RESEARCH ARTICLE

WILEY

Effect of manual physiotherapy in homogeneous individuals with subacromial shoulder impingement: A randomized controlled trial

Helen Land[1] [iD] | Susan Gordon[2] | Kerrianne Watt[3]

[1] College of Healthcare Sciences, James Cook University, Townsville, Queensland, Australia

[2] School of Health Sciences, Flinders University, Bedford Park, South Australia, Australia

[3] College of Public Health, Medical and Vet Sciences, James Cook University, Townsville, Queensland, Australia

Correspondence
Helen Land, James Cook University, Physiotherapy Clinic, Building 500, Townsville. Queensland. Australia.
Email: helen.land@jcu.edu.au

Abstract

Objective: To compare the effect of specific interventions aimed at (1) the upper thoracic spine (passive mobilization) and (2) the posterior shoulder (massage, passive mobilization, and stretching) to (3) an active control intervention in a homogeneous group with extrinsic subacromial shoulder impingement (SSI).

Study Design: Single-centre, prospective, double-blinded, randomized controlled trial.

Method: Eligible individuals with clearly defined extrinsic SSI were randomized to each group. Treatment duration was 12 consecutive weeks consisting of nine treatments over 6 weeks, followed by 6 weeks when one home exercise was performed daily. Outcomes included (1) active thoracic flexion/extension range of motion, (2) passive glenohumeral internal rotation and posterior shoulder range, (3) pain rating, and (4) shoulder pain and function disability index. Data were analysed at baseline, 6 and 12 weeks. Shoulder pain and function disability index scores were investigated via email 6 months after commencement of treatment.

Results: Twenty participants completed treatment in each group. No differences were identified between groups at baseline. Upper thoracic and posterior shoulder interventions, with a targeted home exercise, both significantly decreased pain and increased function scores and increased posterior shoulder range compared with active control at 12 weeks, and 6 months following cessation of the trial.

Conclusion: Manual therapy treatment that addresses these extrinsic factors, of thoracic spine or posterior shoulder tightness, decreases the signs and symptoms of SSI. The trial is registered with the Australian New Zealand Clinical Trials Registry (ANZCTR; 12615001303538).

KEYWORDS

manual therapy, randomized controlled trial, subacromial shoulder impingement, treatment

1 | INTRODUCTION

Subacromial shoulder impingement (SSI) is a frequent condition in those presenting with shoulder pain for primary care (Ostor, Richards, Speed, & Hazleman, 2005). It refers to the insidious presentation of sharp, anterolateral shoulder pain produced during arm elevation, eased on lowering the arm, in the presence of a positive Neer and/or Hawkins Kennedy Test (Carmargo et al., 2015; Cook, Learman, Houghton, Showalter, & O'Halloran, 2014; Kromer, de Bie, & Bastiaenen, 2013; Tate, McClure, Young, Salvatori, & Michener, 2010).

Subjective outcome measures have been used almost exclusively in SSI intervention studies. They have included change in pain, assessed using visual analogue scale or numeric pain rating scale (NPRS; Farrar, Young, LaMoreaux, Werth, & Poole, 2001; Jensen, Karoly, & Braver, 1986); functional scores such as the shoulder pain and disability index (SPADI; Heald, Riddle, & Lamb, 1997; Hill, Lester, Taylor, Shanahan, & Gill, 2011; Roach, Budiman-Mak, Songsiridej, & Lertratanakul, 1991); disabilities of the arm, shoulder, and hand (Hudak, Amadio, & Bombardier, 1996); global impression of change (ten Klooster, Drossaers–Bakker, Taal, & van de Laar, 2006); and the Constant Murley Score (Constant & Murley, 1987). However, reported subjective improvements in pain and function scores are an indication of pain cognition and do not indicate if objective change has occurred (Nijs, De Kooning, Beckwee, & Vaes, 2015).

A recent systematic review of 64 randomized controlled trials (RCTs) investigating the effect of physical therapy on individuals with SSI (Haik, Alburquerque-Sendin, Moreira, Pires, & Carmargo, 2016) reported that all studies measured subjective outcomes of pain and function and only 15 included an objective outcome measure, being active shoulder flexion, and abduction range.

A recent study comparing extrinsic biomechanical factors in homogeneous groups with and without SSI symptoms (Land, Gordon, & Watt, 2017a, 2017b) found that the SSI group had significantly increased resting thoracic flexion, as well as significantly reduced active upper thoracic flexion/extension motion, and reduced passive posterior shoulder range compared with the asymptomatic group (Land et al., 2017a). It is not known if these differences contributed to or were a result of SSI.

No previous study has investigated the effect of physiotherapy interventions that increase thoracic range of motion or increase posterior shoulder range (Dickens, Williams, & Bhamra, 2005; Haik et al., 2016; Kromer et al., 2013). Common clinical physiotherapy techniques used to increase thoracic range of motion include central posteroanterior, unilateral posteroanterior, and transverse accessory mobilizations to the spine, as well as accessory mobilization of the ribs due to their strong attachment to the thoracic spine (Edmondston et al., 2007; Exelby, 2011). Unloaded positions of the thoracic spine allow greater range of thoracic extension, which supports adoption of a lying position for mobilization as well as an accompanying passive extension stretch (Edmondston et al., 2011).

Massage (Yang, Chen, Hsieh, & Lin, 2012) or stretching and glenohumeral anteroposterior glide mobilization (Manske, Meschke, Porter, Smith, & Reiman, 2010) have been shown to be effective in reducing posterior shoulder tightness. A review of manual techniques used in previous RCTs in those with SSI revealed an anteroposterior glenohumeral glide and a cross body adduction posterior shoulder stretch were most commonly included (Bang & Deyle, 2000; Bennell et al., 2007; Carmargo et al., 2015; Conroy & Hayes, 1998; Kachingwe, Phillips, Sletten, & Plunkett, 2008).

The aim of this study was to compare the effect of (1) passive mobilization to the upper thoracic spine; (2) massage, passive mobilization, and stretching to the soft tissues of the posterior shoulder; and (3) an active control intervention, on pain, function, and range of motion in an homogeneous SSI group. The hypothesis was that there would be a significant improvement in pain, function, and range of motion in the groups receiving passive mobilization interventions vs the active control group.

2 | METHODOLOGY

2.1 | Study design

This study was a single-centre, prospective, double-blinded, RCT. Duration of treatment was 12 consecutive weeks with email follow-up of pain and function (SPADI) 6 months after the commencement of treatment. Data were collected at baseline, 3, 6, 9, and 12 weeks to simulate clinical practice assessment. The participants were randomized into three parallel groups: (1) an active control group, which received ultrasound for 6 weeks; (2) an intervention group, which received treatment to the upper thoracic levels for 6 weeks along with a daily thoracic home exercise performed for the entire 12-week period; and (3) an intervention group, which received treatment to the soft tissues of the posterior shoulder for 6 weeks along with a daily posterior shoulder home stretch performed for the entire 12-week period.

2.1.1 | Modifications to the study design

Modifications were made to the trial design after commencement of the study due to concerns with retaining participants in the active control ultrasound group. Recruitment commenced in August 2015 and continued through to September 2016. By July 2016, the active control ultrasound group had four participants cease participation because of dissatisfaction with the intervention. This trend was a concern with all participants needing to complete the trial by the end of 2016. To enhance completion of the remaining control group participants (from July 2016 onwards), the home exercises given to the two treatment groups were prescribed following completion of their ultrasound treatment at 6 weeks.

2.2 | Participants

2.2.1 | Setting and ethics

Ethical approval was granted by the James Cook University (JCU) Human Ethics Committee (approval: H6129). Written informed consent was obtained from each of the eligible participants. All assessments and treatments were performed at the JCU Musculoskeletal Physiotherapy Clinic, Townsville, Australia.

2.2.2 | Inclusion and exclusion

Inclusion and exclusion criteria, to ensure homogeneity of the study population, were the same as a previous study (Land et al., 2017a, 2017b).

An assessment with the principal investigator (H. L.) determined eligibility.

Inclusion criteria included the following:

- being aged between 40 and 60 years;

- testing positive to a minimum of three out of five orthopaedic special tests (had to include Hawkins & Kennedy, 1980, and/or Neer, 1983, along with two of the following: external rotation resistance test; Michener, Walsworth, Doukas, & Murphy, 2009; rotator cuff tendon palpation; Hanchard, Cummins, & Jeffries, 2004; horizontal [cross-body] adduction; Park, Yokota, Gill, Rassi, & McFarland, 2005; painful arc; Kessel & Watson, 1977; drop arm test; Park et al., 2005; or speed test; Dalton, 1989; Park et al., 2005);

- experiencing *catching* or aching pain without appreciable joint stiffness (Hanchard & Handoll, 2008);

- pain localized to the anterior or antero-lateral-superior shoulder (Lewis, Green, & Dekel, 2001); and

- the insidious onset of symptoms with a possible history of gradual progression over time but without history of trauma (Bigliani & Levine, 1997).

Exclusion criteria included the following:

- previous shoulder surgery or fracture of the shoulder girdle;

- the presence of scoliosis (observed visually);

- current cervical or thoracic pain;

- glenohumeral instability indicated by grade 2 or 3 anterior, posterior, or inferior load and shift test, or previous shoulder dislocation;

- participation in elite or fulltime overhead sports;

- presence of diagnosed systemic or neurological disease (diabetes was not excluded);

- shoulder corticosteroid injection at any time in the past; and

- identification of osteophytes within the subacromial space, calcification of tendons, or large rotator cuff tears on X-ray and ultrasound imaging.

Participants were recruited from the Townsville community via emails and word of mouth. In addition, an advertisement was placed in the local Townsville press on three occasions.

2.3 | Interventions

The frequency of treatment, manual therapy techniques, and pre-scribed exercises simulate current Australian clinical practice (Bennell et al., 2010) and closely resemble similar International practice (Bang

& Deyle, 2000; Kromer et al., 2013). All three treatment groups attended treatment for six consecutive weeks. In the initial 3-week period each participant attended for treatment twice a week, then immediately following once a week for three weeks. After 6 weeks all manual therapy ceased and participants were advised to continue the same exercise as prescribed at their initial treatment. All participants were assessed at 9 and 12 weeks.

Detail of each intervention is described in Appendix A.

All participants were asked to decline any other form of treatment for their shoulder during the course of the study including additional physiotherapy, chiropractic, acupuncture, or massage therapy to the shoulder, neck, or upper back. They were instructed to maintain current levels of medication and not to begin any new medication during the course of the study and to continue all usual activities but not to begin new activities.

2.3.1 | Treating therapists

Two physiotherapists provided all interventions. Consistent training and review of techniques by both physiotherapists and the primary investigator (H. L.) ensured, all participants were provided with the same treatment and exercise regime.

2.4 | Outcome measures

The reliability of the assessor (H. L.) for all methods of assessment was established prior to commencement of this study.

2.4.1 | Outcome 1 (Primary): Thoracic range of motion

Postural angles were calculated from sagittal photographs using digitizing software UTHSCSA Image Tool (Wilcox, Dove, Doss, & Greer, 1997), with very high inter-rater reliability indicated for this method (ICC = 0.997). Photographs have been shown to be reliable for measuring changes in thoracic angle (Perry, Smith, Straker, Coleman, & O'Sullivan, 2008) along with using computer software programs to digitize thoracic angles from lateral photographs (Milanese & Grimmer-Sommers, 2010).

Full details of this measurement method are in Appendix B.

Upper thoracic resting posture was measured in degrees from the apex of the midthoracic curvature to spinous process of C7 and true vertical (detailed in Appendix B).

Active movement of upper thoracic flexion through extension was calculated in degrees as the difference in upper thoracic extension–upper thoracic flexion (detailed in Appendix B).

2.4.2 | Outcome 2 (Primary): Passive glenohumeral internal rotation range and posterior shoulder range

Passive glenohumeral internal rotation (IR) was measured in supine using a plastic goniometer. Full details of this measurement method are in Appendix B.

A minimal clinically important difference of 10° has been reported (Manske et al., 2010). Very high intra-rater reliability has been shown for this measurement method (ICC = 0.933).

Posterior shoulder range was measured using the method described by Tyler, Roy, Nicholas, and Gleim (1999) performed in side lying and using a set square to measure the distance from the medial epicondyle of the elbow to the plinth in centimetres (Tyler et al., 1999). Full details of this measurement method are in Appendix B.

2.4.3 | Outcome 3 (Secondary): Pain rating (NPRS)

An 11-point NPRS ranging from 0 (no pain) to 10 (worst imaginable) was used to measure pain (Farrar et al., 2001; Jensen et al., 1986). A minimal clinically important difference of two has been established for NPRS (Childs, Piva, & Fritz, 2005; Farrar et al., 2001).

2.4.4 | Outcome 4 (Secondary): SPADI.

This validated outcome measure was developed to measure pain and disability associated with shoulder impairment (Roach et al., 1991) and has been found to be suitable for assessment of SSI syndrome (Dogu, Sahin, Ozmaden, Yilmaz, & Kuran, 2013). A minimal clinically important difference of between 8 and 13 has been established for SPADI (Roy, MacDermid, & Woodhouse, 2009).

2.5 | Sample size

Sample size calculations were completed for each of the three outcome measures. In order to detect a between group difference of 18° (standard deviation [SD] 14°; Land et al., 2017a) for passive range of internal shoulder rotation with 90% power and alpha 0.05, a total sample size of 25 was estimated. In order to detect a between group difference of 3 (SD 2.5; Childs et al., 2005) on the NPRS with 90% power and alpha 0.05, a total sample of 30 was estimated. In order to detect a between group difference of 30 (SD 20; Heald et al., 1997) on SPADI total score with 90% power and alpha 0.05, a total sample of 20 was estimated. (Altman, 1991). It was estimated a sample size of 20 per group would be more than sufficient. We allowed for some loss to follow-up by increasing the recruitment target from 60 to 69 people.

2.6 | Randomization

Randomization was performed prior to the commencement of the trial by a research assistant using computerized sequence generation from https://www.randomizer.org. The research assistant placed the randomized treatment number on a piece of paper, in order, in a separate opaque envelope in a storage box. The treating therapist would select the next envelope in the box upon presentation of each new consenting participant. If a participant ceased to continue the study, their allocation was re-recorded and placed back in an opaque envelope for re-use.

2.7 | Blinding

Each participant and the treating therapist were unaware of the treatment to be performed until presenting for the initial treatment. The assessor (principal investigator) was blinded to treatment allocation. Participants were instructed by the treating therapist not to discuss their treatment when presenting for assessment. In turn, each participant was instructed by the assessor not to discuss any change in their condition with the treating therapist. The assessor recorded outcome measures on a paper template. A research assistant entered this data into an excel spreadsheet. The completed spreadsheet was deidentified before being returned to the principal investigator for data analysis.

2.8 | Statistical analysis

Data were analysed using IBM SPSS Statistics Version 22. Data were assessed for normality, and all variables were found to be normally distributed. Descriptive statistics (mean, SD, and standard error for numerical variables) were calculated for each physical assessment variable. One-way ANOVA tests were performed for numerical variables or chi-square tests for categorical variables to determine whether there were any between group differences at baseline.

Between group differences were assessed at baseline, week 6 and week 12 time points only. New variables were computed to represent the differences in each variable from baseline to week 6, week 6 to week 12, and baseline to week 12. After data were checked for normality, it was determined that parametric tests were appropriate for testing between group differences. However, because the group sizes were small, nonparametric tests were also completed. The results did not differ; therefore, parametric analyses are presented. Between group differences in each of these, new variables were then assessed using one-way ANOVA tests with post hoc Bonferroni adjustment. The modification in study design resulted in the final eight participants randomized into the active control group being prescribed home exercises following completion of their ultrasound treatment at 6 weeks. These eight participants continued exercises through to week 12. Data of these eight participants from week 6 to week 12 were not included in the final analysis.

Only results of participants who remained in the study were analysed (i.e., data were not analysed on *intention to treat*).

3 | RESULTS

3.1 | Recruitment

Recruitment commenced in August 2015 and continued through to September 2016. Final follow-up of participants at week 12 was completed in November 2016, with email follow-up to provide pain rating and functional score (SPADI) completed in March 2017. The trial ended once 60 participants (20 in each group) had completed the 12-week trial period. The trial was registered with the Australian New Zealand Clinical Trials Registry (ANZCTR; 12615001303538).

One hundred and fifty-two volunteers were assessed for eligibility. Seventy-nine volunteers failed to meet the eligibility criteria, and four elected to not participate (see Figure 1).

Sixty-nine volunteers who consented to participate in the trial were randomly allocated, 23 to the upper thoracic intervention, 22 to the posterior shoulder intervention, and 24 to the active control group (see Figure 1).

Drop outs occurred in each of the groups, resulting in 20 participants completing the intervention in each group. Baseline characteristics of those who dropped out did not differ significantly from participants who completed the trial (Table 1).

Home exercise compliance was consistent in all groups, with home exercises reportedly performed 60 to 75% of the total time advised.

No significant differences in baseline group characteristics (Table 1) and baseline outcome measures were identified (Table 2).

Analysis was performed comparing the change in each outcome measure (NPRS, SPADI, passive IR range, posterior shoulder range,
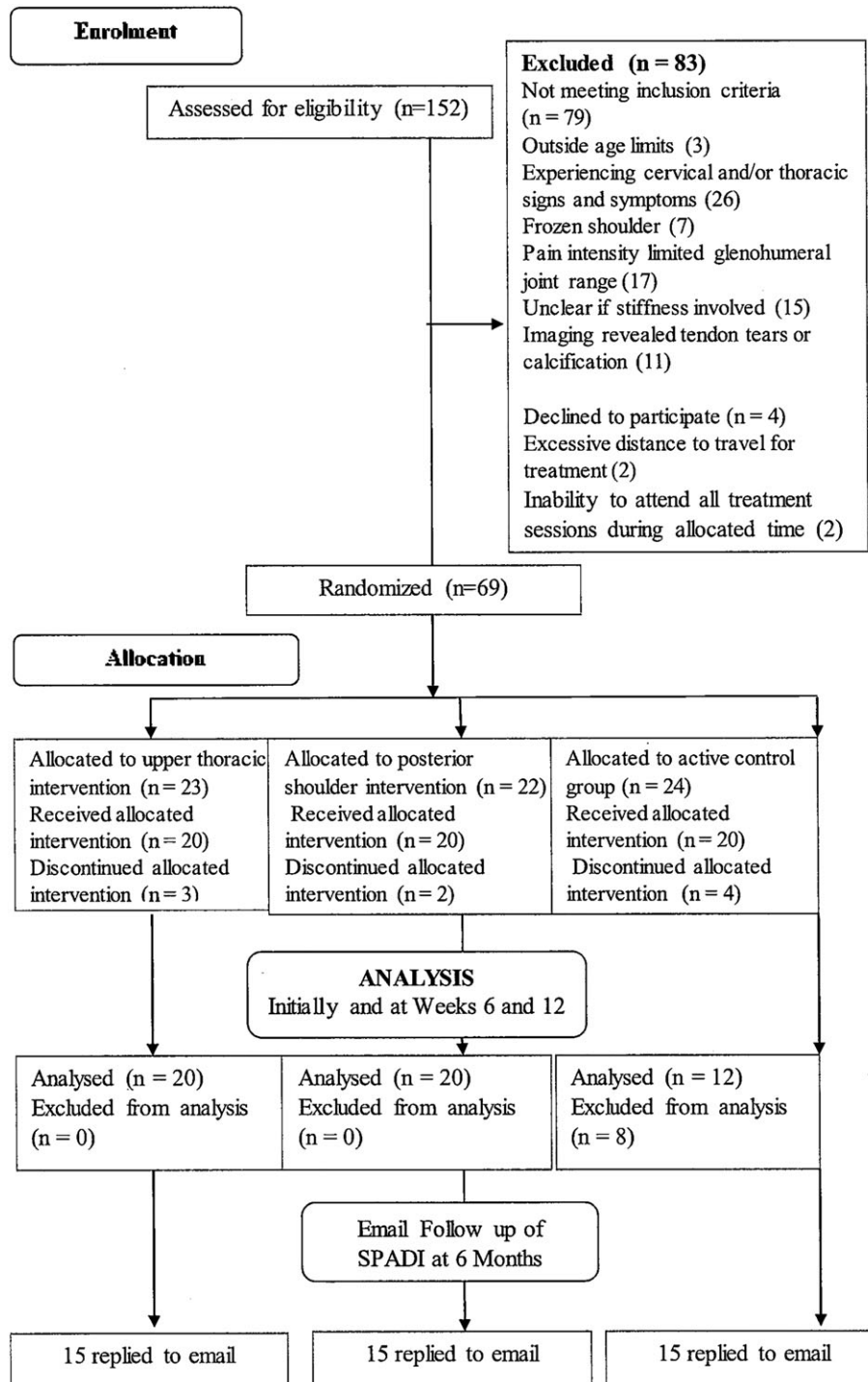
Flow Diagram 1: Participant Recruitment.

FIGURE 1 Flow diagram 1

TABLE 1 Baseline participant characteristics by group

Treatment group	Age (years) Mean ± SD	Gender Male: Female	Dominance Right: Left	Duration of symptoms (months) Mean ± SD	Dominance of injured limb Dominant: Nondominant
Upper thoracic intervention	51 ± 4.4	11: 9	18: 2	8.1 ± 4.0	10: 10
Posterior shoulder intervention	51 ± 5.4	12: 8	17: 3	9.0 ± 4.0	14: 6
Active control group (Ultrasound)	51 ± 6.0	7: 13	18: 2	8.3 ± 4.1	7: 13
	$p = 0.991$	$p = 0.247$	$p = 0.851$	$p = 0.764$	$p = 0.085$
Drop outs $n = 9$	51 ± 6.0	5:4	5:4	9.0 ± 5.5	8:1

TABLE 2 Baseline outcome measures by group

Measurements (no. of participants)	Baseline Mean ± SD (SEM)	p
NPRS		
Thoracic (20)	6.90 ± 1.8 (0.40)	0.73
Shoulder (20)	6.55 ± 1.5 (0.34)	
Ultrasound (20)	6.95 ± 1.9 (0.42)	
SPADI		
Thoracic (20)	41.27 ± 17.3 (3.87)	0.53
Shoulder (20)	36.46 ± 11.1 (2.48)	
Ultrasound (20)	41.38 ± 17.9 (4.00)	
Passive IR		
Thoracic (20)	44.3 ± 12.8 (2.86)	0.86
Shoulder (20)	44.5 ± 12.7 (2.83)	
Ultrasound (20)	46.3 ± 12.1 (2.71)	
Posterior shoulder		
Thoracic (20)	3.5 ± 6.9 (1.55)	0.52
Shoulder (20)	3.7 ± 5.1 (1.14)	
Ultrasound (20)	3.5 ± 6.5 (1.45)	
Thoracic resting		
Thoracic (20)	20.4 ± 4.7 (1.00)	0.43
Shoulder (20)	20.8 ± 3.4 (0.75)	
Ultrasound (20)	22.2 ± 5.3 (1.19)	
Active thoracic range		
Thoracic (20)	23.8 ± 11.1 (2.47)	0.12
Shoulder (20)	26.1 ± 9.9 (2.22)	
Ultrasound (20)	19.7 ± 8.2 (1.83)	

Note. IR, internal rotation; NPRS, numeric pain rating scale; SPADI, shoulder pain and function disability index.

upper thoracic resting posture, and range of motion) from baseline to week 6, week 6 to week 12, and from baseline to week 12 (Table 3).

When comparing all three groups, a significant improvement in SPADI scores, passive IR, and posterior shoulder range was found between baseline and week six (Table 3). Post hoc analysis identified that passive IR, posterior shoulder range, and SPADI scores significantly improved in the groups receiving upper thoracic treatment compared with the active control group and in the posterior shoulder treatment compared with the active control group with no differences detected between the shoulder treatment compared with the thoracic treatment (Table 4). The mean score for change in SPADI score and passive IR range was greater than the predefined minimal clinically important differences of these measurements. This indicates that both manual therapy interventions had a positive effect on reducing pain, improving function and increasing posterior shoulder range after 6 weeks in this homogeneous group with external SSI.

A significant improvement in SPADI score and passive IR was found between baseline and week 12 (Table 4). Post hoc analysis

showed that SPADI scores had significantly improved in the group receiving upper thoracic treatment compared with the active control group and passive IR had significantly improved in the groups receiving upper thoracic treatment and posterior shoulder treatment compared with the active control group (Table 4), with both having a mean score greater than the predefined minimal clinically important differences. These improvements had been maintained across the 12 weeks, with no further significant improvement found between weeks six to 12. This indicates that the benefit gained from manual therapy to the posterior shoulder for 6 weeks along with continuing the cross body adduction stretch for a further 6 weeks maintains an objective increase in posterior shoulder range. Active treatment to the upper thoracic region for 6 weeks and 6 weeks of continued home stretches maintained reduced pain, improved function, and an objective increase in passive IR at 12 weeks in this homogeneous SSI group.

Only the SPADI functional outcome scores and posterior shoulder range were significantly improved in each of the three groups between weeks 6 to 12, but the measurements recorded were not clinically important.

Upper thoracic flexion/extension range and thoracic resting angle revealed no significant differences between groups.

The SPADI outcome measure was emailed to all participants 6 months after the completion of treatment. Fifteen participants from each group replied. A significant improvement in SPADI scores was maintained 6 months after intervention had ceased in the thoracic intervention compared with the active control group ($p = 0.05$) and posterior shoulder intervention compared with the active control group ($p = 0.02$). The changes in SPADI scores between week 12 and 6 months were not significantly different between the three groups, which are consistent with maintaining treatment improvements.

4 | DISCUSSION

Previous studies investigating the effect of manual physiotherapy treatment on SSI have chosen to use a range of techniques concurrently, allowing the treating therapist to choose from a group of treatments or choose their own, dependent on the presentation, with no standardized treatment protocol implemented (Bang & Deyle, 2000; Carmargo et al., 2015; Conroy & Hayes, 1998; Cook et al., 2014; Kaya, Baltaci, Toprak, & Atay, 2014; Kromer et al., 2013). Treatments have included hot packs; stretching of the shoulder or neck; scapular, rotator cuff, or postural strengthening; massage; mobilization to the cervical spine, thoracic spine or shoulder girdle joints; and education (Bang

TABLE 3 Identification of groups with significant change in outcome values between baseline and week 6, week 6 to week 12, and baseline to week 12

Measurements (no. of participants)	Initial to week 6 Mean ± SD (SEM)	p	Week 6 to Week 12 Mean ± SD (SEM)	p	Initial to week 12 Mean ± SD (SEM)	p
NPRS						
Thoracic (20)	2.35 ± 2.6 (0.59)	0.10	1.25 ± 1.9 (0.42)	0.52	3.60 ± 3.2 (0.71)	0.04*
Shoulder (20)	1.95 ± 2.6 (0.58)		1.70 ± 2.0 (0.45)		3.65 ± 2.5 (0.56)	
Ultrasound to week 6 (20)	0.65 ± 2.4 (0.54)		0.75 ± 2.2 (0.64)		0.83 ± 2.6 (0.74)	
Ultrasound week 7 to 12 (12), i.e., no exercises						
SPADI						
Thoracic (20)	21.04 ± 19.5 (4.36)	0.005**	11.08 ± 10.6 (2.38)	0.005**	32.12 ± 17.4 (3.88)	0.007**
Shoulder (20)	18.31 ± 11.1 (2.45)		7.42 ± 8.5 (1.89)		25.73 ± 9.4 (2.10)	
Ultrasound to week 6 (20)	5.18 ± 15.8 (3.53)		3.43 ± 17.2 (5.0)		9.25 ± 20.2 (5.84)	
Ultrasound week 7 to 12 (12), i.e., no exercises						
Passive IR						
Thoracic (20)	17.0 ± 14.6 (3.27)	≤0.001***	2.8 ± 13.2 (3.0)	0.24	19.8 ± 18.5 (4.13)	0.01*
Shoulder (20)	14.0 ± 10.3 (2.31)		4.3 ± 6.7 (1.51)		18.3 ± 9.5 (2.12)	
Ultrasound to week 6 (20)	2.0 ± 8.3 (1.86)		−1.25 ± 10.5 (3.02)		2.5 ± 14.9 (4.29)	
Ultrasound week 7 to 12 (12), i.e., no exercises						
Posterior shoulder						
Thoracic (20)	7.3 ± 5.4 (1.20)	0.002**	0.80 ± 3.6 (0.80)	0.05*	8.1 ± 5.9 (1.32)	0.07
Shoulder (20)	6.8 ± 4.9 (1.11)		0.6 ± 3.6 (0.80)		7.4 ± 4.6 (1.02)	
Ultrasound to week 6 (20)	2.2 ± 4.2 (0.94)		−0.4 ± 3.6 (0.10)		3.3 ± 3.6 (1.04)	
Ultrasound week 7 to 12 (12), i.e., no exercises						
Thoracic resting						
Thoracic (20)	−0.65 ± 3.4 (0.74)	0.38	0.45 ± 3.6 (0.80)	0.31	−0.20 ± 3.4 (0.77)	0.62
Shoulder (20)	0.75 ± 3.3 (0.74)		−0.55 ± 2.3 (0.52)		0.20 ± 2.6 (0.58)	
Ultrasound to week 6 (20)	0.90 ± 4.8 (1.06)		−1.50 ± 3.2 (0.93)		−0.42 ± 3.5 (1.01)	
Ultrasound week 7 to 12 (12). i.e., no exercises						
Active thoracic range						
Thoracic (20)	1.0 ± 9.1 (2.04)	0.36	0.15 ± 9.2 (2.1)	0.58	1.15 ± 10 (2.23)	0.24
Shoulder (20)	3.6 ± 6.6 (1.49)		1.95 ± 6.9 (1.55)		5.55 ± 8.3 (1.9)	
Ultrasound to week 6 (20)	0.2 ± 7.6 (1.69)		0.83 ± 7.3 (2.12)		0.08 ± 10 (2.9)	
Ultrasound week 7 to 12 (12), i.e., no exercises						

Note. IR, internal rotation; NPRS, numerical pain rating scale; SPADI, shoulder pain and disability index.

*p < 0.05. **p < 0.01. ***p < 0.001.

TABLE 4 Post hoc Bonferroni adjustment

Interventions	Week 6 to 12 SPADI	Posterior shoulder	Baseline to week 6 SPADI	Passive IR	Posterior shoulder	Baseline to week 12 SPADI	Passive IR
Upper thoracic Posterior shoulder	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upper thoracic Active control	0.88	1.00	0.007**	≤0.001***	.004**	0.006**	0.02*
Posterior shoulder Active control	1.00	1.00	0.03*	0.005**	.01*	0.09	0.04*

Note. IR, internal rotation; NPRS, numerical pain rating scale; SPADI, shoulder pain and disability index.

*p < 0.05. **p < 0.01. ***p < 0.001.

& Deyle, 2000; Carmargo et al., 2015; Conroy & Hayes, 1998; Cook et al., 2014; Kaya et al., 2014; Kromer et al., 2013). This study showed that specific targeted treatment can have a positive effect.

Previous studies, which investigated exercises versus manual treatment reported manual therapy, were superior to exercises in improving pain and function scores but did not include objective shoulder measures (Bang & Deyle, 2000; Kachingwe et al., 2008). Without objective assessment significant reductions in pain may be attributed to the individual attention and improvement in mood provided by the attending therapist (Woolf, 2010) or may be attributed

to the mechanical stimulus provided through the manual techniques initiating a number of potential neurophysiological effects from the peripheral and central nervous system (Bialosky, Bishop, Price, Robinson, & George, 2009). This study provides evidence that clinically meaningful improvements in objective measures of passive IR and posterior shoulder range occur alongside subjective improvements in function with thoracic mobilization and posterior shoulder treatment in extrinsic SSI.

Studies, which previously reported manual therapy, had no superior effect than exercise to improve pain, and function scores in those

with SSI have included the same supervised exercise regime for each group, making the isolated effect of the manual techniques difficult to establish (Carmargo et al., 2015; Kromer et al., 2013).

Previous studies have prescribed both rotator cuff and scapular strengthening as well as anterior and posterior shoulder and neck stretching (Carmargo et al., 2015; Kromer et al., 2013). This study chose to prescribe only one home exercise specific to the maintenance of gains from the intervention provided, suggesting that a targeted exercise may achieve a similar benefit.

The current study identified a significant improvement in posterior shoulder range occurred in both the upper thoracic treatment group and the posterior shoulder treatment group, with neither group showing a greater degree of benefit. It is possible that either thoracic mobilization or posterior shoulder stretching and direct humeral head mobilization can alter humeral head position and potentially reduce any compressive effect within the subacromial space. It is also possible that the prone position adopted to perform the passive thoracic mobilizations evoked an effect on humeral head position. It is not known if the techniques used directly affected the humeral head position or if the effect was via the muscles, which maintain humeral head positioning (Oatis, 2009). However, the outcome of this study supports the hypothesis that extrinsic factors contribute to pain production in SSI.

The range of upper thoracic flexion/extension and thoracic resting angle was not found to significantly change in any of the groups in this trial. It may be possible that treatment to the upper thoracic spine does not have a biomechanical effect on the thoracic spine, but instead the mechanical stimulus provided in this area may be producing a neurophysiological cascade resulting in this positive effect (Bialosky et al., 2009). Small mean differences in upper thoracic flexion/extension range were recorded along with large *SD*s and standard error, which may suggest that the method of measurement used may not be sufficiently accurate for detecting these ranges but is more likely a reflection of the small sample sizes.

5 | LIMITATIONS

Limitations of this study included the availability of appropriate participants meeting the trial criteria, which lead to an alteration (eight out of twenty participants) in the active control group being given exercises at 6 weeks. Although the differences in retention did not differ substantively across conditions (20/23 vs 20/22 vs 20/24), the higher dropout rate for those receiving ultrasound may reflect frustration of participants due to lack of progress or the expectation that treatment will be active, with self-management strategies, rather than passive ultrasound.

The possible lack of sensitivity of the upper thoracic measurement method to detect small changes in range and selection bias (specifically volunteer bias) may impact on the generalizability of these findings to the general population. Although participants were prevented from receiving concurrent treatments and were checked to have not received recent treatment, previous treatment interventions (physiotherapy, medical or other) were not considered. Any previous treatment experiences (successful or otherwise) may have impacted on subjective outcome measures.

Given the novelty of this intervention, and in particular within this context, the authors intentionally conducted a *per protocol* analyses in order to demonstrate efficacy of the intervention (vs effectiveness, which would be analysed by intention-to-treat analyses), this may be considered a limitation of the study. Group sizes were found to not be a limitation with post study sample size calculation (using passive range of internal shoulder rotation [mean difference 10° and *SD* 5°]; SPADI total score [mean difference 20 *SD* 17]) revealing that the power of the study was greater than 0.9 and alpha = 0.5 (level of significance; Altman, 1991).

6 | CONCLUSION

Mobilization of the upper thoracic spine or massage and mobilization of posterior shoulder structures combined with a targeted home exercise, in a homogenous group with extrinsic SSI, significantly improves function and passive IR range. The improvements continued to be significant 6 months after cessation of intervention. These findings suggest that manual therapy treatment that addresses these extrinsic contributing factors decreases the signs and symptoms of SSI.

ORCID

Helen Land https://orcid.org/0000-0003-0440-0952

REFERENCES

Ainsworth, R., Dziedzic, K., Hiller, L., Daniels, J., Bruton, A., & Broadfield, J. (2007). A prospective double blind placebo-controlled randomized trial of ultrasound in the physiotherapy treatment of shoulder pain. *Rheumatology*, *46*, 815–820. https://doi.org/10.1093/rheumatology/kel423. Web of Science

Altman, D. G. (1991). *Practical Statistics for Medical Reseach*. London: Chapman and Hall.

Bang, M. D., & Deyle, G. D. (2000). Comparison of supervised exercise with and without manual physical therapy for patients with shoulder impingement syndrome. *Journal of Orthopaedic & Sports Physical Therapy*, *30*(3), 126–137. Web of Science. https://doi.org/10.2519/jospt.2000.30.3.126

Hengeveld, & Banks, K. (2005). The shoulder and shoulder girdle complex. In E. Hengeveld, & K. Banks (Eds.), *Maitland's Peripheral Manipulation* (Fourth ed.) (pp. 275–356). Edinburgh: Elsevier Butterworth Heinemann.

Banks, K., & Hengeveld, E. (2014). The Maitland concept as a clinical practice framework for neuromusculoskeletal disorders. In E. Hengeveld, & K. Banks (Eds.), *Maitland's Peripheral Manipulation. Management of Neuromuscoloskeletal Disorders* (ed., Vol. 2) (pp. 1–65). Edinburgh: Churchill Livingstone Elsevier.

Bennell, K., Coburn, S., Wee, E., Green, S., Harris, A., Forbes, A., & Buchbinder, R. (2007). Efficacy and cost-effectiveness of a physiotherapy program for chronic rotator cuff pathology: A protocol for a randomised, double-blind, placebo controlled trial. *BMC Musculoskeletal Disorders*, *8*(86), 12.

Bennell, K., Wee, E., Coburn, S., Green, S., Harris, A., Staples, M., ... Buchbinder, R. (2010). Efficacy of standardised manual therapy and home exercise programme for chronic rotator cuff disease: randomised placebo controlled trial. *BMJ*, *340*(c2756), 1–10. https://doi.org/10.1136/bmj.c2756

Bialosky, J. E., Bishop, M. D., Price, D. D., Robinson, M. E., & George, S. Z. (2009). The mechanisms of manual therapy in the treatment of

musculoskeletal pain: A comprehensive model. *Manual Therapy*, *14*, 531–538. https://doi.org/10.1016/j.math.2008.09.001. Web of Science

Bigliani, L. U., & Levine, W. N. (1997). Subacromial impingement syndrome. *Journal of Bone and Joint Surgery*, *79*(12), 1854–1868. https://doi.org/10.2106/00004623-199712000-00012

Boon, A. J., & Smith, J. (2000). Manual scapular stabilization: Its effect on shoulder rotational range of motion. *Archives of Physical Medicine and Rehabilitation*, *81*, 978–983. https://doi.org/10.1053/apmr.2000.5617 Web of Science

Carmargo, P. R., Alburquerque-Sendin, F., Avila, M. A., Haik, M. N., Vieira, A., & Salvini, T. F. (2015). Effects of stretching and strengthening exercises, with and without manual therapy, on scapular kinematics, function, and pain in individuals with shoulder impingement: A randomized controlled trial. *The Journal of Orthopaedic and Sports Physical Therapy*, *45*(12), 984–997. https://doi.org/10.2519/jospt.2015.5939. Web of Science

Childs, J. D., Piva, S. R., & Fritz, J. M. (2005). Responsiveness of the numeric pain rating scale in patients with low back pain. *Spine*, *30*(11), 1331–1334. Web of Science. https://doi.org/10.1097/01.brs.0000164099.92112.29

Conroy, D. E., & Hayes, K. W. (1998). The effect of joint mobilization as a component of comprehensive treatment for primary shoulder impingement syndrome. *Journal of Orthopaedic & Sports Physical Therapy*, *28*(1), 3–14. Web of Science. https://doi.org/10.2519/jospt.1998.28.1.3

Constant, C. R., & Murley, A. H. G. (1987). A clinical method of functional assessment of the shoulder. *Clinical Orthopaedics and Related Research*, *214*(January), 160–164.

Cook, C., Learman, K., Houghton, S., Showalter, C., & O'Halloran, B. (2014). The addition of cervical unilateral posterioreanterior mobilisation in the treatment of patients with shoulder impingement syndrome: A randomised clinical trial. *Manual Therapy*, *19*, 18–24. https://doi.org/10.1016/j.math.2013.05.007. Web of Science

Dalton, S. E. (1989). Clinical examination of the painful shoulder. *Ballieres Clinical Rheumatology*, *3*(3), 453–474. Web of Science. https://doi.org/10.1016/S0950-3579(89)80004-4

Dickens, V. A., Williams, J. L., & Bhamra, M. S. (2005). Role of physiotherapy in the treatment of subacromial impingement syndrome: A prospective study. *Physiotherapy*, *91*(3), 159–164. https://doi.org/10.1016/j.physio.2004.10.008. Web of Science

Dogu, B., Sahin, F., Ozmaden, A., Yilmaz, F., & Kuran, B. (2013). Which questionaire is more effective for follow-up diagnosed subacromial impingement syndrome? A comparison of the responsiveness of SDQ, SPADI and WORC index. *Journal of Back and Musculoskeletal Rehabilitation*, *26*, 1–7. https://doi.org/10.3233/BMR-2012-0342. Web of Science

Edmondston, S. J., Aggerholm, M., Elfving, S., Flores, N., Ng, C., Smith, R., & Netto, K. (2007). Influence of posture on the range of axial rotation and coupled lateral flexion of the thoracic spine. *Journal of Manipulative and Physiological Therapeutics*, *30*(3), 193–199. https://doi.org/10.1016/j.jmpt.2007.01.010. Web of Science

Edmondston, S. J., Waller, R., Vallin, P., Holthe, A., Noebauer, A., & King, E. (2011). Thoracic spine extension mobility in young adults: Influence of subject position and spinal curvature. *Journal of Orthopaedic & Sports Physical Therapy*, *41*(4), 266–273. Web of Science. https://doi.org/10.2519/jospt.2011.3456

Exelby, L. (2011). Examination of the thoracic region. In N. J. Petty (Ed.), *Neuromuscular Examination and Assessment. A Handbook for Therapists* (Fourth ed.) (pp. 235–252). Edinburgh: Churchill Livingstone Elsevier.

Farrar, J. T., Young, J. P., LaMoreaux, L., Werth, J. L., & Poole, R. M. (2001). Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. *Pain*, *94*, 149–158. Web of Science, DOI: https://doi.org/10.1016/S0304-3959(01)00349-9

Greenfield, B. H., Donatelli, R., Wooden, M. J., & Wilkes, J. (1990). Isokinetic evaluation of shoulder rotational strength between the plane

of the scapula and the frontal plane. *American Journal of Sports Medicine*, *18*(2), 124–128. Web of Science

Grimmer-Somers, K., Milanese, S., & Louw, Q. (2008). Measurement of cervical posture in the sagittal plane. *Journal of Manipulative and Physiological Therapeutics*, *31*(7), 509–517. https://doi.org/10.1016/j.jmpt.2008.08.005 Web of Science

Haik, M. N., Alburquerque-Sendin, F., Moreira, R. F. C., Pires, E. D., & Carmargo, P. R. (2016). Effectiveness of physical therapy treatment of clearly defined subacromial pain: a systematic review of randomised controlled trials. *British Journal of Sports Medicine*, *50*, 1124–1134. https://doi.org/10.1136/bjsports-2015-095771

Hanchard, N., Cummins, J., & Jeffries, C. (2004). Evidence-based clinical guidelines for the diagnosis, assessment and physiotherapy management of shoulder impingement syndrome. Retrieved from

Hanchard, N. C. A., & Handoll, H. H. G. (2008). Physical tests for shoulder impingements and local lesions of bursa, tendon or labrum that may accompany impingement. *Cochrane Database of Systematic Reviews*, *4*. https://doi.org/10.1002/14651858.CD007427

Hawkins, R. J., & Kennedy, J. (1980). Impingement syndrome in athletes. *American Journal of Sports Medicine*, *8*(3), 151–158. https://doi.org/10.1177/036354658000800302 Web of Science

Heald, S. L., Riddle, D. L., & Lamb, R. L. (1997). The shoulder pain and disability index: The construct validity and responsiveness of a region- specific disability measure. *Physical Therapy*, *77*(10), 1079–1089. Web of Science

Hill, C. L., Lester, S., Taylor, A. W., Shanahan, M. E., & Gill, T. K. (2011). Factor structure and validity of the shoulder pain and disability index in a population-based study of people with shoulder symptoms. *BMC Musculoskeletal Disorders*, *12*, 8. https://doi.org/10.1186/1471-2474-12-8 Web of Science

Hudak, P. L., Amadio, P. C., & Bombardier, C. (1996). Development of an upper extremity outcome measure: The DASH (disabilities of the arm, shoulder, and hand). *American Journal of Industrial Medicine*, *29*, 602–608. Web of Science. https://doi.org/10.1002/(SICI)1097-0274(199606)29:6<602::AID-AJIM4>3.0.CO;2-L

Jensen, M. P., Karoly, P., & Braver, S. (1986). The measurement of clinical pain intensity: a comparison of six methods. *Pain*, *27*, 117–126. Web of Science

Kachingwe, A. F., Phillips, B., Sletten, E., & Plunkett, S. W. (2008). Comparison of manual therapy techniques with therapeutic exercise in the treatment of shoulder impingement: A randomised controlled clinical trial. *The Journal of Manual & Manipulative Therapy*, *16*(4), 238–247. https://doi.org/10.1179/106698108790818314

Kaya, D. O., Baltaci, G., Toprak, U., & Atay, A. O. (2014). The clinical and sonographic effects of kinesiotaping and exercise in comparison with manual therapy and exercise for patients with subacromial impingement syndrome: A preliminary trial. *Journal of Manipulative and Physiological Therapeutics*, *37*(6), 422–432. https://doi.org/10.1016/j.jmpt.2014.03.004 Web of Science

Kessel, L., & Watson, M. (1977). The painful arc syndrome. Clinical classification as a guide to management. *The Journal of Bone and Joint Surgery*, *59*(2), 166–172. Web of Science

Kromer, T. O., de Bie, R. A., & Bastiaenen, C. H. G. (2013). Physiotherapy in patients with clinical signs of shoulder impingement syndrome: A randomized controlled trial. *Journal of Rehabilitation Medicine*, *45*(5), 488–497. https://doi.org/10.2340/16501977-1142 Web of Science

Land, H., Gordon, S., & Watt, K. (2017a). Clinical assessment of subacromial shoulder impingement—Which factors differ from the asymptomatic population? *Musculoskeletal Science and Practice*, *27*, 49–56. https://doi.org/10.1016/j.msksp.2016.12.003

Land, H., Gordon, S., & Watt, K. (2017b). Isokinetic clinical assessment of rotator cuff strength in subacromial shoulder impingement. *Musculoskeletal Science and Practice*, *27*, 32–39. https://doi.org/10.1016/j.msksp.2016.11.012

Lewis, J. S., Green, A. S., & Dekel, S. (2001). The aetiology of subacromial impingement syndrome. *Physiotherapy*, 87(9), 458–469.

Manske, R. C., Meschke, M., Porter, A., Smith, B., & Reiman, M. (2010). A randomized controlled single-blinded comparison of stretching versus stretching and joint mobilization for posterior shoulder tightness measured by internal rotation motion loss. *Sports Health: A Multidisciplinary Approach*, 2(2), 94–100. https://doi.org/10.1177/1941738109347775

McClure, P., Balaicuis, J., Heiland, D., Broersma, M. E., Thorndike, C. K., & Wood, A. (2007). A randomized controlled comparison of stretching procedures for posterior shoulder tightness. *Journal of Orthopaedic & Sports Physical Therapy*, 37(3), 108–114. https://doi.org/10.2519/jospt.2007.2337 Web of Science

McClure, P. W., Bialker, J., Neff, N., Williams, G., & Karduna, A. (2004). Shoulder function and 3-dimensional kinematics in people with shoulder impingement syndrome before and after a 6-week exercise program. *Physical Therapy*, 84(9), 832–848. Web of Science

Michener, L. A., Walsworth, M. K., Doukas, W. C., & Murphy, K. P. (2009). Reliability and diagnostic accuracy of 5 physical examination tests and combination of tests for subacromial impingement. *Archives of Physical Medicine and Rehabilitation*, 90, 1898–1903. https://doi.org/10.1016/j.apmr.2009.05.015 Web of Science

ten Klooster, P. M., Drossaers–Bakker, K. W., Taal, E., & van de Laar, M. A. F. J. (2006). Patient-perceived satisfactory improvement (PPSI): Interpreting meaningful change in pain from the patient's perspective. *Pain*, 121, 151–157. https://doi.org/10.1016/j.pain.2005.12.021 Web of Science

Neer, C. S. I. (1983). Impingement lesions. *Clinical Orthopaedics and Related Research*, 173(March), 70–77.

van Niekerk, S.-M., Louw, Q., Vaughan, C., Grimmer-Somers, K., & Schreve, K. (2008). Photographic measurement of upper-body sitting posture pf high school students: A reliability and validity study. *BMC Musculoskeletal Disorders*, 9. https://doi.org/10.1186/1471-2474-9-113 Web of Science

Nijs, J., De Kooning, M., Beckwee, D., & Vaes, P. (2015). The neurophysiology of pain and pain modulation: Modern pain neurosciences for musculoskeletal physiotherapists. In G. Jull, A. Moore, D. Falla, J. Lewis, C. McCarthy, & M. Sterling (Eds.), *Grieve's Modern Musculoskeletal Physiotherapy* (Fourth ed.) (pp. 8–18). Edinburgh: Elsevier.

Nykanen, M. (1995). Pulsed ultrasound treatment of the painful shoulder: A randomized, double-blind, placebo-controlled study. *Scandinavian Journal of Rehabilitation Medicine*, 27(2), 105–108. Web of Science

Oatis, C. A. (2009). Structure and function of the bones and joints of the shoulder complex. In C. A. Oatis (Ed.), *Kinesiology. The Mechanics and Pathomechanics of Human Movement* (Second ed.) (pp. 120–149). Baltimore: Lippincott Williams and Wilkins.

Ostor, A. J. K., Richards, C. A. A. T. P., Speed, C. A., & Hazleman, B. L. (2005). Diagnosis and relation to general health of shoulder disorders presenting to primary care. *Rheumatology*, 44, 800–805. https://doi.org/10.1093/rheumatology/keh598 Web of Science

Park, H. B., Yokota, A., Gill, H. S., Rassi, G. E., & McFarland, E. G. (2005). Diagnostic accuracy of clinical tests for the different degrees of subacromial impingement syndrome. *Journal of Bone and Joint Surgery*, 87-A(7), 1446–1455.

Roach, K. E., Budiman-Mak, E., Songsiridej, N., & Lertratanakul, Y. (1991). Development of a shoulder pain and disability index. *Arthritis Care and Research*, 4(4), 143–149.

Roy, J. S., MacDermid, J. C., & Woodhouse, L. J. (2009). Measuring shoulder function: A systematic review of four questionnaires. *Arthritis & Rheumatism (Arthritis Care & Research)*, 61(5), 623–632. https://doi.org/10.1002/art.24396 Web of Science

Tate, A. R., McClure, P. W., Young, I. A., Salvatori, R., & Michener, L. A. (2010). Comprehensive impairment-based exercise and manual therapy intervention for patients with subacromial impingement syndrome: A case series. *Journal of Orthopaedic & Sports Physical Therapy*, 40(8), 474–493. Web of Science

Tyler, T. F., Roy, T., Nicholas, S. J., & Gleim, G. W. (1999). Reliability and validity of a new method of measuring posterior shoulder tightness. *Journal of Orthopaedic and Sports Physical Therapy*, 29(5), 262–274. Web of Science

Watson, T. (2008). Ultrasound in contemporary physiotherapy practice. *Ultrasonics*, 48, 321–329. https://doi.org/10.1016/j.ultras.2008.02.004 Web of Science

Wells, P., & Banks, K. (2014). Management of thoracic spine disorders. In E. Hengeveld, & K. Banks (Eds.), *Maitland's Vertebral Manipulation* (ed., Vol. 1) (pp. 174–227). Edinburgh: Churchill Livingstone Elsevier.

Wilcox, C. D., Dove, S. D., Doss, W. M., & Greer, D. B. (1997). *UTHSCSA Image Tool*. San Antonio: Texas. U.S.A. Department of Dental Diagnostic Science University of Texas Health Science Center.

Woolf, C. J. (2010). What is this thing called pain? *The Journal of Clinical Investigation*, 120(11), 3742–3744. https://doi.org/10.1172/JCI45178 Web of Science

Yang, J.-l., Chen, S.-y., Hsieh, C.-L., & Lin, J.-j. (2012). Effects and predictors of shoulder muscle massage for patients with posterior shoulder tightness. *BMC Musculoskeletal Disorders*, 13(46), 1–8. https://doi.org/10.1186/1471-2474-13-46

APPENDIX A

A.1 | Active control group

Ultrasound has previously been reported to have no superior effect when compared with placebo in the short-term treatment of shoulder pain (Ainsworth et al., 2007; Nykanen, 1995). However, ultrasound has been, and continues to be, used regularly in a physiotherapy clinical setting predominantly in soft tissue lesion management (Watson, 2008), making it suitable as an active control. Participants randomized to this group received ultrasound of 1 MHz 50% pulsed 0.5 wcm^2 for 8 minutes directed at the subacromial area while lying in supine (http://www.electrotherapy.org).

A.2 | Upper thoracic intervention

Intervention consisted of upper thoracic transverse mobilizations (T1–T6), grade 3, performed from the side of the painful shoulder (Figure A1); costovertebral mobilizations (T1–T6), grade 3, on the side of the painful shoulder (Wells & Banks, 2014; Figure A2). The total session time was 20 minutes (Banks & Hengeveld, 2014). The home exercise of passive thoracic extension was localized to the area of treatment by participants lying in supine on a rolled towel positioned longitudinally along the thoracic spine for 5 minutes, twice a day (McClure, Bialker, Neff, Williams, & Karduna, 2004; Tate et al., 2010;
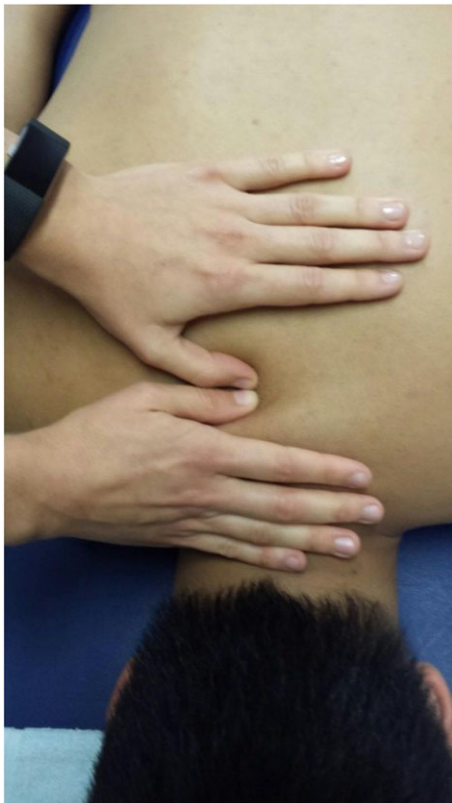
FIGURE A1 Thoracic transverse mobilizations

FIGURE A2 Costovertebral mobilizations

Figure A3). Compliance with the exercise was monitored via an exercise diary.

A.3 | Posterior shoulder intervention

Intervention consisted of massage of the posterior shoulder soft tissues, focusing along the length of infraspinatus and teres minor, performed for 15 minutes with the participant lying on the nonsymptomatic side, the painful shoulder supported in elevation (Bennell et al., 2007; Figure A4). The participant was then positioned in supine, and anteroposterior glenohumeral mobilizations, grade three, were performed to the painful shoulder for approximately 2 minutes (Hengeveld & Banks, 2005; Figure A5). The total session time was 20 minutes. The participant was instructed to perform a passive cross adduction stretch in standing, twice for the count of 20, two times during the day (McClure et al., 2007; Figure A6). Compliance with the exercise was monitored via an exercise diary.

APPENDIX B

B.1 | Posture assessment

The participant stood at 90° in a direct line to a JVC hard disc camcorder positioned on a tripod. A spirit level was used on top of the camera and the front of the lens to confirm horizontal and vertical alignments of the camera respectively. The camera distance from each subject was standardized to 2 m with the tripod position maintained using tape on the floor. Floor markers were used to standardize the participant position. Markers were attached to the spine using double-sided tape. Markers were placed overlying C7, the apex of the mid thoracic curve and overlying T12 (Edmondston et al., 2011). The assessor demonstrated to the participant the postures to be adopted.

Three photographs were taken to measure the change in thoracic angles. Photograph 1 relaxed resting posture (Figure B1): The participant was instructed to roll their shoulders forward and back three times and then stand relaxed in their normal posture (Greenfield, Donatelli, Wooden, & Wilkes, 1990). The photo was then taken.

Photograph 2 thoracic flexion (Figure B2): The participant was instructed to round their upper back as much as possible and then the photo was taken.

Photograph 3 thoracic extension (Figure B3): The participant was instructed to extend their upper back as much as possible and then the photo was taken.

Files were downloaded directly from the JVC Hard Drive Camcorder to a lap top computer via a USB connecting cord. Each photo was a .jpg individually numbered file. Relative motion of the upper thoracic was to be established. Digital photograph measurements have been shown to be reliable and valid for postural measurements (Grimmer-Somers, Milanese, & Louw, 2008; van Niekerk, Louw, Vaughan, Grimmer-Somers, & Schreve, 2008). Digitizing software UTHSCSA Image Tool was used to calculate the x,y plane coordinates, from which postural angles were calculated as shown in Figures B1–B3.

FIGURE A3 Thoracic towel stretch

FIGURE A4 Massage to posterior shoulder

Upper thoracic resting posture was measured in degrees from the apex of the midthoracic curvature to spinous process of C7 and true vertical.

Active movement of upper thoracic flexion through extension was calculated in degrees as the difference in upper thoracic extension–upper thoracic flexion.

B.2 | Measurement of passive IR range

Measured with the participant lying in supine with the humerus at 90° abduction in the coronal plane and a folded towel supporting beneath the humerus to maintain the humerus in a horizontal position. The assessor palpated the spine of the scapula while passively internally rotating the humerus. The end range of IR was determined when palpable movement of the scapula occurred. This position for measuring has previously been shown to be acceptable (Boon & Smith, 2000; Manske et al., 2010). A measurement in degrees was then taken using a plastic universal goniometer positioned with its axis level with the olecranon process and the fixed arm vertical.

B.3 | Measurement of posterior shoulder range

Measurements were taken in side lying as seen in Figure B4. Male subjects had removed their shirt, whereas female subjects were in their bra only. The subject lay with hips flexed to 90°, stabilizing the lower back, close enough to the edge of the plinth so the hand could be lowered unhindered by the plinth surface. Both acromion processes were perpendicular to the plinth, with the arm not being tested positioned so as not to hinder the movement of the test arm. The spine was maintained in neutral flexion, extension, and rotation. The medial epicondyle of the humerus was marked with a black dot. The tester grasped the distal humerus and passively positioned it in 90° abduction and 0 degrees internal/external rotation. The scapula was glided into a retracted position with the opposite hand. The humerus was lowered until the motion ceased or if rotation of the humerus was observed, indicating the end of posterior tissue flexibility. A measurement in centimetres was then taken using the carpenters square from the medial epicondyle to the plinth (Tyler et al., 1999).

FIGURE A5 AP glenohumeral mobilizations

FIGURE A6 Cross adduction stretch

FIGURE B1 Relaxed resting

FIGURE B2 Thoracic flexion

FIGURE B3 Thoracic extension

FIGURE B4 Measurement of posterior shoulder range