# Therapeutic exercise for rotator cuff tendinopathy: a systematic review of contextual factors and prescription parameters

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**Exercise is widely regarded as an effective intervention for symptomatic rotator cuff tendinopathy but the prescription is diverse and the important components of such programmes are not well understood. The objective of this study was to systematically review the contextual factors and prescription parameters of published exercise programmes for rotator cuff tendinopathy, to generate recommendations based on current evidence. An electronic search of AMED, CiNAHL, CENTRAL, MEDLINE, PEDro and SPORTDiscus was undertaken from their inception to June 2014 and supplemented by hand searching. Eligible studies included randomized controlled trials evaluating the effectiveness of exercise in participants with rotator cuff tendinopathy. Included studies were appraised using the Cochrane risk of bias tool and synthesized narratively. Fourteen studies were included, and suggested that exercise programmes are widely applicable and can be successfully designed by physiotherapists with varying experience; whether the exercise is completed at home or within a clinic setting does not appear to matter and neither does pain production or pain avoidance during exercise; inclusion of some level of resistance does seem to matter although the optimal level is unclear, the optimal number of repetitions is also unclear but higher repetitions might confer superior outcomes; three sets of exercise are preferable to two or one set but the optimal frequency is unknown; most programmes should demonstrate clinically significant outcomes by 12 weeks. This systematic review has offered preliminary guidance in relation to contextual factors and prescription parameters to aid development and application of exercise programmes for rotator cuff tendinopathy.** *International Journal of Rehabilitation Research* **00:000–000** 

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## Introduction

Exercise is regarded as an effective intervention to address the pain and disability associated with symptomatic rotator cuff tendinopathy (Littlewood *et al.*, 2013). However, exercise is not a panacea and prescription is diverse (Littlewood *et al.*, 2012a, 2012b). In terms of exercise programmes it is currently unknown what works for whom and in what circumstances (Hanratty *et al.*, 2012). Although exercise prescription should be individualized, an understanding of the factors to consider will help the clinician optimize rehabilitation.

The purpose of this review is to identify and synthesize the published evaluative data relating to exercise interventions for rotator cuff tendinopathy. Through comparison of the different contextual factors and prescription parameters of the exercise programmes with reference to patient reported outcome (PROM), the aim is to generate recommendations, based on current evidence, through which effective exercise programmes can be developed.

## Participants and Methods

An electronic search of AMED, CiNAHL, Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, PEDro and SPORTDiscus was undertaken from their inception to June 2014. The Cochrane highly sensitive search to identify randomized trials was adopted (Lefebvre *et al.*, 2008). The search terms used for the MEDLINE search are displayed in Table 1.

The electronic search was complemented by hand searching the reference lists of the articles found and a recent review of systematic reviews (Littlewood *et al.*, 2013). This process was undertaken by one reviewer.

### Inclusion and exclusion criteria

#### *Participants*

Studies of adult patients presenting with signs and symptoms suggestive of rotator cuff tendinopathy were included. Because of previously recognized diagnostic limitations and overlapping nomenclature (Littlewood *et al.*, 2012a, 2012b), a pragmatic approach was taken. Studies were included that investigated a condition



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**Table 1 MEDLINE search strategy**

| | Search term | Limited to |
|---|---|---|
| 1 | Shoulder pain or shoulder impingement* or shoulder tend* or shoulder burs* or rotator cuff* or subacromial impingement* or subacromial burs* or supraspinatus* or impingement* or contractile dysfunction or painful arc* | Title and abstract |
| 2 | Exercise* or eccentric* or concentric* or loaded* or resistance* or muscle* or physiotherapy* or physical therapy* or rehabilitation* or conservative management | Title and abstract |
| 3 | Randomized controlled* or randomized controlled* or controlled clinical trial or randomized or placebo or randomly or trial or groups | Title and abstract |
| 4 | 1 and 2 and 3 | |

*Wildcard, which means that words with different endings will be retrieved without having to type all the variations in. For example, 'shoulder tend*' would retrieve 'shoulder tendinopathy', 'shoulder tendinosis', 'shoulder tendinitis' etc.

described as, or synonymous with, rotator cuff tendinopathy (e.g. subacromial impingement syndrome) where other diagnoses (e.g. frozen shoulder) had been ruled out.

#### *Interventions*

Studies that evaluated the effectiveness of any active exercise intervention in one of the treatment arms were included. Combined interventions, for example, exercise and electrotherapy, were excluded.

#### *Outcomes*

Studies that described PROMs of pain and disability where a minimal clinically important change, that is, the smallest change in health status that patients perceive as beneficial, had been established were included.

#### *Study design*

Only randomized controlled trials (RCTs) were included. Data relating to the exercise intervention were extracted, typically from one intervention arm, as this review is based on the assumption that exercise is an effective intervention (Littlewood *et al.*, 2012a, 2012b, 2013). However, inclusion of RCTs only is still important to minimize the potential for selection bias.

#### *Language*

For pragmatic reasons, only studies published in full in English were included.

Following the search, one reviewer undertook screening of titles and abstracts to identify articles that should be retrieved for full-text review. The reviewer then extracted data in relation to the study context, participants, intervention, dosage parameters and outcomes (Table 2).

### Risk of bias assessment

Assessment of the risk of bias of the included studies was undertaken by one reviewer using the Cochrane Back Review Group (CBRG) risk of bias tool (Furlan *et al.*, 2009). It has been recognized that this tool is also useful for the assessment of trials in other conditions (Van Tulder *et al.*, 2009) and has been employed in other systematic reviews evaluating the effectiveness of exercise for shoulder-related disorders (Hanratty *et al.*, 2012; Littlewood *et al.*, 2012a, 2012b). The completed risk of bias tool is displayed in Table 3. Each item was rated as yes (=1), no (=0), unclear (=0). A study with a low risk of bias was defined as one fulfilling six or more of the criteria items and with no fatal flaw which is defined as:

(1) Drop-out greater than 50%.
(2) Statistically and clinically significant differences between groups at baseline indicating unsuccessful randomization.

This approach has previously been validated (Van Tulder *et al.*, 2009).

### Data synthesis

Because of the heterogeneity with regards to the exercise interventions evaluated, a narrative synthesis was conducted that related contextual factors and exercise prescription parameters to PROMs.

## Results

Figure 1 depicts the study selection process; 14 studies ($n=396$) were included in this review. The list of excluded full-text articles along with the reasons for exclusion is available from the corresponding author.

The results of the risk of bias assessment are shown in Table 3. In terms of the number of criteria met, scores ranged from 3 to 11/12 (mean=6). The majority of studies (9/14) were regarded as presenting a low risk of bias (Ludewig and Borstad, 2003; Walther *et al.*, 2004; Giombini *et al.*, 2006; Lombardi *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Yiasemides *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a). As Table 3 demonstrates, the most common limitation across studies related to a lack of blinding of the patients, therapists and/or outcome assessors. An association between risk of bias and PROMs is not clearly supported by the data from this appraisal.

A summary of the characteristics of the exercise intervention arm(s) of the included studies along with the main results are shown in Table 2.

### Outcome measures and outcomes

Six studies reported the Shoulder Pain and Disability Index (SPADI) (Kachingwe *et al.*, 2008; Bal *et al.*, 2009; Engebretsen *et al.*, 2009, 2011; Yiasemides *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a), three

**Table 2 Characteristics of the included studies**

| References | Context | Participants | Intervention | Dosage parameters | Outcomes |
|---|---|---|---|---|---|
| Engebretsen *et al.* (2009, 2011) | Based in Norway<br>Treated by two experienced physiotherapists<br>No further detail reported | $n=51$<br>(a) Age 18–70 years<br>(b) Shoulder pain > 3 months<br>(c) Pain with shoulder abduction<br>(d) Maintained ROM<br>(e) Pain with isometric tests<br>(f) Positive Hawkins–Kennedy impingement test<br>Mean age of participants: 49 years<br>Mean duration of symptoms: unclear<br>Mean baseline SPADI score: 48.8 | Home-based exercise programme with direct supervision × 2/week:<br>Commenced with sling suspension to negate gravity; repeated movement through all ranges in sequence<br>Resistance gradually added as pain free range of movement increases, using Theraband, to strengthen the rotator cuff and scapular stabilizers | Repetitions: 50<br>Sets: 3<br>Frequency: × 2/week clinic visits and home exercise daily<br>Duration: 12 weeks<br>Low-load exercise emphasized | SPADI (0–6 weeks)<br>48.8–25.8 = 23.0 mean improvement (significance not reported)<br>SPADI (0–12 weeks)<br>48.8–27.0 = 21.8 mean improvement (significance not reported)<br>SPADI (0–18 weeks)<br>48.8–24.5 = 24.3 mean improvement (significance not reported)<br>SPADI (0–52 weeks)<br>48.8–24.0 = 24.8 mean improvement (significance not reported) |
| Giombini *et al.* (2014a) | Based in Italy<br>Treated by a 'fully trained' rehabilitation specialist<br>No further detail reported | $n=11$<br>(a) Positive Hawkins impingement test<br>(b) Positive empty-can test<br>(c) Tissue changes evident through ultrasonography without tear<br>(d) Athletes attending a rehabilitation unit<br>Mean age of participants: 26 years<br>Mean duration of symptoms: 4.8 months<br>Mean baseline Constant score: 59.5 | Home exercise programme with direct supervision × 1/week:<br>Comprised pendular swinging and stretching<br>No further detail reported | Repetitions: 5 min<br>Sets: unclear<br>Frequency: × 2/day<br>Duration: 4 weeks<br>Unloaded exercise emphasized | Constant score (0–4 weeks)<br>59.5–61.2 = 1.7 mean improvement ($P=0.07$)<br>Constant score (0–6 weeks)<br>59.5–63.3 = 3.8 mean improvement ($P=0.07$) |
| Kromer *et al.* (2013) | Based in Germany<br>Treated by 12 experienced physiotherapists (mean clinical experience > 23 years) across 6 centres | $n=44$<br>(a) Age 18–75 years<br>(b) Symptoms > 4 weeks<br>(c) Local shoulder and/or upper arm pain<br>(d) Positive Neer, Hawkins–Kennedy or painful arc<br>(e) Pain with at least one resisted test<br>Mean age of participants: 54 years<br>Mean duration of symptoms: 10 months<br>Mean baseline SPADI score: 41.3 | Home exercise programme with direct supervision × 2/week for 5 weeks:<br>Progressive strengthening exercises for the rotator cuff and scapula stabilizers using Theraband and combined with stretches and exercises for pain relief, for example, pendular exercises, longitudinal self-traction | Repetitions: 10–20<br>Sets: 2–3<br>Frequency: × 2/day during week 1, then once daily for next 4 weeks and × 3/week for further 7 weeks<br>Duration: 12 weeks<br>Gradual increase of resistance, for example, yellow to red to green Theraband<br>Pain < 3/10 permitted | SPADI (0–5 weeks)<br>41.3–26.8 = 14.4 mean improvement (95% CI 9.2–19.6)<br>SPADI (0–12 weeks)<br>41.3–19.8 = 21.5 mean improvement (significance not reported) |
| Littlewood *et al.* (2014a) | Based in UK<br>Treated by 2 experienced physiotherapists (>20 years of clinical experience) in one centre | $n=12$<br>(a) Age > 18 years<br>(b) Primary complaint of shoulder pain with or without referral into the upper limb for > 3 months<br>(c) No/minimal resting shoulder pain<br>(d) Range of shoulder movement largely preserved<br>(e) Shoulder pain provoked consistently with resisted muscle tests, usually abduction or lateral rotation<br>Mean age of participants: 63 years<br>Mean duration of symptoms: 29 months<br>Mean baseline SPADI score: 44.6 | Home exercise programme with option to return to physiotherapist for advice and guidance:<br>Exercise programme comprised of progressive resistance using one exercise only at any one time. Exercise selection was based on symptomatic response; direction was selected by matching to most provocative resisted test, and repetition and load to produce pain during exercise that is no worse on cessation | Repetitions: 10–15<br>Sets: 3<br>Frequency: × 2/day during<br>Duration: 12 weeks<br>Gradual increase of resistance, for example, yellow to red to green Theraband<br>Pain reproduction was permitted providing it was no worse on cessation | SPADI (0–12 weeks)<br>44.6–20.9 = 23.7 mean improvement (95% CI 14.4–33.3) |
| Lombardi *et al.* (2008) | Based in Brazil<br>No further detail reported | $n=30$<br>(a) Positive Hawkins and Neer test | Clinic-based exercise programme with direct supervision: | Repetitions: 8<br>Sets: 2 | |

**Table 2 (*continued*)**

| References | Context | Participants | Intervention | Dosage parameters | Outcomes |
|---|---|---|---|---|---|
| | | (b) Pain between 3 and 8 on a numeric rating scale<br>Mean age of participants: 56 years<br>Mean duration of symptoms: 14 months<br>Mean baseline Disabilities of the Arm, Shoulder and Hand (DASH) score: 44.0 | Exercises included flexion, extension, medial and lateral rotation | Frequency: ×2/week<br>Duration: 8 weeks<br>Exercise prescription based on 6 repetition maximum<br>Comprised 2 sets of 8 repetitions: 50% of 6RM for the first set and 70% of 6RM for the second set<br>Pain production was not permitted | DASH (0–8 weeks)<br>44.0–33.2 = 11.8 mean improvement ($P = 0.046$) |
| Ludewig and Borstad (2003) | Based in USA<br>No further detail reported | $n = 34$<br>(a) Occupational exposure to overhead work > 1 year<br>(b) Minimum of 130° abduction<br>(c) Painful arc on abduction<br>(d) Local tenderness to palpation<br>(e) Positive Neer, Hawkins–Kennedy, Yocum, Jobe and/or Speeds test<br>(f) Pain with at least one resisted test<br>Mean age of participants: 48 years<br>Mean duration of symptoms: 29 months<br>Mean baseline Shoulder Rating Questionnaire (SRQ) score: 44.6 | Home exercise programme:<br>Exercise programme comprised of relaxation, stretching and then progressive resistance exercises for serratus anterior and shoulder external rotators using hand-weights and Theraband<br>Initial instruction provided by a physiotherapist re-enforced through written/pictorial instructions. Return was arranged 1 week later with a follow-up telephone call at 4 weeks with optional visit to the physiotherapist at this stage | Repetitions: 10 (week 1) to 15 (week 2) to 20 (week 3 onwards)<br>Sets: 3<br>Frequency: ×3/week<br>Duration: 8 weeks<br>Gradual increase of resistance, for example, yellow to red to green Theraband<br>Shoulder fatigue permitted but no increase in shoulder pain | SRQ (0–12 weeks)<br>65.9–75.8 = 9.9 mean improvement (significance not reported) |
| Østerås *et al.* (2009, 2010); Østerås and Torstensen (2010) | Based in Norway<br>Treated by 3 experienced physiotherapists (many years of experience) across 3 centres | (a) Age 18–60 years<br>(b) Unilateral shoulder pain<br>(c) Positive Hawkins impingement test<br>(d) Symptoms > 3 months<br>Mean age of participants: 44 years<br>Mean duration of symptoms: 36 months<br>Mean baseline SRQ score: 43.8 | Clinic-based exercise programme with direct supervision:<br>$n = 31$; high dosage medical exercise therapy<br>3 sets of 30 repetitions<br>$n = 30$; low dosage medical exercise therapy<br>2 sets of 10 repetitions | Frequency: ×3/week clinic visits<br>Duration: 12 weeks<br>Exercise is undertaken close to the pain-free threshold; shoulder pain should not increase significantly | (a) High-dose MET<br>SRQ (0–12 weeks)<br>43.7–69.1 = 25.4 mean improvement (95% CI 19.1–32.1)<br>SRQ (0–36 weeks)<br>43.7–76.8 = 33 mean improvement ($P < 0.01$)<br>SRQ (0–60 weeks)<br>43.7–79.1 = 35.4 mean improvement ($P < 0.01$)<br>(b) Low-dose MET<br>SRQ (0–12 weeks)<br>43.8–51.5 = 7.7 mean improvement (95% CI 4.5–10.9)<br>SRQ (0–36 weeks)<br>43.8–56.3 = 12.5 mean improvement (significance not reported)<br>SRQ (0–60 weeks)<br>43.8–54.7 = 10.9 mean improvement (significance not reported)<br>Statistically significant differences between groups at all 3 and 6-month follow-up in favour of high-dose MET |

| | | | | | |
|---|---|---|---|---|---|
| | | | Medical exercise therapy (MET) consists of 1 h active group therapy (max. 5 participants) under the supervision of a physiotherapist<br>MET applies progressive resistance exercise combined with aerobic activity, for example, cycling<br>9–11 exercises are performed with aim of achieving over 1000 repetitions | | |
| Walther *et al.* (2004) | Based in Germany<br>No further detail reported | $n = 20$<br>(a) Positive Neer impingement test<br>(b) Confirmatory radiograph and ultrasonography<br>Mean age of participants: 52 years<br>Mean duration of symptoms: 23 months<br>Mean baseline Constant score: 59.0 | Home exercise programme with option to return to physiotherapist for advice and guidance up to a maximum of 4 sessions<br>Comprised 7 strengthening exercises and one cervical stretch, primarily using Theraband, with the aim of centering the humeral head and training the scapula stabilizers | Repetitions: 10<br>Sets: unclear – encouraged to exercise for 10–15 min<br>Frequency: at least × 5/week<br>Duration: 12 weeks<br>No further detail reported | Constant score (0–6 weeks)<br>59.0–8.0 = 9.0 mean improvement (significance not reported)<br>Constant score (0–12 weeks)<br>59.0–75.0 = 16.0 mean improvement ($P < 0.05$) |
| Yiasemides *et al.* (2011) | Based in Australia<br>Treated by 17 physiotherapists with a range of experience (2–28 years of clinical experience) across 1 large centre | $n = 51$<br>(a) Age > 18 years<br>(b) Symptoms > 1 month<br>(c) Painful active shoulder flexion or abduction<br>(d) Minimum of 140° abduction<br>(e) Positive Neer, Hawkins–Kennedy or Jobes test<br>(f) Pain with at least two resisted tests<br>Mean age of participants: 58 years<br>Mean duration of symptoms: 22 months<br>Mean baseline SPADI score: 50.0 | Home exercise programme with 1 or 2 sessions with a physiotherapist per week for the first month followed by additional treatment over the next 4 weeks to a maximum of 12 sessions<br>Individualized exercise programme comprised of stretching and strengthening to regain normal dynamic stability | Repetitions: unclear/individualized<br>Sets: unclear/individualized<br>Frequency: daily<br>Duration: 12 weeks<br>Pain was not permitted during exercise | SPADI (0–4 weeks) 50–34 = 16 mean improvement (significance not reported)<br>SPADI (0–12 weeks) 50–21 = 29 mean improvement (significance not reported)<br>SPADI (0–24 weeks) 50–14 = 36 mean improvement (significance not reported) |
| Bal *et al.* (2009) | Based in Turkey<br>No detail relating to experience or training of therapists | $n = 20$<br>(a) Positive Neer and Hawkins–Kennedy tests<br>Mean age of participants: 53 years<br>Mean duration of symptoms: not reported<br>Median baseline Shoulder Pain and Disability Index (SPADI): 69.1 | Home exercise programme:<br>Commenced with pendular circumduction and passive self-shoulder stretching followed by isometrics in all planes, Theraband exercises with progressive resistance, scapular stabilization exercises and 'advanced' muscle strengthening with dumbbells | Repetitions: not reported<br>Sets: not reported<br>Frequency: not reported<br>Duration: 12 weeks<br>No further detail provided | SPADI (0–12 weeks); 69.1–19.6 = 49.5 median improvement ($P < 0.001$) |
| Kachingwe *et al.* (2008) | Based in USA<br>Treated by one experienced research physiotherapist (14 years of clinical experience) | $n = 8$<br>(a) Superolateral shoulder pain<br>(b) 2 out of 4 positive tests – Neer, Hawkins–Kennedy, painful limitation of active shoulder elevation, pain or limitation of hand-behind-back or hand-behind-head<br>Mean age of participants: 47 years<br>Mean duration of symptoms: 33 months<br>Mean baseline SPADI score: 48.0 | Home exercise programme with direct supervision × 1/week:<br>Comprised stretching, postural correction and resistance exercises for the rotator cuff and scapular stabilizers<br>No further detail reported | Repetitions: unclear<br>Sets: unclear<br>Frequency: × 1/week clinic visits and home exercise daily<br>Duration: 6 weeks<br>No further detail reported | SPADI (0–6 weeks)<br>48.0–18.4 = 29.6 (transformed from original data)<br>Mean improvement (significance not reported) |
| Calis *et al.* (2011) | Based in Turkey<br>Treated by one physiotherapist<br>No further detail reported | $n = 16$<br>(a) 18–65 years<br>(b) Stage II subacromial impingement syndrome according to MRI<br>Mean age of participants: 50 years<br>Mean duration of symptoms: 3 months<br>Mean baseline Constant score: 48.4 | Clinic-based exercise programme with direct supervision:<br>Comprised stretching, and gradually progressed to strengthening exercise for the rotator cuff, biceps and deltoid<br>No further detail reported | Repetitions: 5 (5-s hold)<br>Sets: 1<br>Frequency: × 2/week clinic visits<br>Duration: 3 weeks<br>No further detail reported | Constant (0–3 weeks)<br>48.4–56.3 = 7.9 mean improvement ($P = 0.001$) |
| Baskurt *et al.* (2011) | Based in Turkey<br>No detail relating to experience or training of therapists | $n = 20$<br>(a) Positive Neer, Hawkins or Jobe test<br>(b) Confirmatory radiograph and diagnostic ultrasound<br>Mean age of participants: 51 years<br>Mean duration of symptoms: 11 months<br>Mean baseline Western Ontario Rotator Cuff (WORC) index: 40 | Clinic-based exercise programme under direct supervision:<br>Comprised stretches for anterior, posterior and inferior capsule and flexion, abduction and internal rotation with a towel. Strengthening component consisted of subscapularis, infraspinatus, supraspinatus and anterior/posterior deltoid exercise using Theraband | Repetitions: 10<br>Sets: 3<br>Frequency: × 3/week clinic visits<br>Duration: 6 weeks<br>Resistance was progressed when the exercise prescription was | WORC (0–6 weeks)<br>37.1–70.9 = 33.8 mean improvement ($P < 0.05$) |

**Table 2 (*continued*)**

| References | Context | Participants | Intervention | Dosage parameters | Outcomes |
|---|---|---|---|---|---|
| | | | | completed without substantial pain or fatigue | |
| | | | Clinic-based exercise programme with direct supervision: | | |
| | | (a) Registered nurse, nurse technician or nurse aid at the host institution<br>(b) Medical diagnosis of rotator cuff disorder | $n=9$; cryotherapy, stretching, strengthening and proprioceptive drills<br>Proprioceptive regime | Repetitions: unclear<br>Sets: unclear<br>Frequency: ×2/week clinic visits<br>Duration: 6 weeks | (a) Cryotherapy, stretching and strengthening and proprioceptive drills; WORC (0–6 weeks) reported as statistically significant change ($P=0.01$)<br>(b) Cryotherapy, stretching and strengthening alone; WORC (0–6 weeks) reported as statistically significant change ($P=0.06$) |
| | | Mean age of participants: unclear<br>Mean duration of symptoms: unclear | $n=9$; cryotherapy, stretching and strengthening | Progressive increase in resistance after 3 sessions | No significant difference between groups ($P=0.11$) |
| Martins and Marziale (2012) | Based in Brazil<br>No further detail reported | Mean baseline WORC score: unclear | Programme comprised pendular exercises, stretching of the neck and shoulder muscles, active-assisted shoulder range of movement exercise and exercise to strengthen the rotator cuff and scapula stabilizers | No further detail reported | |

studies (Walther *et al.*, 2004; Giombini *et al.*, 2006; Calis *et al.*, 2011) reported the Constant score, two studies (Baskurt *et al.*, 2011; Martins and Marziale, 2012) reported the Western Ontario Rotator Cuff index, two studies (Ludewig and Borstad, 2003; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010) reported the Shoulder Rating Questionnaire, and one study (Lombardi *et al.*, 2008) reported the Disabilities of the Arm, Shoulder and Hand questionnaire (Table 4).

Postrandomization follow-up periods ranged from 3 to 60 weeks (median = 12 weeks). Six of nine studies with less than 12 weeks of follow-up (Kachingwe *et al.*, 2008; Lombardi *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Baskurt *et al.*, 2011; Yiasemides *et al.*, 2011; Kromer *et al.*, 2013) reported clinically significant changes. Of the three that did not, one study (Walther *et al.*, 2004) subsequently demonstrated clinically significant changes by 12 weeks but the other two (Giombini *et al.*, 2006; Calis *et al.*, 2011) did not follow-up to this time point. At and beyond the 12-week follow-up point, seven of eight studies (Walther *et al.*, 2004; Bal *et al.*, 2009; Engebretsen *et al.*, 2009, 2011; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Yiasemides *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a) reported clinically significant changes with a general trend towards greater change over time.

Below 12 weeks of follow-up the mean change in SPADI score was 21 (range 14.4–29.6); the mean change in Constant score was 5 (range 1.7–9.0); only one study provided an interpretable Western Ontario Rotator Cuff index score, which indicated a 33.8 point change (Baskurt *et al.*, 2011); and one study provided a Disabilities of the Arm, Shoulder and Hand score, which indicated an 11.8 point change (Lombardi *et al.*, 2008).

At and beyond the 12-week follow-up point the mean change in SPADI score was 26 (range 21.5–36) [Bal *et al.* (2009) excluded from this analysis due to reporting of SPADI as median]; only one study provided a Constant score which indicated a 16.0 point change (Walther *et al.*, 2004); the mean change in Shoulder Rating Questionnaire score was 19 (range 7.7–35.4). At the 12-week follow-up point; the mean change in SPADI score was 24 (range 21.5–29).

### Contextual factors

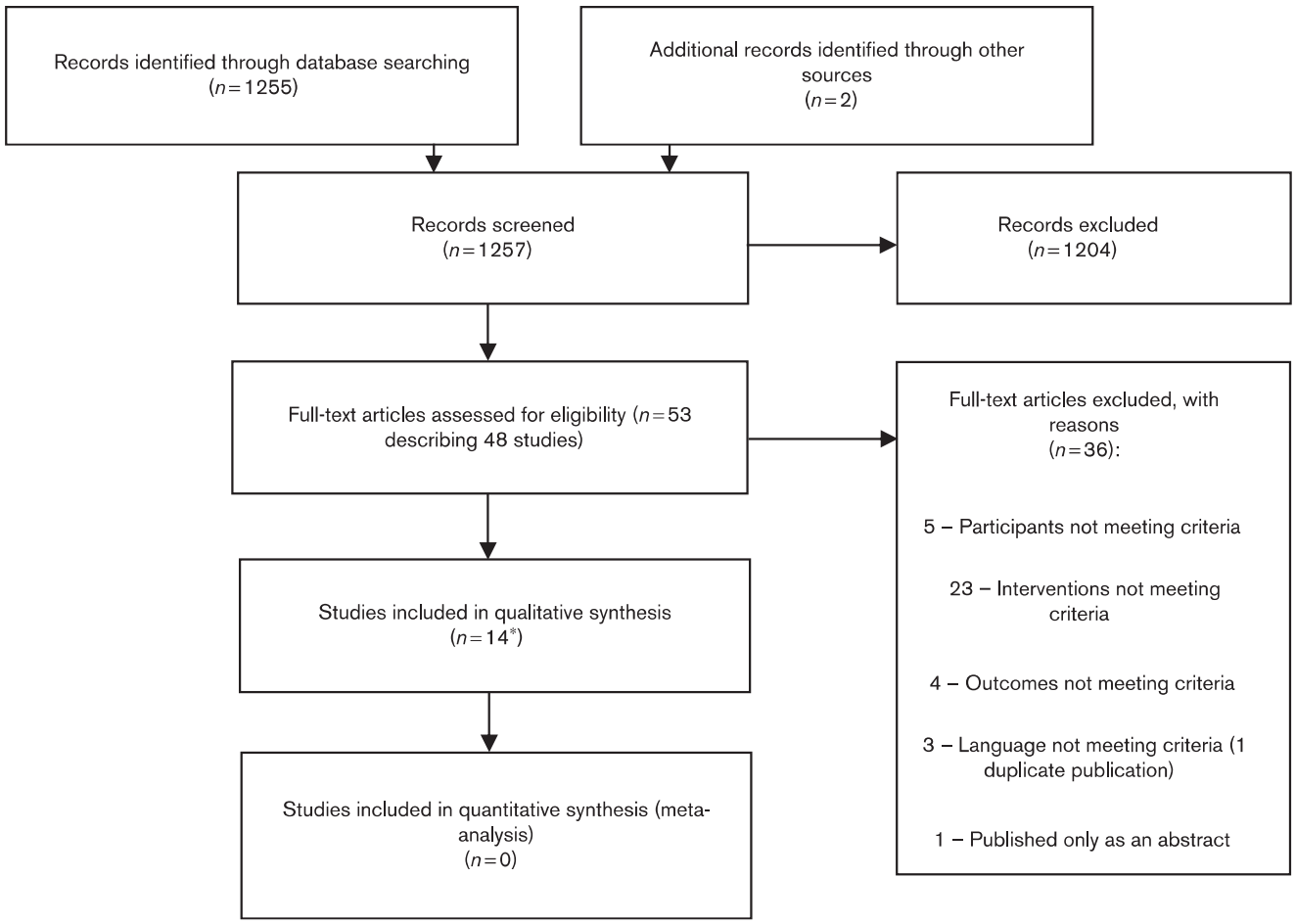
Nine studies were conducted in Europe (Walther *et al.*, 2004; Giombini *et al.*, 2006; Engebretsen *et al.*, 2009, 2011; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Baskurt *et al.*, 2011; Calis *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a), two studies were conducted in North America (Ludewig and Borstad, 2003; Kachingwe *et al.*, 2008), two in South America (Lombardi *et al.*, 2008; Martins and Marziale, 2012), and one study was conducted in Australia (Yiasemides *et al.*, 2011). An association between geographical location and clinical outcome is not clearly supported by this data.

**Table 3 Risk of bias appraisal of the included studies**

| | Cochrane RoB appraisal | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| References | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Cochrane RoB score |
| Engebretsen *et al.* (2009, 2011) | ✓ | ✓ | x | x | x | ✓ | ✓ | ✓ | ✓ | – | – | ✓ | 7/12 |
| Giombini *et al.* (2006) | – | – | x | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 7/12 |
| Kromer *et al.* (2013) | ✓ | ✓ | x | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 9/12 |
| Littlewood *et al.* (2014a) | ✓ | ✓ | x | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 9/12 |
| Lombardi *et al.* (2008) | ✓ | ✓ | x | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 9/12 |
| Ludewig and Borstad (2003) | ✓ | ✓ | x | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | – | ✓ | 8/12 |
| Østerås *et al.* (2009, 2010); Østerås and Torstensen (2010) | ✓ | ✓ | – | x | x | ✓ | ✓ | ✓ | ✓ | – | – | ✓ | 7/12 |
| Walther *et al.* (2004) | ✓ | ✓ | ✓ | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 11/12 |
| Yiasemides *et al.* (2011) | ✓ | ✓ | x | x | x | ✓ | ✓ | ✓ | ✓ | – | – | ✓ | 7/12 |
| Bal *et al.* (2009) | – | – | x | x | x | ✓ | – | ✓ | x | – | – | ✓ | 3/12 |
| Kachingwe *et al.* (2008) | x | x | ✓ | x | ✓ | ✓ | – | – | x | – | – | – | 3/12 |
| Calis *et al.* (2011) | – | – | x | x | x | x | x | ✓ | x | ✓ | x | ✓ | 3/12 |
| Baskurt *et al.* (2011) | – | – | – | – | – | ✓ | ✓ | ✓ | ✓ | – | – | ✓ | 5/12 |
| Martins and Marziale (2012) | – | – | x | x | x | ✓ | ✓ | – | – | – | ✓ | – | 3/12 |

1. Adequate randomization?; 2. Concealed allocation?; 3. Patient blinded?; 4. Therapist blinded?; 5. Outcome assessor blinded?; 6. Drop-out rate described and acceptable?; 7. Intention-to-treat analysis?; 8. Free of selective reporting?; 9. Similarity of baseline characteristics?; 10. Cointerventions avoided or similar?; 11. Compliance acceptable?; 12. Timing of outcome assessments similar?

**Fig. 1**




Study selection process. *14 studies described by 16 full-text papers.

**Table 4 Outcome measures employed by the included studies and summary of the main outcomes**

| Primary outcome measures | Psychometric properties | References | Within-group change (mean unless otherwise indicated) |
|---|---|---|---|
| Shoulder Pain and Disability Index | Valid, reliable MCIC of 8–13 points (Roy *et al.*, 2009) | Engebretsen *et al.* (2009, 2011) | 23.0 at 6/52 |
| | | | 21.8 at 12/52 |
| | | | 24.3 at 18/52 |
| | | | 24.8 at 52/52 |
| | | Kromer *et al.* (2013) | 14.4 at 5/52 |
| | | | 21.5 at 12/52 |
| | | Littlewood *et al.* (2014a) | 23.7 at 12/52 |
| | | Yiasemides *et al.* (2011) | 16 at 4/52 |
| | | | 29 at 12/52 |
| | | | 36 at 24/52 |
| | | Bal *et al.* (2009) | 49.5 at 12/52 (median) |
| | | Kachingwe *et al.* (2008) | 29.6 at 6/52 |
| Constant score | Valid, reliable (Roy *et al.*, 2010) | Giombini *et al.* (2006) | 1.7 at 4/52 |
| | MCIC of 10 points (Kukkonen *et al.*, 2013) | | 3.8 at 6/52 |
| | | Walther *et al.* (2004) | 9.0 at 6/52 |
| | | | 16.0 at 12/52 |
| | | Calis *et al.* (2011) | 7.9 at 3/52 |
| Western Ontario Rotator Cuff index | Valid, reliable (De Witte *et al.*, 2012) | Baskurt *et al.* (2011) | 33.8 at 8/52 |
| | MCIC of 12 points (Kirkley *et al.*, 2003) | | |
| | | Martins and Marziale (2012) | Unclear |
| Shoulder Rating Questionnaire | Valid, reliable MCIC of 12 points (L'Insalata *et al.*, 1997) | Ludewig and Borstad (2003) | 9.9 at 12/52 |
| | Østerås *et al.* (2009, 2010); Østerås and Torstensen (2010) | High-dose MET; 25.4 at 12/52 | Low-dose MET; 7.7 at 12/52 |
| | | 33 at 36/52 | 12.5 at 36/52 |
| | | 35.4 at 60/52 | 10.9 at 60/52 |
| Disabilities of the Arm, Shoulder and Hand | Valid, reliable (Roy *et al.*, 2009) | Lombardi *et al.* (2008) | 11.8 at 8/52 |
| | MCIC of 10 points (Roy and Esculier, 2011) | | |

MCIC, minimal clinically important change.

Eight studies (Giombini *et al.*, 2006; Kachingwe *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Baskurt *et al.*, 2011; Yiasemides *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a) referred to the therapists involved in the delivery of the exercise interventions. One study (Giombini *et al.*, 2006) referred to a rehabilitation specialist, whereas the other six studies referred to physiotherapists (PT). Three studies utilized one therapist (Giombini *et al.*, 2006; Kachingwe *et al.*, 2008; Calis *et al.*, 2011), two studies utilized two PTs (Engebretsen *et al.*, 2009, 2011; Littlewood *et al.*, 2014b), one study utilized three PTs (Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010), one study utilized 12 PTs (Kromer *et al.*, 2013) and one study utilized 17 PTs (Yiasemides *et al.*, 2011). Six studies (Kachingwe *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Yiasemides *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a) referred to the experience of the PTs, typically in relation to the number of years postqualification. All but one of these studies (Yiasemides *et al.*, 2011) utilized 'experienced' PTs. An exercise programme designed by PTs seemed preferable, but an association between the experience, number of PTs involved in delivery and patient outcome was not clearly supported, that is, studies including PTs with a range of experience reported results that were at least comparable with those studies that included experienced PTs only.

## Patient factors

The mean age of the participants was 50 years (range 26–63 years). Eleven studies (Ludewig and Borstad, 2003; Walther *et al.*, 2004; Giombini *et al.*, 2006; Lombardi *et al.*, 2008; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Yiasemides *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a) provided sufficient data to calculate an overall mean duration of symptoms of 20 months (range 3–36 months). An association between age, duration of symptoms and PROM was not clearly supported, but this must be seen in the context of limited data.

All but one of the included studies (Martins and Marziale, 2012) described patient reported pain and disability at baseline. One study (Bal *et al.*, 2009) reported a median value which hampers comparisons with other studies reporting mean values and was hence omitted from this aspect of the synthesis. The mean SPADI score at baseline for the five studies using this measure (Kachingwe *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Yiasemides *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a) was 47 (range 41.3–50.0). In the context of limited data and heterogeneity within the presented data, an association between baseline pain and disability, and clinical outcome is not clearly supported. The variability across the other included studies in terms of the PROMs employed and the diverse follow-up points hamper further attempts to usefully synthesize the data.

## Type of exercise

### *Home-based versus clinic-based exercise*

The included studies evaluated exercise programmes that could be broadly categorized as home-based, that is,

exercise undertaken away from clinic with minimal contact with therapist (Ludewig and Borstad, 2003; Walther *et al.*, 2004; Giombini *et al.*, 2006; Kachingwe *et al.*, 2008; Bal *et al.*, 2009; Yiasemides *et al.*, 2011; Littlewood *et al.*, 2014a); home-based with PT supervision and clinic attendance greater than 1/week (Engebretsen *et al.*, 2009, 2011; Kromer *et al.*, 2013); and clinic-based with PT supervision (Lombardi *et al.*, 2008; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Baskurt *et al.*, 2011; Calis *et al.*, 2011; Martins and Marziale, 2012). An association between the location of the exercise programme, degree of supervision by the therapist and PROM was not clearly supported by this data. Beyond reporting the number of treatment sessions attended, only three studies (Walther *et al.*, 2004; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a) referred to levels of exercise adherence.

### *Content of the exercise programmes*

The content of the individual programmes are described in Table 2. Four studies (Engebretsen *et al.*, 2009, 2011; Yiasemides *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a) evaluated individually adapted exercise programmes, the other studies reported largely standardized programmes with some level of tailoring regarding exercise commencement and progression criteria. Eight studies (Ludewig and Borstad, 2003; Lombardi *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Baskurt *et al.*, 2011; Yiasemides *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a) described their exercise progression criteria, six of these related this to provocation of pain or fatigue not beyond a predefined threshold (Ludewig and Borstad, 2003; Engebretsen *et al.*, 2009, 2011; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Baskurt *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a). One study (Lombardi *et al.*, 2008) utilized the six repetition maximum, and one study (Yiasemides *et al.*, 2011) utilized PT judgement regarding motor control.

Five of eight adequately reported studies (Ludewig and Borstad, 2003; Lombardi *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Baskurt *et al.*, 2011; Yiasemides *et al.*, 2011) did not permit pain production during exercise, whereas three studies did (Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a). Kromer *et al.* (2013) utilized a patient reported numeric rating scale where less than 3/10 pain production was permitted. Littlewood *et al.* (2014a) required that pain was produced during exercise but was no worse on cessation but no upper bound was placed on the degree of pain provocation. Østerås *et al.* (2009, 2010) and Østerås and Torstensen (2010) stated that exercise was undertaken close to the pain-free threshold and should be no worse on cessation of the exercise. Whether pain production or pain avoidance during exercise is associated with improved clinical outcomes is not clear from this data.

A wide variety of exercises were used across the different studies (Table 2). Most programmes included a number of different exercises, with a focus on activating rotator cuff and periscapular muscles. Littlewood *et al.* (2014a) was the only study to employ one rather than a range of exercises. One study (Giombini *et al.*, 2006) did not include resistance exercises, and reported negligible change (Constant score) at 4 and 6 weeks.

## Dosage parameters

### *Repetitions*

Nine studies (Ludewig and Borstad, 2003; Walther *et al.*, 2004; Lombardi *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Baskurt *et al.*, 2011; Calis *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a) adequately reported the number of exercise repetitions. Six of these studies (Ludewig and Borstad, 2003; Walther *et al.*, 2004; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Baskurt *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a) used 10 repetitions with two studies (Ludewig and Borstad, 2003; Kromer *et al.*, 2013) progressing the number of repetitions according to ability and/or time rather than maintaining a fixed number. One study (Calis *et al.*, 2011) used five repetitions with 5-s holds. One study (Lombardi *et al.*, 2008) used eight repetitions, another (Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010) used 30 repetitions and Engebretsen *et al.* (2009, 2011) used 50 repetitions. Clinically significant responses were reported across all repetition prescriptions but Østerås *et al.* (2009, 2010) and Østerås and Torstensen (2010) reported a dose–response effect with higher repetitions and sets conferring superior PROMs.

### *Sets*

Eight studies (Ludewig and Borstad, 2003; Lombardi *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Baskurt *et al.*, 2011; Calis *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014b) adequately reported the number of exercise sets used. Six of these studies (Ludewig and Borstad, 2003; Engebretsen *et al.*, 2009, 2011; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Baskurt *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014b) used three sets. Two studies (Lombardi *et al.*, 2008; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010) used two sets and one study (Kachingwe *et al.*, 2008) used one set. Lower numbers of sets are associated with PROMs that are not regarded as clinically significant at 3 weeks (Calis *et al.*, 2011) and 12 weeks (Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010), and of marginal clinical significance at 8 weeks (Lombardi *et al.*, 2008). There appears to be an association between number of sets and PROMs.

### *Frequency*

Thirteen studies (Ludewig and Borstad, 2003; Walther *et al.*, 2004; Giombini *et al.*, 2006; Kachingwe *et al.*, 2008; Lombardi *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Baskurt *et al.*, 2011; Calis *et al.*, 2011; Yiasemides *et al.*, 2011; Martins and Marziale, 2012; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a) adequately reported the frequency of undertaking the exercise. Of the eight studies that evaluated largely home-based exercise programmes (Ludewig and Borstad, 2003; Walther *et al.*, 2004; Giombini *et al.*, 2006; Kachingwe *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Yiasemides *et al.*, 2011; Kromer *et al.*, 2013; Littlewood *et al.*, 2014a), three (Kachingwe *et al.*, 2008; Engebretsen *et al.*, 2009, 2011; Yiasemides *et al.*, 2011) used daily exercise; two (Giombini *et al.*, 2006; Littlewood *et al.*, 2014a) used twice daily exercise; one (Kromer *et al.*, 2013) commenced with twice daily exercise and gradually reduced frequency over time; one (Walther *et al.*, 2004) used a minimum of five exercise sessions per week; one (Ludewig and Borstad, 2003) used three exercise sessions per week. Of the five studies that evaluated largely clinic-based exercise programmes (Lombardi *et al.*, 2008; Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010; Baskurt *et al.*, 2011; Calis *et al.*, 2011; Martins and Marziale, 2012) two (Østerås *et al.*, 2009, 2010; Østerås and Torstensen, 2010) used three exercise sessions per week, three (Lombardi *et al.*, 2008; Calis *et al.*, 2011; Martins and Marziale, 2012) used two exercise sessions per week. An association between frequency of undertaking a home exercise programme and PROMs is not apparent. With regard to frequency of undertaking a clinic-based exercise programme, lower frequency (i.e. twice per week) is associated with PROMs that are not regarded as clinically significant at 3 weeks (Calis *et al.*, 2011) and of marginal clinical significance at 8 weeks (Lombardi *et al.*, 2008).

## Discussion

The data evaluated within this systematic review offers some preliminary guidance in relation to the development and application of an exercise programme for rotator cuff tendinopathy. Geographical location does not appear to be a barrier to achieving significant clinical outcomes, and hence such exercise programmes might be regarded as widely applicable. Significant outcomes can be achieved when therapists with varying degrees of experience prescribe programmes, giving pragmatic value to such programmes. Patients of varying age, duration of symptoms and severity of pain and disability can achieve a significant outcome, which adds further utility. There appears to be no difference between home-based or clinic-based exercise programmes, or between pain production or avoidance during exercise, regarding clinical outcomes. Inclusion of some level of resisted exercise does seem to matter, although the optimal level is unclear. Also unclear is the optimal number of exercise repetitions, but higher repetitions might offer superior outcomes in some circumstances. Three sets of exercise is preferable to two or one set, but the optimal frequency is unknown. Exercise programmes should demonstrate clinically significant clinical outcomes by 12 weeks, the potential for achieving significant outcomes for shorter programmes is unclear.

In keeping with the findings of Kuhn (2009), specific guidance regarding the superiority of one or a group of related exercises is not apparent from the available literature. Hanratty *et al.* (2012) were unable to draw conclusion or offer specific recommendation regarding the content of an exercise programme citing heterogeneity of exercise interventions and poor reporting as barriers. Although limited in similar ways to these previous systematic reviews, our review has been able to shed some light on what might and what might not be important when developing and applying an exercise programme. Notably, such programmes can be successfully designed by therapists with a range of experience and undertaken by a wide range of patients in a home-based or clinic setting. Resistance exercise might be an important component of such programmes, but the optimal level of resistance remains unclear. Pain and/or fatigue can successfully be used to guide treatment prescription, but whether pain should be produced or avoided during exercise is not clear; it is possible that such judgements might be most appropriately made in conjunction with knowledge of both patient and therapist preference (Littlewood *et al.*, 2014b). Indeed, it might also be sensible to suggest that, from a pragmatic perspective, decisions regarding exercise dosage, that is, repetitions, sets, frequency, might also be undertaken in the context of knowledge of relevant patient factors, for example, motivation, on the understanding that higher dosage, at least in terms of repetitions and sets, might lead to superior outcomes. Finally, it appears that an exercise programme should be maintained for at least 12 weeks before a decision regarding the potential of such an approach to confer a clinically significant outcome is taken.

### Limitations of this review

Having one reviewer search, retrieve, extract and appraise studies might be seen as a limitation. It can also be argued that having one reviewer can reduce errors such as erroneous data input, due to the repetitive nature of the process. It is interesting to note that there is movement in the field of systematic review methodology towards an appreciation of rapid reviews. Frequently such reviews use one reviewer at the various stages for pragmatic reasons, and although it is recognized that the potential for error is higher, it is generally suggested that most errors or omissions do not lead to substantial changes in any conclusion (Jones *et al.*, 2005).

The search was restricted to studies published in English. It has been suggested that identifying non-English language and unpublished studies for inclusion is important to minimize language and publication bias respectively. However, this has been questioned and suggested that many unpublished studies eventually become published and truly unpublished studies might have poor or unclear methodology, which in turn might serve to introduce bias to any systematic review (Van Driel *et al.*, 2009).

### Conclusion

Although the data are limited and there is significant heterogeneity across the different exercise programmes evaluated to date, this systematic review has been able to offer some preliminary guidance in relation to contextual factors and prescription parameters to aid development and application of exercise programmes for rotator cuff tendinopathy. Specific factors relating to the patient and the therapist, at least as currently reported in RCTs, might not be a barrier to successful outcome and neither is geographical location or setting, for example, home-based or clinic-based exercise. Resistance exercise appears to be an important component of such programmes, but the optimal level of resistance remains unclear. Pain and/or fatigue can successfully be used to guide treatment prescription, but whether pain should be produced or avoided during exercise is not clear. Higher doses of exercises might confer superior outcomes, and an exercise programme should be maintained for at least 12 weeks before a decision regarding the potential of such an approach to offer a clinically significant outcome is taken.

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### Conflicts of interest

There are no conflicts of interest.

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