE programmes in the treatment of tendinopathy.

ACKNOWLEDGEMENTS

Dr Melanie Bell from the Department of Preventative and Social Medicine, University of Otago, Dunedin, New Zealand for statistical support, and the administration staff at the School of Physiotherapy, University of Otago, Dunedin, New Zealand.

Authors' affiliations

B L Woodley, R J Newsham-West, G D Baxter, Centre for Physiotherapy Research, School of Physiotherapy, University of Otago, Dunedin, New Zealand

Competing interests: None identified.

REFERENCES

1 **Maffulli N**, Kahn KM, Puddu G. Overuse tendon conditions: Time to change a confusing terminology. *Arthroscopy* 1998;**14**:840–3.
2 **Jarvinen TAH**, Kannus P, Paavola M, *et al*. Achilles tendon injuries. *Cur Opin Rheumatol* 2001;**13**:150–5.
3 **Gabel GT**. Acute and chronic tendinopathies at the elbow. *Cur Opin Rheumatol* 1999;**11**:138–143.
4 **Kannus P**, Aho H, Jarvinen M, *et al*. Computerized recording of visits to an outpatient sports clinic. *Am J Sports Med* 1987;**15**:79–85.
5 **Maffulli N**, Wong J, Almekinders LC. Types and epidemiology of tendinopathy. *Clin Sports Med* 2003;**22**:675–692.
6 **Wang JH**, Iosifidis MI, Fu FH. Biomechanical basis for tendinopathy. *Clin Orthop Relat Res* 2006;**443**:320–332.
7 **Whaley AL**, Baker CL. Lateral epicondylitis. *Clin Sports Med* 2004;**23**:677–691.
8 **Ashe MC**, McCauley T, Khan KM. Tendinopathies in the upper extremity: a paradigm shift. *J Hand Ther* 2004;**17**:329–334.
9 **Cook JL**, Khan KM, Purdam CR. Masterclass. Conservative treatment of patellar tendinopathy. *Physical Therapy in Sport* 2001;**2**:54–65.
10 **Kader D**, Saxena A, Movin T, *et al*. Achilles tendinopathy: some aspects of basic science and clinical management. *Br J Sports Med* 2002;**36**:239–249.
11 **Hunter G**. Master class. The conservative management of Achilles tendinopathy. *Physical Therapy in Sport* 2000;**1**:6–14.
12 **Alfredson H**. Chronic midportion Achilles tendinopathy: an update on research and treatment. *Clin Sports Med* 2003;**22**:727–741.
13 **Alfredson H**, Lorentzon R. Chronic Achilles tendinosis: recommendations for treatment and prevention. *Sports Med* 2000;**29**:135–146.
14 **Cook JL**, Khan KM. What is the most appropriate treatment for patellar tendinopathy? *Br J Sports Med* 2001;**35**:291–4.

15 **Evans PJ**, Miniaci A. Rotator cuff tendinopathy: many causes, many solutions… part 2 conservative and surgical management. *Journal of Musculoskeletal Medicine* 1998;**15**:32–4.
16 **Fyfe I**, Stanish WD. The use of eccentric training and stretching in the treatment and prevention of tendon injuries. *Clin Sports Med* 1992;**11**:601–24.
17 **Khan KM**, Cook JL, Taunton JE, *et al*. Overuse tendinosis, not tendinitis. Part 1: a new paradigm for a difficult clinical problem. *Phys Sportsmed* 2000;**5**:38–43.
18 **LaStayo PC**, Woolf JM, Lewek MD, *et al*. Eccentric muscle contractions: their contribution to injury, prevention, rehabilitation, and sport. *J Orthop Sports Phys Ther* 2003;**33**:557–571.
19 **Peers KHE**, Lysens RJJ. Patellar tendinopathy in athletes: Current diagnostic and therapeutic recommendations. *Sports Med* 2005;**35**:71–87.
20 **Alfredson H**. The chronic painful Achilles and patellar tendon: research on basic biology and treatment. *Scand J Med Sci Sports* 2005;**15**:252–9.
21 **Jeffery R**, Cronin J, Bressel E. Eccentric strengthening: Clinical applications to Achilles tendinopathy. *New Zealand Journal of Sports Medicine* 2005;**33**:22–30.
22 **Riley G**. The pathogenesis of tendinopathy. A molecular perspective. *Rheumatology* 2004;**43**:131–142.
23 **Sandrey MA**. Using Eccentric Exercise in the Treatment of Lower Extremity Tendinopathies. *Athletic Therapy Today* 2004;**9**:58–9.
24 **Stanish WD**, Rubinovich RM, Curwin S. Eccentric exercise in chronic tendinitis. *Clin Orthop Relat Res* 1986;**208**:65–8.
25 **Alfredson H**, Pietila T, Jonsson P, *et al*. Heavy-load eccentric calf muscle training for the treatment of chronic achilles tendinosis. *Am J Sports Med* 1998;**26**:360–6.
26 **Fahlstrom M**, Jonsson P, Lorentzon R, *et al*. Chronic Achilles tendon pain treated with eccentric calf-muscle training. *Knee Surg Sports Traumatol Arthrosc* 2003;**11**:327–333.
27 **Mafi N**, Lorentzon R, Alfredson H. Superior short-term results with eccentric calf muscle training compared to concentric training in a randomized prospective multicenter study on patients with chronic Achilles tendinosis. *Knee Surg Sports Traumatol Arthrosc* 2001;**9**:42–7.
28 **Khan KM**, Cook PT. Overuse Tendon Injuries: Where does the pain come from? *Sports Medicine and Arthroscopic Review* 2000;**8**:17–31.
29 **Ovid Technologies Inc**. N.Y. Ovid web gateway. http://gateway.ut.ovid.com/gw1/ovidweb.cgi (accessed 21 January 2006).
30 **Robinson KA**, Dickersin K. Development of a highly sensitive search strategy for the retrieval of reports of controlled trials using PubMed. *Int J Epidemiol* 2002;**31**:150–3.
31 **Centre for Evidence-Based Physiotherapy, Sydney**. PEDro. Physiotherapy Evidence Database. http://www.pedro.fhs.usyd.edu.au (accessed 21 January 2006).
32 **Merskey H**, Bogduk, N. *Classification of Chronic Pain: Descriptions of Chronic Pain Syndromes and Definitions of Pain Terms*, 2nd edn. Seattle: IASP Press, 1994:211.
33 **Miller MD**, Ferris DG. Measurement of subjective phenomena in primary care research: the visual analogue scale. *Fam Pract Res J* 1993;**13**:15–24.
34 **Melzack R**. The McGill Pain Questionnaire: major properties and scoring methods. *Pain* 1975;**1**:277–299.
35 **Ong KS**, Seymour RA. Pain measurement in humans. *Surgeon* 2004;**2**:15–27.
36 **Allen RE**, Fowler HW, Fowler FG. *The Concise Oxford Dictionary of Current English*. Oxford: Clarendon Press; New York, Oxford University Press, 1990.
37 **Lawton MP**. The functional assessment of elderly people. *J Am Geriatr Soc* 1971;**19**:465–481.
38 **Deyo RA**, Battie M, Beurskens AJ, *et al*. Outcome measures for low back pain research. A proposal for standardized use. *Spine* 1998;**23**:2003–2013.
39 **van Tulder M**, Furlan A, Bombardier C, *et al*. Updated method guidelines for systematic reviews in the Cochrane collaboration back review group. *Spine* 2003;**28**:1290–9.
40 **Verhagen AP**, de Vet HC, de Bie RA, *et al*. The Delphi list: a criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. *J Clin Epidemiol* 1998;**51**:1235–41.
41 **Maher CG**, Sherrington C, Herbert RD, *et al*. Reliability of the PEDro scale for rating quality of randomized controlled trials. *Phys Ther* 2003;**83**:713–21.
42 **van Tulder MW**, Touray T, Furlan AD, *et al*. Muscle relaxants for non-specific low back pain: a systematic review within the framework of the Cochrane collaboration. *Spine* 2003;**28**:1978–92.
43 **Cochrane Collaboration, The**. Oxford. Review Manager (RevMan). http://www.cc-ims.net/RevMan (accessed January 2006).
44 **UCLA Department of Statistics, L**. A. Power Calculator. http://calculators.stat.ucla.edu/powercalc (accessed 30 March 2006).
45 **Jonsson P**, Alfredson H. Superior results with eccentric compared to concentric quadriceps training in patients with jumper's knee: A prospective randomised study. *Br J Sports Med* 2005;**39**:847–50.
46 **Martinez-Silvestrini JA**, Newcomer KL, Gay RE, *et al*. Chronic lateral epicondylitis: Comparative effectiveness of a home exercise program including stretching alone versus stretching supplemented with eccentric or concentric strengthening. *J Hand Ther* 2005;**18**:411–20.
47 **Ohberg L**, Lorentzon R, Alfredson H. Eccentric training in patients with chronic Achilles tendinosis: Normalised tendon structure and decreased thickness at follow up. *Br J Sports Med* 2004;**38**:8–11.
48 **Purdam CR**, Johnsson P, Alfredson H, *et al*. A pilot study of the eccentric decline squat in the management of painful chronic patellar tendinopathy. *Br J Sports Med* 2004;**38**:395–7.
49 **Roe C**, Odegaard TT, Hilde F, *et al*. Effect of supplement of essential fatty acids on lateral epicondylitis: A randomised trial. (In Norwegian.) *Tidsskr Nor Laegeforen* 2005;**125**:2615–8.
50 **Roos EM**, Engstrom M, Lagerquist A, *et al*. Clinical improvement after 6 weeks of eccentric exercise in patients with mid-portion Achilles tendinopathy – a randomized trial with 1-year follow-up. *Scand J Med Sci Sports* 2004;**1**:286–95.
51 **Shalabi A**, Kristoffersen-Wiberg M, Aspelin P, *et al*. Immediate Achilles tendon response after strength training evaluated by MRI. *Med Sci Sports Exerc* 2004;**36**:1841–6.
52 **Silbernagel KG**, Thomee R, Thomee P, *et al*. Eccentric overload training for patients with chronic Achilles tendon pain – a randomised controlled study with reliability testing of the evaluation methods. *Scand J Med Sci Sports* 2001;**11**:197–206.
53 **Stasinopoulos D**, Stasinopoulos I. Comparison of effects of exercise programme, pulsed ultrasound and transverse friction in the treatment of chronic patellar tendinopathy. *Clin Rehabil* 2004;**18**:347–52.
54 **Svernlov B**, Adolfsson L. Non-operative treatment regime including eccentric training for lateral humeral epicondylalgia. *Scand J Med Sci Sports* 2001;**11**:328–34.
55 **Visnes H**, Hoksrud A, Cook J, *et al*. No effect of eccentric training on jumper's knee in volleyball players during the competitive season: A randomized clinical trial. *Clin J Sport Med* 2005;**15**:225–32.
56 **Young MA**, Cook JL, Purdam CR, *et al*. Eccentric decline squat protocol offers superior results at 12 months compared with traditional eccentric protocol for patellar tendinopathy in volleyball players. *Br J Sports Med* 2005;**39**:102–5.
57 **Cannell LJ**, Taunton JE, Clement DB, *et al*. A randomised clinical trial of the efficacy of drop squats or leg extension/leg curl exercises to treat clinically diagnosed jumper's knee in athletes: pilot study. *Br J Sports Med* 2001;**35**:60–4.
58 **Jensen K**, Di Fabio RP. Evaluation of eccentric exercise in treatment of patellar tendinitis. *Phys Ther* 1989;**69**:211–6.
59 **Niesen-Vertommen SL**, Taunton JE, Clement DB, *et al*. The effect of eccentric versus concentric exercise in the management of Achilles tendonitis. *Clin J Sport Med* 1992;**2**:109–13.
60 **Pienimaki T**, Karinen P, Kemila T, *et al*. Long-term follow-up of conservatively treated chronic tennis elbow patients. A prospective and retrospective analysis. *Scand J Rehabil Med* 1998;**30**:159–66.
61 **Pienimaki TT**, Tarvainen TK, Siira PT, *et al*. Progressive strengthening and stretching exercises and ultrasound for chronic lateral epicondylitis. *Physiotherapy* 1996;**82**:522–30.
62 **Smidt N**, van der Windt DA, Assendelft WJ, *et al*. Corticosteroid injections, physiotherapy, or a wait-and-see policy for lateral epicondylitis: a randomised controlled trial. *Lancet* 2002;**359**:657–62.
63 **Selvanetti A**, Barrucci A, Antonaci A, *et al*. The role of eccentric exercise in the functional re-education of lateral epicondylitis: A randomised controlled clinical trial. (In Italian.) *Med Sport (Roma)*, 2003;**56**:103–13.
64 **Shalabi A**, Kristoffersen-Wilberg M, Svensson L, *et al*. Eccentric training of the gastrocnemius-soleus complex in chronic Achilles tendinopathy results in decreased tendon volume and intratendinous signal as evaluated by MRI. *Am J Sports Med* 2004;**32**:1286–96.
65 **Moher D**, Cook DJ, Eastwood S, *et al*. Improving the quality of reports of meta-analyses of randomised controlled trials: the QUOROM statement. Quality of Reporting of Meta-analyses. *Lancet* 1999;**354**:1896–900.
66 **Visentini PJ**, Khan KM, Cook JL, *et al*. The VISA score: an index of severity of symptoms in patients with jumper's knee (patellar tendinosis). Victorian Institute of Sport Tendon Study Group. *J Sci Med Sport* 1998;**1**:22–8.
67 **Robinson JM**, Cook JL, Purdam C, *et al*. The VISA-A questionnaire: a valid and reliable index of the clinical severity of Achilles tendinopathy. *Br J Sports Med* 2001;**35**:335–41.
68 **Hudak PL**, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand). TheUpper Extremity Collaborative Group (UECG). *Am J Ind Med* 1996;**29**:602–8.
69 **Roos EM**. A User's Guide to: Foot and Ankle Outcome Score (FAOS) http://www.koos.nu/FAOSGuide2003.pdf (accessed 20 April 2006).
70 **Ko JY**, Chen HS, Chen LM. Treatment of lateral epicondylitis of the elbow with shock waves. *Clin Orthop Relat Res* 2001;**387**:60–7.
71 **Jonnson P**, Wahlstrom P, Ohberg L, *et al*. Eccentric training in chronic painful impingement syndrome of the shoulder: results of a pilot study. *Knee Surg Sports Traumatol Arthrosc* 2006;**14**:76–81.
72 **Bisset L**, Paungmali A, Vicenzino B, *et al*. A systematic review and meta-analysis of clinical trials on physical interventions for lateral epicondylalgia. *Br J Sports Med* 2005;**39**:411–22.
73 **Liddle SD**, Baxter GD, Gracey JH. Exercise and chronic low back pain: what works? *Pain* 2004;**107**:176–90.
74 **Schulz KF**, Chalmers I, Hayes RJ, *et al*. Empirical evidence of bias. Dimensions of methodological quality associated with estimates of treatment effects in controlled trials. *JAMA* 1995;**273**:408–12.
75 **Moher D**, Pham B, Jones A, *et al*. Does quality of reports of randomised trials affect estimates of intervention efficacy reported in meta-analyses? *Lancet* 1998;**352**:609–13.
76 **Alfredson H**, Nordstrom P, Pietila T, *et al*. Bone mass in the calcaneus after heavy loaded eccentric calf-muscle training in recreational athletes with chronic achilles tendinosis. *Calcif Tissue Int* 1999;**64**:450–5.
77 **Alfredson H**, Lorentzon R. Intratendinous glutamate levels and eccentric training in chronic Achilles tendinosis: a prospective study using microdialysis technique. *Knee Surg Sports Traumatol Arthrosc* 2003;**11**:196–9.
78 **Sayana MK**, Maffulli N. Eccentric calf muscle training in non-athletic patients with Achilles tendinopathy. *J Sci Med Sport* 2007;**10**:52–8.
79 **Reeves BC**, MacLehose RR, Harvey IM, *et al*. Comparisons of effect sizes derived from randomised and non-randomised studies. In: Black N, Reeves B, Brazier J, *et al*, eds. *Health Services Research Methods: A Guide to Best Practice*. London: BMJ Books, 1998:73–85.

COMMENTARY 1

Treatment of tendinopathy is an important clinical issue, and treatment modalities have been long discussed. Working our way away from surgical intervention, training intervention with eccentric exercise has been a magic phrase based on some very early studies. With this review it is easier to understand where we are regarding the evidence for this treatment.

M Kjær
Bispebjerg Hospital, Sports Medicine Research Unit, Copenhagen, Denmark; m.kjaer@mfi.ku.dk

COMMENTARY 2

Chronic tendinopathy is a challenging condition. Recently, there has been considerable interest in using eccentric training to treat these conditions. Unfortunately, the studies examining the effects of eccentric training have been varied in terms of methodology and protocol, making the evidence difficult to interpret. This review critically examines the available research. Unfortunately, there remains a paucity of high-quality evidence surrounding eccentric training and tendinopathy. The authors are able to make some weak conclusions about the efficacy of eccentric training, but they reasonably conclude that more studies using better randomisation, larger sample sizes and more standardised outcome measures are necessary before stronger conclusions can be made.

M S Koehle
Allan McGavin Sport Medicine Centre, University of British Columbia, Vancouver, Canada; koehle@interchange.ubc.ca

EDITORIAL BOARD MEMBER

John Orchard

John Orchard is a sports physician based in Sydney with a research interest in football injuries, ground conditions and muscle strains among other topics. He has academic appointments at the UNSW (conjoint senior lecturer) and University of Melbourne (senior fellow). John is team physician for the Sydney Roosters in the National Rugby League and also the New South Wales Blues State of Origin team. He is a member of the NSW Sporting Injuries Committee. His full research and career details are available at www.johnorchard.com, and he is involved in producing the website www.injuryupdate.com.au, which is dedicated to providing information on professional football injuries in Australia.

doi: 10.1136/bjsm.2006.032235

Figure 1 John Orchard.