Article

CLINICAL REHABILITATION

Clinical Rehabilitation
2014, Vol 28(1) 3–19

DOI: 10.1177/0269215513491974
cre.sagepub.com
SAGE

Is eccentric exercise an effective treatment for lateral epicondylitis? A systematic review

Frances L Cullinane, Mark G Boocock and Fiona C Trevelyan

Abstract

Objective: To establish the effectiveness of eccentric exercise as a treatment intervention for lateral epicondylitis.

Data sources: ProQuest, Medline via EBSCO, AMED, Scopus, Web of Science, CINAHL.

Review methods: A systematic review was undertaken to identify randomized and controlled clinical trials incorporating eccentric exercise as a treatment for patients diagnosed with lateral epicondylitis. Studies were included if: they incorporated eccentric exercise, either in isolation or as part of a multimodal treatment protocol; they assessed at least one functional or disability outcome measure; and the patients had undergone diagnostic testing. The methodological quality of each study was assessed using the Modified Cochrane Musculoskeletal Injuries Group score sheet.

Results: Twelve studies met the inclusion criteria. Three were deemed 'high' quality, seven were 'medium' quality, and two were 'low' quality. Eight of the studies were randomized trials investigating a total of 334 subjects. Following treatment, all groups inclusive of eccentric exercise reported decreased pain and improved function and grip strength from baseline. Seven studies reported improvements in pain, function, and/or grip strength for therapy treatments inclusive of eccentric exercise when compared with those excluding eccentric exercise. Only one low-quality study investigated the isolated effects of eccentric exercise for treating lateral epicondylitis and found no significant improvements in pain when compared with other treatments.

Conclusion: The majority of consistent findings support the inclusion of eccentric exercise as part of a multimodal therapy programme for improved outcomes in patients with lateral epicondylitis.

Keywords

Exercise programme, eccentric exercise, tennis elbow, lateral epicondylitis, rehabilitation, systematic review

Received: 29 April 2013; accepted: 30 April 2013

AUT University, Auckland, New Zealand

Corresponding author:
Mark G Boocock, AUT University, 90 Akoranga Drive, North Shore, Auckland 1142, New Zealand.
Email: mark.boocock@aut.ac.nz

Introduction

Lateral epicondylitis is a disabling musculoskeletal condition leading to pain and/or tenderness around the elbow.[1] It is estimated to affect up to 3% of the population and have significant personal, psychosocial, and economic consequences.[1,2] Many treatment options have been proposed for the rehabilitation of patients with lateral epicondylitis, the effectiveness of which are largely unknown. These include exercise, massage, manipulation, taping, acupuncture, orthotic devices, ultrasound, activity modification, and rest.[3–6] Identifying an effective treatment programme for patients with lateral epicondylitis would have significant benefits for patient recovery and for the delivery of an improved service by healthcare providers.[7]

Exercise programmes incorporating eccentric muscle activity are becoming increasingly popular as they are considered to provide a more effective treatment than other forms of exercise therapy.[8,9] At present, the role of eccentric exercise in the treatment of lateral epicondylitis is not entirely clear. A systematic review by Malliaras et al.[10] showed promising results in support of eccentric exercise as a treatment for lateral epicondylitis, however the review sourced only one electronic database, was restricted to four articles and failed to consider the methodological quality of each study.

The aim of this systematic review was to investigate the effectiveness of eccentric exercise as a physical therapy intervention for patients with lateral epicondylitis.

Methods

Six electronic databases were searched (ProQuest, Medline via EBSCO, AMED, Scopus, Web of Science, and CINAHL). Existing systematic reviews and major publications on lateral epicondylitis were sourced to identify appropriate search terms. The search strategy combined terms appropriate to: the condition (lateral epicondylitis, lateral epicondyle, lateral epicondylalgia, tennis elbow, elbow tendinopathy), the therapy goal (intervention, management, treatment, rehabilitation), and the intervention (physiotherapy, physical therapy, exercise, strengthening, eccentric and resistance). The search protocol used on the Scopus database is provided at Appendix A (available online). The search was completed on 26 February 2013 (Figure 1).

An initial review was undertaken of all titles and abstracts. All articles considered appropriate were read in full to establish if they met the eligibility criteria. Where it was unclear from the abstract about the suitability of the study, the full article was retrieved and read. Only randomized control studies or controlled clinical trials were included in the review, and studies had to include:

- at least one treatment programme involving an eccentric exercise therapy, either exclusively or in conjunction with other treatments;
- patients who had undergone a diagnostic test for lateral epicondylitis, or had been diagnosed by a General Practitioner; and
- at least one functional or disability outcome measure.

Studies were excluded if patients had received corticosteroid injections prior to the intervention or as part of the treatment or comparative therapy. Only articles published in English were included in the review.

The methodological quality of those studies meeting the inclusion/exclusion criteria was assessed using the Modified Cochrane Musculoskeletal Injuries Group score sheet (Appendix B, available online).[11] The Modified Cochrane Musculoskeletal Injuries Group score sheet comprises 13 questions, scored between zero and two (maximum score of 26), which assesses aspects of study design and outcome measures. At least two independent reviewers assessed and scored each article. Where there was disagreement over the quality rating of a study, discussions took place between the two reviewers to reach a consensus. Each study was rated as either 'low quality' (with a Cochrane Musculoskeletal Injuries Group score of less than or equal to 12), 'medium quality' (a score greater than 12, but less than 18), or 'high quality' (a score equal to or greater than 18). The cut-off points for each level of grading were based on the overall distribution of scores.

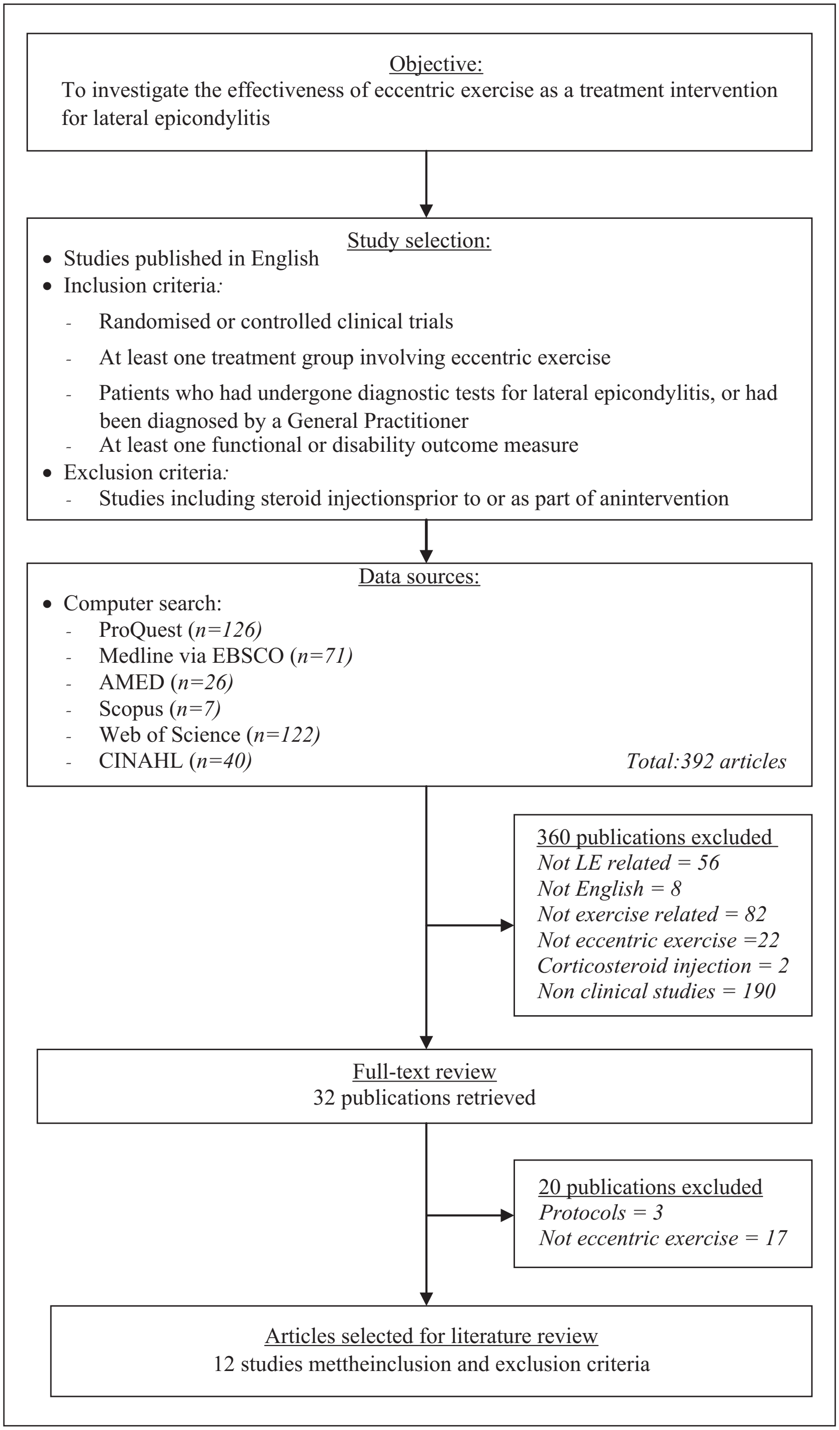

Figure 1. A flow-chart of the methodology used in this review.

Results

A flowchart of the selection process used to identify studies is shown in Figure 1. Of the 392 articles, 32 underwent a full-text review, of which 12 met the inclusion criteria. One article[12] identified two studies (a pilot study and a clinical study) within the one article, but only the pilot study met the criteria for this review. The important characteristics of each study (e.g. the number of participants, and the treatment and comparison groups) were extracted from each article and tabulated (Tables 1 and 2). Details of the eccentric exercise programmes (e.g. exercise, frequency, duration) are shown in Tables 3 and 4.

The 12 studies involved 616 participants consisting of 336 females and 280 males. A total of 326 participants underwent eccentric exercise as part of their rehabilitation. None of the 12 studies provided rationale for the exercise parameters used in their treatment programmes. All 12 studies used a visual analogue scale as an outcome measure for pain, and eight studies[12,14–17,20,21,23] measured grip strength (Tables 1 and 2). Seven studies[14–20] used a variety of questionnaires to measure function and/or disability (Tables 1 and 2).

Of the 12 studies, two[13,22] were considered to be 'low' quality, seven[12,14–18,20] were 'medium' quality, and three[19,21,23] were 'high' quality (Table 5, available online). Eight studies[12–18,23] were randomized trials and four studies[19–22] were controlled clinical trials. According to the intervention and comparison treatment, studies were grouped into four categories: (1) isolated eccentric exercise programme versus different therapies, (2) eccentric exercise and adjunct therapies versus the same adjunct therapies, (3) eccentric exercise and adjunct therapies versus different therapies, and (4) identical eccentric exercise programmes with different study parameters.

Only one low-quality study[13] (Cochrane Musculoskeletal Injuries Group Score of 11 out of 26) investigated the effects of an isolated eccentric exercise programme on pain levels. The eccentric exercise group and control group both reported a significant reduction in pain from baseline at the four-week follow-up ($p < 0.01$). However, no significant difference existed between the groups at week four ($p > 0.05$). This suggests that an isolated eccentric exercise programme offered no greater benefits for improving pain in patients with lateral epicondylitis when compared with a programme of iontophoresis, ultrasound, and stretches.

Four studies exposed participants to the same therapies, while adding an eccentric exercise programme to one group (Tables 1 and 2). All four studies reported improvements in outcome measure from baseline in both groups. Of these, two high-quality studies (Cochrane Musculoskeletal Injuries Group Score of 18 out of 16[19] and 20 out of 26[23]) and one medium-quality study (Cochrane Musculoskeletal Injuries Group Score of 15 out of 26[15]) found that the addition of eccentric exercise led to greater reduction in pain, disability, and/or improvement in grip strength compared with the same adjunct therapies exclusive of eccentric exercise. However, one medium-quality study (Cochrane Musculoskeletal Injuries Group Score of 16 out of 26[14]) found no difference in three functional-related measures, grip strength, and pain when eccentric exercise was added to the adjunct treatment (i.e. stretches).

Five medium-quality studies (Cochrane Musculoskeletal Injuries Group Score of 16 out of 26,[16] 14 out of 26,[12] 14 out of 26,[17] 16 out of 26,[20] and 18 out of 26[18]) found that eccentric exercise when combined with adjunctive therapies resulted in significant improvements in pain, function, and grip strength from baseline (Table 1). Four[12,17,18,20] of the five studies showed improved benefits of the multimodal treatment programme inclusive of eccentric exercise when compared with different therapy treatments. However, one study[16] found that the eccentric exercise and adjunct therapies were less effective than a Cyriax therapy programme exclusive of eccentric exercise.

One high-quality study (Cochrane Musculoskeletal Injuries Group Score of 20 out of 26[21]) and one low-quality study (Cochrane Musculoskeletal Injuries Group Score of 12 out of 26[22]) exposed participants to the same eccentric exercise programmes, but altered another aspect of the treatment programme (Table 1). The low-quality study[22] showed the addition of ice to the eccentric exercise programme offered no additional improvements in pain, and the

Table 1. The main characteristics of the randomized trials included in the review.

Study	Subject number (male, female)	Group inclusive of eccentric exercise (T) and group exclusive of eccentric exercise (C)	LE diagnosis	Outcome measures and (follow-up period in weeks)	Findings of T group	Findings of C group	CMIG score (quality rating)
Isolated eccentric exercise programme versus different therapies							
Wen et al. (2011)[13]	*N*=28 (15, 13)	T (*n*=14): eccentric exercises C (*n*=14): iontophoresis, ultrasound and stretches	LEP tenderness, resisted wrist extension pain	VAS pain (0, 4, 8, 12, 16)	***Pain*** Baseline=63/100 (SD 19) Week 4=27/100	***Pain*** Baseline=61/100 (SD 19) Week 4=33/100	11/26 (Low)
Eccentric exercise and adjunct therapies versus the same adjunct therapies							
Martinez-Silvestrini et al. (2005)[14]	*N*=94 (50, 44)	T (*n*=27): eccentric exercises and stretching C_1 (*n*=26): concentric exercises and stretching C_2 (*n*=28): stretching alone	LEP pain or tenderness, pain on 2+ of: resisted wrist extension, resisted middle finger extension, chair lift test	Pain-free grip strength, PRFE, DASH, SF-36 VAS pain (0, 6)	***Pain*** Baseline=46/100 (SD 20) Week 6=24/100 (SD 24) *Effect size=1.0* F***unction – DASH*** Baseline=25/100 (SD 13) Week 6=16/100 (SD 15) *Effect size=0.6* ***Function – PRFEQ*** Baseline=3.3/10 (SD 1.5) Week 6=1.2 (SD 1.7) Effect size=1.3 Grip-strength Baseline=22 kg (SD 12) Week 6=26 kg (SD 14) *Effect size=0.03*	***Pain*** C_1 baseline=49 (SD 21) C_1 week 6=35 (SD 25) *Effect size=0.6* C_2 baseline=48 (SD 21) C_2 week 6=25 (SD 24) Effect size=1.0 ***Function – DASH*** C_1 baseline=26 (SD 13) C_1 week 6=17 (SD 14) *Effect size=1.0* C_2 baseline=27 (SD 14) C_2 week 6=15 (SD 14) *Effect size=0.9* F***unction – PRFEQ*** C_1 baseline=3.8 (SD 1.7) C_1 week 6=1.3 (SD 1.8) *Effect size=1.4* C_2 baseline=3.7 (SD 1.7)	16/26 (Med)

(*Continued*)

Table 1. (Continued)

Study	Subject number (male, female)	Group inclusive of eccentric exercise (T) and group exclusive of eccentric exercise (C)	LE diagnosis	Outcome measures and (follow-up period in weeks)	Findings of T group	Findings of C group	CMIG score (quality rating)
						C_2 week 6=1.5 (SD 1.6) *Effect size=1.3* ***Grip-strength*** C_1 baseline=17 (SD 9.7) C_1 week 6=25 (SD 12) *Effect size=0.7* C_2 baseline=23 (SD 15) C_2 week 6=30 (SD 17) *Effect size=0.4*	
Tyler et al. (2010)[15]	*N*=21 (10, 11)	T (*n*=11): eccentric wrist extensor strengthening and wrist extensor stretching, US, massage, heat and ice C (*n*=10): isotonic wrist extensor strengthening stretching, US, massage, heat and ice	LEP pain, resisted wrist extension and resisted middle-finger extension pain	DASH, VAS pain, Tenderness at LEP, strength testing (0, 7)	***Pain*** Baseline=6.7/10 (SD 2.8) Week 7=1.3/10 (SD 2.7) *Effect size=1.9* ***Function*** Baseline=38/100 (SD 29) Week 7=9/100 (SD 21) *Effect size=1.1* ***Grip-strength deficit*** Baseline=24% (SD 15) Week 7=5% (SD 20) *Effect size=1.1*	***Pain*** Baseline=6.3 (SD 2.8) Week 7=4.9 (SD 2.7) *Effect size=0.5* ***Function*** Baseline=38 (SD 30) Week 7=33 (SD 22) *Effect size=0.2* ***Grip-strength deficit*** Baseline=20 (SD 16) Week 7=17 (SD 18) *Effect size=0.2*	15/26 (Med)

Table 1. (Continued)

Study	Subject number (male, female)	Group inclusive of eccentric exercise (T) and group exclusive of eccentric exercise (C)	LE diagnosis	Outcome measures and (follow-up period in weeks)	Findings of T group	Findings of C group	CMIG score (quality rating)
Söderberg et al. (2012)[23]	*N*=42 (18, 24)	T (*n*=20): forearm band, wrist-extensor warm-up, eccentric exercises C (*n*=22): forearm band, wrist-extensor warm-up exercises	History of pain around LEP for at least 1 month, pain on palpation of LEP, and two of: middle-finger test, resisted extension of the wrist, vigorimeter test	Pain-free grip-strength, pain-free isometric extensor strength, average VAS pain in the previous week (0, 3, 6)	***Proportion of cases*** Baseline=100% Week 6=44% ***Pain*** Baseline=24/100 Week 6=6/100 ***Pain-free grip-strength*** Baseline=46 kPa Week 6=82 kPa ***Pain-free isometric extensor strength*** Baseline=5.8 kg Week 6=10 kg	***Proportion of cases*** Baseline=100% Week 6=79% ***Pain*** Baseline=32/100 Week 6=6/10 ***Pain-free grip-strength*** Baseline=50 kPa Week 6=57 kPa ***Pain-free isometric extensor strength*** Baseline=6.0 kg Week 6=6.2 kg	20/26 (High)
Eccentric exercise and adjunct therapies versus different therapies							
Nagrale et al. (2009)[16]	*N*=60 (18, 42)	T (*n*=30): eccentric exercises and phonophoresis C (*n*=30): Cyriax physiotherapy	LEP pain, resisted wrist extension pain, pain with gripping, painful passive wrist flexion	VAS pain, Tennis Elbow Function Scale, Pain-free grip strength (0, 2, 4, 8)	***Pain*** Baseline=8.1/10 Week 4=4.3/10 Week 8=5.6/10 ***Function*** Baseline=33.1/40 Week 4=16.3/40 Week 8=21.2/40 ***Grip-strength*** Baseline=7.8 kg Week 4=15.2 kg Week 8=12.7 kg	***Pain*** Baseline=8.2/10 Week 4=2.6/10 Week 8=3.2/10 ***Function*** Baseline=33.7/40 Week 4=9.1/40 Week 8=12.7 ***Grip-strength*** Baseline=7.4 kg Week 4=20.4 kg Week 8=18.9 kg	16/26 (Med)

(Continued)

Table 1. (Continued)

Study	Subject number (male, female)	Group inclusive of eccentric exercise (T) and group exclusive of eccentric exercise (C)	LE diagnosis	Outcome measures and (follow-up period in weeks)	Findings of T group	Findings of C group	CMIG score (quality rating)
Svernlov & Adolfsson (2001)[12]	*N*=30 (19, 11)	T (*n*=15): eccentric programme and stretches C (*n*=15): contract-relax-stretch programme described by Solveborn (1997)	LEP pain, resisted wrist extension and resisted middle finger extension pain	VAS on rest, palpation, resisted wrist extension, middle finger test, grip-strength (0, 12, 28, 52)	***Grip-strength*** Baseline=54.8 kg (range 33.9–83.2) Week 28=67.9 kg (range 43.7–89.4) Week 52=66.0 kg (range 43.0–92.3)	***Grip-strength*** Baseline=45.3 kg (range 28.6–71.8) Week 28=54.2 kg (range 36.9–81.5) Week 52=54.6 kg (range 35.3–89.9)	14/26 (Med)
Pienimaki et al. (1996)[17]	*N*=39 (14, 25)	T (*n*=20): eccentric, fist-clenching, resisted wrist, wrist rotation and occupational training exercises and stretches C (*n*=19): US over 5 cm^2 of common extensor origin	Mill's test, resisted wrist and/or middle finger extension pain, local tenderness over LEP	VAS on pain at rest and under strain, ability to work, ability to lift objects, restrictions on hobbies, sleep disturbance, grip-strength, isokinetic muscle performance (0, 6–8)	***Pain – at rest*** Baseline=3.7 Week 8=1.8 ***Pain – under strain*** Baseline=7.3 Week 8=3.8 ***Function*** Baseline=4.6 Week 8=3.1 ***Grip-strength*** Baseline=361 (SD 159) Week 8=404 (SD 164)	***Pain – at rest*** Baseline=3.7 Week 8=3.9 ***Pain – under strain*** Baseline=7.8 Week 8=6.4 ***Function*** Baseline=6.1 Week 8=5.1 ***Grip-strength*** Baseline=301 (SD 114) Week 8=303 (SD 122)	14/26 (Med)
Viswas et al. (2012)[18]	*N*=20 (10, 10)	T (*n*=10): Supervised static stretches and eccentric strengthening C (*n*=10): Cyriax physiotherapy, single Mill's manipulation	Pain with gripping, resisted wrist extension, passive wrist flexion with extended elbow, LEP tenderness on palpation	VAS pain, TEFS (0, 4)	***Pain*** Baseline=7.9/10 Week 4=4.3/10 ***Function*** Baseline=33.2 Week 4=23.9	***Pain*** Baseline=7.9/10 Week 4=5.6/10 ***Function*** Baseline=33.2 Week 4=25.8	15/26 (Med)

T: treatment group inclusive of eccentric exercise; C: comparison group exclusive of eccentric exercise; LE: lateral epicondylitis; CI: confidence interval; CMIG: Cochrane Musculoskeletal Injuries Group score sheet; *N*: number of participants; LEP: lateral epicondyle; VAS: visual analogue scale; SD: standard deviation; C1: first comparison group exclusive of eccentric exercise; C2: second comparison group exclusive of eccentric exercise; Med: medium quality; US: ultrasound; TENS: transcutaneous electrical nerve stimulation; PRFE: patient-related forearm evaluation; DASH: disability of the arm and shoulder questionnaire; SF-36: Standard Form 36 questionnaire; T1: first treatment group inclusive of eccentric exercise; T2: second treatment group inclusive of eccentric exercise; PT: physiotherapist; TEFS: Tennis Elbow Functional Scale.

Table 2. The main characteristics of the controlled clinical trials included in the review.

Study	Subject number (male, female)	Group inclusive of eccentric exercise (T) and group exclusive of eccentric exercise (C)	LE diagnosis	Outcome measures and (follow-up period in weeks)	Findings of T group	Findings of C group	CMIG score (quality rating)
Eccentric exercise and adjunct therapies versus the same adjunct therapies							
Croisier et al. (2007)[19]	*N*=92 (36, 56)	T (*n*=46): eccentric strengthening and ice, analgesic TENS, US, deep friction massage, stretching C (*n*=46): ice, analgesic TENS, US, deep friction massage, stretching	LEP pain, proximal extensor muscle pain, resisted middle finger extension pain, elbow extension pain, US examination	VAS pain, ultrasound, Muscle strength Disability questionnaire (0, 4, 7, 9)	***Pain*** Baseline=6.9/10 (SD 1.5) Week 9=1.2/10 (SD 0.9) *Effect size=4.7* ***Function*** Baseline=8.5/20 (SD 3.8) Week 9=14.4/20 (SD 4.6) *Effect size=1.1*	***Pain*** Baseline=6.7 (SD 1.5) Week 9=4.3 (SD 1.6) *Effect size=1.5* ***Function*** Baseline=7.8 (SD 3.5) Week 9=10.2 (SD 3.8) *Effect size=1.4*	18/26 (High)
Eccentric exercise and adjunct therapies versus different therapies							
Stasinopoulos & Stasinopoulos (2006)[20]	*N*=75 (46, 39)	T (*n*=25): eccentric exercises and static stretching C_1 (*n*=25): Cyriax physiotherapy C_2 (*n*=25): Bioptron light therapy	LEP pain, less pain with resisted supination in flexion than extension, pain on 2+ of: Tomsen test, resisted middle finger test, Mill's test, dynamometer test	VAS pain, VAS function, Grip-strength, Drop-outs (0, 4, 8, 16, 28)	***Pain*** Baseline=6.9/10 (range 6.5–7.2) Week 4=2.2/10 (range 1.9–2.4) Week 28=0.9/10 (range 0.6–1.2) ***Function*** Baseline=3.9/10 (range 3.6–4.2) Week 4=7.8/10 (range 7.5–8) Week 28=8.4/10 (range 8.2–8.7) ***Grip-strength*** PainBaseline=11.75 kg (range 10.85–12.15) Week 4=33.43 kg (range 31.0–35.33) Week 28=34.83 kg (range 32.9–36.7)	***Pain*** C_1=Baseline=6.9/10 (range 6.6–7.3) C_1=Week 4=2.8/10 (range 2.5–3.1) C_1=Week 28=1.9/10 (range 1.6–2.3) C_2=Baseline=7/10 (range 6.6–7.3) C_2=Week 4=3.3/10 (range 3–3.6) C_2=Week 28=2.6/10 (range 2.4–2.8) ***Function*** C_1=Baseline=3.9/10 (range 3.4–4.3) C_1=Week 4=7.1/10 (range 6.6–7.5) C_1=Week 28=7.8/10 (range 7.4–8.1) C_2=Baseline=3.9/10 (range 3.6–4.2) C_2=Week 4=6.7/10 (range 6.4–7)	16/26 (Med)

(Continued)

Table 2. (Continued)

Study	Subject number (male, female)	Group inclusive of eccentric exercise (T) and group exclusive of eccentric exercise (C)	LE diagnosis	Outcome measures and (follow-up period in weeks)	Findings of T group	Findings of C group	CMIG score (quality rating)
						C_2=Week 28=7.3/10 (range 7.1–7.5) ***Grip-strength*** C_1=Baseline =11.6 (range 10.7–12.5) C_1=Week 4 =29.9 (range 27.7–32.5) C_1=Week 28=31.1 (range 28.5–33.6) C_2=Baseline =11.7 (range 11.2–12.2) C_2=Week 4=28.4 (range 27.7–29.5) C_2=Week 28=29.4 (range 28.5–30.3)	
Identical eccentric exercise programmes with different study parameters							
Stasinopoulos et al. (2010)[21]	*N*=70 (33, 37)	T_1 (*n*=35): eccentric exercise programme and static stretches at home, with PT once per week for further instructions T_2 (*n*=35): eccentric exercise programme and static stretches under supervision of PT	LEP pain, less pain with resisted elbow in flexion than extension, pain on 2+ of: Tomsen test, resisted middle finger test, Mill's test, dynamometer test	VAS pain, Pain-free grip strength Drop-out rate (0, 12, 24)	***Pain*** T_1 Baseline=8.75/10 (range 8.30–8.93) T_1 Week 24=3.19 (range 2.87–3.75) T_2 Baseline=8.7/10 (range 8.31–8.87) T_2 Week 24=1.38 (range 1.02–1.85) ***Function*** T_1 Baseline=3.55/10 (range 3.24–4.01) T_1 Week 24=5.67 (range 5.14–6.19) T_2 Baseline=3.65 (range 3.47–4.12) T_2 Week 24=8.58 (range 7.67–8.88)		

Table 2. (Continued)

Study	Subject number (male, female)	Group inclusive of eccentric exercise (T) and group exclusive of eccentric exercise (C)	LE diagnosis	Outcome measures and (follow-up period in weeks)	Findings of T group	Findings of C group	CMIG score (quality rating)
					Grip-strength T_1 Baseline=11.42 kg (range 11.11–11.6) T_1 Week 24=19.8 kg (range 19.7–20.0) T_2 Baseline=11.35 (range 11.09–11.61) T_2 Week 24=27.5 (range 27.3–27.8)		20/26 (High)
Manias & Stasinopoulos (2006)[22]	*N*=40 (13, 27)	T_1 (*n*=20): eccentric exercise programme and static stretches and ice bag T_2 (*n*=20): eccentric exercise programme and static stretches	LEP pain, less pain with resisted elbow in flexion than extension, pain on 2+ of: Tomsen test, resisted middle finger test, Mill's test, dynamometer test	VAS pain, Drop-out rate (0, 4, 16)	***Pain*** T_1 Baseline=8.6/10 (95% for 8.22–8.98) T_1 Week 4=1.7/10 (95% for 0.99–2.41) T_1 Week 16=1.5/10 (range 0.94–2.06) T_2 Baseline= 8.80/10 (95% at 8.35–9.25) T_2 Week 4=1.9/10 (95% for 1.08–2.72) T_2 Week 16=1.60 (range 0.83–2.37)		12/26 (Low)

T: treatment group inclusive of eccentric exercise; C: comparison group exclusive of eccentric exercise; LE: lateral epicondylitis; CI: confidence interval; CMIG: Cochrane Musculoskeletal Injuries Group score sheet; *N*: Number of participants; LEP: lateral epicondyle; VAS: visual analogue scale; SD: standard deviation; C1: first comparison group exclusive of eccentric exercise; C2: second comparison group exclusive of eccentric exercise; Med: medium quality; US: ultrasound; TENS: transcutaneous electrical nerve stimulation; PRFE: Patient-related forearm Evaluation; DASH: disability of the arm and shoulder questionnaire; SF-36: Standard Form 36 questionnaire; T1: First treatment group inclusive of eccentric exercise; T2: second treatment group inclusive of eccentric exercise; PT: physiotherapist; TEFS: Tennis Elbow Functional Scale.

Table 3. The exercise parameters of the eccentric programmes used in the randomised trials.

Study	Performance description of eccentric exercises	Frequency per week	Duration (weeks)	Sets (rest)	Reps	Intensity progression method
Isolated eccentric exercise programme versus different therapies						
Wen et al. (2011)[13]	Wrist and elbow extended, and forearm on table. Opposite hand used to resist wrist flexion for 6–8 s	7	14	3	15	Contralateral hand used to apply more force as pain tolerance improved
Eccentric exercise and adjunct therapies versus the same adjunct therapies						
Martinez-Silvestrini et al. (2005)[14]	Flexed elbow, forearm resting on thigh, hand extending beyond the knee, and resistance (elastic) band around foot. Pulling the pronated wrist into full extension with the opposite wrist, band was released to allow wrist flexion	7	6	3 (2–5 min rest)	10	Resistance of elastic band selected according to ten-rep trial. Resistance increased when 3 sets could be performed easily without notable pain, by shortening band by 1 inch
Tyler et al. (2010)[15]	Performed using a rubber bar twisted by flexing the wrist. Untwisting of the bar was controlled with eccentric wrist extension for 4 s	7	GP opinion	3 (30 s rest)	15	Intensity increased using a thicker rubber bar when participants no longer experienced discomfort during exercise
Söderberg et al. (2012)[23]	Elbow flexed at 70 degrees, patients sit on a chair with affected forearm pronated and resting on a Table with the wrist and hand over the edge holding a bucket of water as a training weight. Non-affected hand was placed over the hand holding the bucket and slowly lifted it to avoid the concentric phase. With the affected hand extended, the patient removes the contralateral hand then lowers the hand into flexion over 2 s	Week 1 = 7 times for first week, then 14 times for remaining weeks	6	2 for Week 1, then 3 for remaining weeks	8–12	'Adjust their resisted weight' to ensure pain-free intervals equal to or below a Borg score of 2
Eccentric exercise and adjunct therapies versus different therapies						
Nagrale et al. (2009)[16]	Extended elbow on table, forearm pronated, wrist extended, and hand beyond edge of table. Wrist flexed for 30 s and returned to start position with opposite hand	3	4	3 (1 min rest)	10	When minor or no pain was experienced during exercise, load was increased with free weight based on patient's 10RM
Svernlov & Adolfsson (2001)[12]	Elbow at 90 degrees, forearm pronated on table, wrist pronated in neutral, dumbbell in hand which extended beyond edge of table. Wrist flexed for 10 s	7	12	3	5	Males started with 1 kg, females with 0.5 kg, and weight increased by 10% each week

Table 3. (Continued)

Study	Performance description of eccentric exercises	Frequency per week	Duration (weeks)	Sets (rest)	Reps	Intensity progression method
Pienimaki et al. (1996)[17]	Wrist flexion resisted against an elastic band	7	6–8	2–3	10	Exercises were performed in 4 stages. At each stage, progression was determined by a physiotherapist
Viswas et al. (2012)[18]	In the seated position, full elbow extension, forearm pronation, maximum wrist extension. Patient lowers wrist into flexion over 30 s, using the contralateral hand to return the wrist to maximum extension	3	4	3 (1 min rest)	10	When performed without minor discomfort or pain, load increased with free weights based on patient's 10RM

Reps: repetitions; RM: maximal number of repetitions performed; Min: minutes.

one high-quality study[21] comparing a regularly supervised physiotherapy group with an unsupervised home programme group found significantly decreased pain and improved function at 24 weeks in the supervised group compared with the unsupervised group. Both studies found improvements in pain and function from baseline in all eccentric exercise programmes.

Discussion

This systematic review found that patients with lateral epicondylitis who underwent an eccentric exercise programme, either in isolation or as an adjunct to other therapies, decreased pain and improved function and grip strength in comparison to their baseline measures. Seven out of the nine studies that involved eccentric exercise as part of a multimodal therapy programme showed improved outcomes for pain, function, and/or grip strength in comparison to other combined treatment programmes. The one study that investigated isolated eccentric exercise found no significant improvements in pain when compared with a multimodal treatment programme. However, this study was considered to be of low quality. Overall, the majority of consistent findings support the inclusion of eccentric exercise as part of multimodal therapy programme for improving outcomes in patients with lateral epicondylitis. Findings from this review are in contrast with the systematic review by Woodley et al.[9] that found limited evidence that eccentric exercise has a positive effect on pain, function, and patient satisfaction/return-to-work when compared with other treatment interventions. However, their findings were based on three randomized controlled trials, one of which was deemed to be of low quality.

A systematic review by Raman et al.[8] found 'moderate research evidence' to support isotonic eccentric exercise for improving pain, strength, and function over time. However, findings appeared inconclusive as to the additional benefits of eccentric exercise when added to an existing multimodal treatment programme and compared with other forms of treatment.

Table 4. The exercise parameters of the eccentric programmes used in the controlled clinical trials.

Study	Performance description of eccentric exercises	Frequency per week	Duration (weeks)	Sets (rest)	Reps	Intensity progression method
Eccentric exercise and adjunct therapies versus the same adjunct therapies						
Croisier et al. (2007)[19]	Forearm on horizontal plane, elbow flexed at 60 degrees. Wrist joint aligned to rotational axis of the Cybex Norm dynamometer with forearm pronated. After eccentric contraction, subjects passively returned to the start position	3	9	2	10	Initially set at 30% of 1RM, and velocity and intensity progressively increased when no pain was reported
Eccentric exercise and adjunct therapies versus the same adjunct therapies						
Stasinopoulos & Stasinopoulos (2006)[20]	Extended elbow on bed, forearm pronated and wrist extended beyond edge of bed. Patients flexed wrist for 30 s, and used opposite hand to return to start position	3	4	3 (1 min rest)	10	Free weights added to hand when mild or no pain was experienced during exercise
Identical eccentric exercise programmes with different study parameters						
Manias & Stasinopoulos (2006)[22]	Extended elbow on bed, forearm pronated, wrist extended, and hand extended beyond edge of bed. Wrist flexed for 30 s and returned to start position with opposite hand	5	4	3 (1 min rest)	10	Individualised exercise programme progressed with free weights when no pain experienced during exercise
Stasinopoulos et al. (2010)[21]	Extended elbow on bed, forearm pronated, wrist in full extension, and hand extended beyond edge of bed. Wrist was slowly flexed over 30 s, with opposite hand used to return it to start position	5	12	3 (1 min rest)	12	Individualised exercise programme progressed with free weights when no pain experienced during exercise

Reps: repetitions; RM: maximal number of repetitions performed; Min: minutes.

As in Raman et al.'s[8] review, we chose to exclude those studies that incorporated steroid injections immediately prior to, or as part of, the treatment programme. Steroid injections have been found to have significant short-term effects on pain, function, and grip strength when compared with other physiotherapy treatments.[17,24]

This review is not without its limitations. Of the 12 studies included in the review, only three[19,21,23] were of high quality and only eight[12–18,23] involved randomized controlled trials. The most common methodological weakness was the lack of blinding of participants and treatment providers, with all studies scoring zero for question F and 11 studies scoring 0 for question E on the quality scoring sheet (Table 5, available online). The blinding of participants and therapists to the exercise therapy intervention is problematic and remains a challenge in studies of this nature.

Given that 11 of the studies incorporated eccentric exercise programmes alongside other therapy treatments, it is difficult to infer whether the effects observed are solely owing to the eccentric exercise, or stem from the combined effects of the treatment protocols. However, multimodal treatment protocols are reflective of real world practice.[25]

As none of the 12 studies had control groups who did not participate in any form of treatment, it is not known what affect the natural healing process had on recovery. There is evidence to suggest that some patients with lateral epicondylitis do recover within 12 months without treatment.[25] However, given the pain and loss of function that this condition causes, it would be difficult to find individuals with lateral epicondylitis who had not sought some form of treatment.

The wide variation of diagnostic criteria used across the 12 studies reflects the lack of consensus regarding lateral epicondylitis classification.[6] This is of concern, as conditions such as radial nerve entrapment, radius fractures, or neck dysfunctions have a similar clinical presentation to lateral epicondylitis, such as tenderness in close proximity to the lateral epicondyle, and pain in the upper forearm muscles.[26] This highlights the need for a consensus on the diagnostic criteria for lateral epicondylitis and a set of agreed clinical assessment criteria based on well-defined methodological approaches (e.g. consensus based on an expert opinion or statistical modelling), similar to those proposed by Boocock et al.[27]

The failure to accurately report exercise protocols and the substantial variation in exercise parameters made it difficult to assess the effectiveness of each study's ability to isolate an eccentric exercise component and provide a progressive muscle stimulus (Tables 3 and 4). For example, Martinez-Silvestrini et al.[14] describes in detail the use of the contralateral hand to lengthen the resistance band at the end of each eccentric exercise repetition in order to exclude a concentric component of the exercise, whereas Pienimaki et al.[17] only offered one pictorial explanation of the eccentric component and failed to mention aspects of the concentric element of the exercise. In the study by Wen et al.,[13] the contralateral hand was the only procedure used to provide resistance during the exercise. This method is likely to be highly variable and unlikely to provoke a progressive increase in resistance over the duration of the therapy treatment. Progressively increasing the intensity of exercise is considered an important component of an exercise programme to promote the necessary stimulus required for tendon healing.[28]

A major concern across the studies was the lack of reporting of compliance and adherence to the exercise programmes, with only four studies[20,21,22,23] documenting exercise adherence. Evidence from the literature[29] suggests that compliance and adherence are important mediators impacting the effectiveness of an exercise programme, along with psychosocial factors, such as low-efficacy and poor social support. Also, it cannot be assumed that improvements were sustained as only three studies followed participants beyond 24 weeks.[12,20,21] This is disappointing, given the high recurrence rate of lateral epicondylitis.[25]

Pain, grip strength, and functional and disability measures were the primary outcome measures reported by studies. However, measurement methods varied widely and there was often insufficient data from which to estimate effect sizes arising from the treatment protocols. Few studies reported on sample size or the statistical power of their study.

The findings of this review are important to clinicians and other healthcare providers given the direct and indirect costs associated with the rehabilitation of patients with lateral epicondylitis.[1,2] Exercise programmes prescribed by therapists and which can be performed at home[30] are inexpensive and have limited ongoing costs attached to the treatment. As the study by Stasinopoulos et al.[21] reported, supervision is important to ensure ongoing adherence and the effective implementation (i.e. progressions, frequency, and performance) of a physical therapy treatment programme.

This review found no adverse effects arising from the prescription of eccentric exercise as a treatment for lateral epicondylitis. The absence of adverse effects, coupled with evidence of improved pain and function recovery in comparison to other treatment therapies, lends support to the inclusion of eccentric exercise within a multimodal treatment programme for the rehabilitation of patients with lateral epicondylitis. The standardisation of lateral epicondylitis diagnostic testing and clearly defined eccentric exercise parameters should be a priority for future research. Studies should also consider the long-term effectiveness of these exercise programmes.

Clinical messages

- Eccentric exercise, used in isolation or as an adjunctive therapy, decreases pain and improves function in lateral epicondylitis patients when compared with baseline.
- When compared with other treatment therapies, evidence supports the use of multimodal treatment programmes inclusive of eccentric exercise for improving pain and function in lateral epicondylitis patients.

Conflict of interest

The authors are responsible for the content and writing of this article. The authors declare that there is no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

References

1. Helliwell P, Bennett R, Littlejohn G, et al. Towards epidemiological criteria for soft-tissue disorders of the arm. *Occup Med (Lond)* 2003; 53: 313–319.
2. Alizadehkhaiyat O, Fisher A, Kemp G, et al. Pain, functional disability, and psychologic status in tennis elbow. *Clin J Pain* 2007; 23: 482–489.
3. Barr S, Cerisola F and Blanchard V. Effectiveness of corticosteroid injections compared with physiotherapeutic interventions for lateral epicondylitis: a systematic review. *Physiotherapy* 2009; 95: 251–265.
4. Bisset L, Beller E, Jull G, et al. Mobilisation with movement and exercise, corticosteroid injection, or wait and see for tennis elbow: randomised trial. *BMJ* 2006; 333: 939–943.
5. Kohia M, Brackle J, Byrd K, et al. Effectiveness of physical therapy treatments on lateral epicondylitis. *J Sport Rehabil* 2008; 17: 119–136.
6. Trudel D, Duley J, Zastrow I, et al. Rehabilitation for patients with lateral epicondylitis: a systematic review. *J Hand Ther* 2004; 17: 243–266.
7. Maffulli N and Longo U. How do eccentric exercises work in tendinopathy? *Rheumatology (Oxford)* 2008; 47: 1444–1445.
8. Raman J, Macdermid JC and Grewal R. Effectiveness of different methods of resistance exercises in lateral epicondylosis-a systematic review. *J Hand Ther* 2012; 25(1): 5.
9. Woodley B, Newsham-West R and Baxter G. Chronic tendinopathy: effectiveness of eccentric exercise. *Br J Sports Med* 2007; 41: 188–198.
10. Malliaras P, Maffulli N and Garau G. Eccentric training programmes in the management of lateral elbow tendinopathy. *Disabil Rehabil* 2008; 30: 1590–1596.
11. Thompson L, Handoll H, Cunningham A, et al. Physiotherapist-led programmes and interventions for rehabilitation of anterior cruciate ligament, medial collateral ligament and meniscal injuries of the knee in adults (Cochrane Review). *The Cochrane Library* 2004.
12. Svernlov B and Adolfsson L. Non-operative treatment regime including eccentric training for lateral humeral epicondylalgia. *Scand J Med Sci Sports* 2001; 11: 328–334.
13. Wen D, Schultz B, Schaal B, et al. Eccentric strengthening for chronic lateral epicondylosis: a prospective randomized study. *Sports Health* 2011; 3: 500–503.
14. Martinez-Silvestrini J, Newcomer K, Gay R, 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: 411–419.

15. Tyler T, Thomas G, Nicholas S, et al. Addition of isolated wrist extensor eccentric exercise to standard treatment for chronic lateral epicondylosis: a prospective randomized trial. *J Shoulder Elbow Surg* 2010; 19: 917–922.
16. Nagrale A, Herd C, Ganvir S, et al. Cyriax physiotherapy versus phonophoresis with supervised exercise in subjects with lateral epicondylalgia: a randomized clinical trial. *J Man Manip Ther* 2009; 17: 171–178.
17. Pienimaki T, Tarvainen T and Siira P. Progressive strengthening and stretching exercises and ultrasound for chronic lateral epicondylitis. *Physiotherapy* 1996; 82: 522–530.
18. Viswas R, Ramachandran R and Korde Anantkumar P. Comparison of effectiveness of supervised exercise program and Cyriax physiotherapy in patients with tennis elbow (lateral epicondylitis): a randomized clinical trial. *Scientific World J* 2012; 2012: 939645.
19. Croisier J-L, Foidart-Dessalle M, Tinant F, et al. An isokinetic eccentric programme for the management of chronic lateral epicondylar tendinopathy. *Br J Sports Med* 2007; 41(4): 269–275.
20. Stasinopoulos D and Stasinopoulos I. Comparison of effects of Cyriax physiotherapy, a supervised exercise programme and polarized polychromatic non-coherent light (Bioptron light) for the treatment of lateral epicondylitis. *Clin Rehabil* 2006; 20: 12–23.
21. Stasinopoulos D, Stasinopoulos I, Pantelis M, et al. Comparison of effects of a home exercise programme and a supervised exercise programme for the management of lateral elbow teninopathy. *Br J Sports Med* 2010; 44: 579–583.
22. Manias P and Stasinopoulos D. A controlled clinical pilot trial to study the effectiveness of ice as a supplement to the exercise programme for the management of lateral elbow tendinopathy. *Br J Sports Med* 2006; 40: 81–85.
23. Söderberg J, Grooten WJ and Äng BO. Effects of eccentric training on hand strength in subjects with lateral epicondylalgia: a randomized-controlled trial. *Scand J Med Sci Sports* 2012; 22(6): 797–803.
24. Luginbuhl R, Bruuner F and Schneeberger A. No effect of forearm band and extensor strengthening exercises for the treatment of tennis elbow: a prospective randomised study. *Chir Organi Mov* 2006; 91: 35–40.
25. Faro F and Wolf J. Lateral epicondylitis: review and current concepts. *J Hand Surg Am* 2007; 32: 1271–1279.
26. Miller T, Shapiro M, Schultz E, et al. Comparison of sonography and MRI for diagnosing epicondylitis. *J Clin Ultrasound* 2002; 30: 193–202.
27. Boocock M, Collier J, McNair P, et al. A framework for the classification and diagnosis of work-related upper extremity conditions: systematic review. *Semin Arthritis Rheum* 2009; 38: 296–311.
28. Nimgade A, Sullivan M and Goldman R. Physiotherapy, steroid injections, or rest for lateral epicondylosis? What the evidence suggests. *Pain Pract* 2005; 5: 203–215.
29. Jack K, McLean SM, Moffett JK, et al. Barriers to treatment adherence in physiotherapy outpatient clinics: a systematic review. *Man Ther* 2010; 15(3): 220–228.
30. MacDermid J, Wojkowski S, Kargus C, et al. Hand therapist management of the lateral epicondylosis: a survey of expert opinion and practice patterns. *J Hand Ther* 2010; 23: 18–29.