Changes in Shoulder Pain and Disability After Thrust Manipulation in Subjects Presenting With Second and Third Rib Syndrome

James Dunning, DPT, MSc,[a] Firas Mourad, PT, OMT, Cert. SMT,[b]
Giuseppe Giovannico, PT, MSc, OMT,[c] Filippo Maselli, PT, MSc, OMT,[d]
Thomas Perreault, DPT, Cert. SMT, Cert. DN,[e] and
César Fernández-de-las-Peñas, PT, DO, PhD, DMSc[f]

ABSTRACT

Objective: The purpose of this preliminary study was to investigate changes in shoulder pain, disability, and perceived level of recovery after 2 sessions of upper thoracic and upper rib high-velocity low-amplitude (HVLA) thrust manipulation in patients with shoulder pain secondary to second and third rib syndrome.

Methods: This exploratory study evaluated 10 consecutive individuals with shoulder pain, with or without brachial pain, and a negative Neer impingement test, who completed the Shoulder Pain and Disability Index (SPADI), the numeric pain rating scale (NPRS), and the global rating of change. Patients received 2 sessions of HVLA thrust manipulation targeting the upper thoracic spine bilaterally and the second and third ribs on the symptomatic side. Outcome measures were completed after the first treatment session, at 48 hours, 1 month, and 3 months.

Results: Patients showed a significant decrease in SPADI ($F = 59.997$; $P = .001$) and significant decrease in resting shoulder NPRS ($F = 63.439$; $P = .001$). For both NPRS and SPADI, there were significant differences between the pretreatment scores and each of the postintervention scores through 3-month follow-up ($P < .05$). Large within-group effect sizes (Cohen's $d \geq 0.8$) were found between preintervention data and all postintervention assessments in both outcomes. Mean global rating of change scores (+6.8 at 3 months) indicated "a very great deal better" outcome at long-term follow-up.

Conclusion: This group of patients with shoulder pain secondary to second and third rib syndrome who received upper thoracic and upper rib HVLA thrust manipulations showed significant reductions in pain and disability and improvement in perceived level of recovery. (J Manipulative Physiol Ther 2015;38:382-394)

Key Indexing Terms: *Shoulder Pain; Manipulation; Spinal; Manual Therapy; Thoracic Vertebrae; Ribs*

Only 50% of all new episodes of shoulder pain conditions resolve within 6 months, whereas at 12 months, more than 40% of the individuals are still disabled during work and leisure activities.[1,2] Although infrequently reported,[3-13] dysfunction of the cervicothoracic vertebrae[6,10-24] and/or upper ribs[7,10,13,20,25-29] has been suggested as a causative factor in patients presenting with shoulder and arm pain.[10-13] Dysfunction of the

[a] PhD Student, College of Health Care Sciences, Nova Southeastern University, Ft. Lauderdale, FL.

[b] PhD Student, Department of Physical Therapy, Universidad Rey Juan Carlos, Alcorcòn, Madrid, Spain.

[c] Lecturer, Department of Physiotherapy, Università di Padova, Padova, Italy.

[d] Lecturer, Department of Physiotherapy, Università di Genova, Genova, Italy.

[e] Senior Physical Therapist, Portsmouth Physical Therapy, Portsmouth, NH.

[f] Professor, Department of Physical Therapy, Occupational Therapy, Rehabilitation and Physical Medicine, Universidad Rey Juan Carlos, Alcorcòn, Madrid, Spain.

Submit requests for reprints to: James Dunning, DPT, MSc, FAAOMPT, 1036 Old Breckenridge Ln, Montgomery, AL 36117. (e-mail: *jamesdunning@hotmail.com*).

http://dx.doi.org/10.1016/j.jmpt.2015.06.008

cervicothoracic spine and/or adjacent ribs (ie, the shoulder-girdle) triples the risk[30] for the development of shoulder pain and also appears to predict poor outcome in shoulder disorders.[11,30,31]

In 1988, Grieve[32] appears to have been one of the first to publish the name "second rib syndrome"; however, he refrained from providing any specifics on the actual clinical presentation, pain pattern, or neuroanatomy of the disorder. In 1999, Boyle[25] published a case report of 2 patients with "second rib syndrome." Furthermore, Boyle proposed, "a sprain or subluxation/displacement of the second rib spinal articulations in isolation, either acutely or chronically induced, is a cause of shoulder pain that is commonly misdiagnosed as shoulder impingement syndrome and/or rotator cuff muscle partial tear."[25] Notably, Boyle stated that second rib syndrome "may be a relatively common clinical presentation."[25]

In a prospective single-arm trial of 21 patients with a primary complaint of unilateral shoulder pain, Strunce et al[7] found cervicothoracic junction restrictions, upper thoracic restrictions, and unilateral rib restrictions in 71%, 100%, and 79% of patients with shoulder pain, respectively. Similarly, after examining 101 patients with shoulder pain and 75 healthy controls, Sobel et al[12] reported, "palpation of the second and third ribs were found to be painful significantly more often and the mobility of the cervicothoracic spine was found to be limited significantly more often" in patients with shoulder pain compared to asymptomatic controls.

In 28 of 32 patients with radiographically confirmed restrictions of mobility of the first rib with the inhale or exhale position, Jirout[33] detected rotational hypomobility and twisting of the C7 and T1 vertebrae. Jirout[33] concluded that hypomobility or positional faults of upper thoracic vertebrae affects the mobility, function, and position of the respective rib—that is, causes the rib on the side toward which the vertebral rotation occurs to elevate.[11,33] Moreover, restrictions of mobility and rotational positional faults in cervicothoracic vertebrae can cause restrictions of mobility in the scapulohumeral joint through restrictions of the upper ribs.[11,12,33,34]

The neuroanatomical rationale for the complaint of shoulder girdle and/or upper arm pain is thought to be an "anterior and superior subluxation or sprain of the second rib in isolation"[25] that subsequently entraps or irritates the dorsal ramus of the second thoracic nerve as it passes through a vertical opening limited caudally by the rib and laterally by the superior costotransverse ligament.[35] Furthermore, the dorsal ramus of the second thoracic nerve provides the cutaneous distribution to the posterolateral shoulder.[35-40]

A recent randomized and sham-controlled trial[41] reported reductions in shoulder pain after midthoracic high-velocity low-amplitude (HVLA) thrust manipulation in individuals with shoulder impingement syndrome;

however, the between-group difference was not statistically significant, the within-group change scores did not exceed the minimum clinically important difference (MCID) or the minimum detectable change for the numeric pain rating scale (NPRS), and the longest outcome measure was taken just 3 minutes after the treatment. Nevertheless, 3 prospective single-arm trials[6,7,23] and 3 randomized-controlled trials[10,13,24,42] have previously demonstrated the effectiveness of nonthrust mobilization and/or HVLA thrust manipulation to the cervicothoracic spine, upper thoracic spine, and upper ribs in patients with shoulder impingement syndrome and/or shoulder girdle disorder.

However, to date and to our knowledge, only 1 case report[25] involving 2 patients has been published in the peer-reviewed literature that has directly named second rib syndrome as the primary cause or underlying pain generator in patients presenting with shoulder pain. In addition, no study to date has targeted exclusively the upper thoracic (T2-T3) spine and the second and third ribs with HVLA thrust manipulation for the management of patients with shoulder pain. Therefore, the purpose of this study was to investigate changes in shoulder pain, disability, and perceived level of recovery after upper thoracic and upper rib HVLA thrust manipulation in patients with shoulder pain of any duration secondary to second and third rib syndrome.

METHODS

Subjects

We recruited 10 consecutive patients (5 males and 5 females) with nonmidline, posterolateral upper thoracic, and unilateral posterior shoulder girdle pain with or without posterolateral upper brachial pain, who presented to 1 of 3 private physical therapy outpatient clinics in Italy (Brescia, Lecce, and Bari) between December 2012 and January 2014. Their ages ranged from 18 to 61 years with a mean (SD) of 33.6 (13.4) years. Height ranged from 158 to 185 cm with a mean (SD) of 170.0 (9.5) cm. Weight was 50.1 to 83.0 kg with a mean (SD) of 69.6 (10.7) kg. The duration of symptoms ranged from 1 and 270 days with a mean (SD) of 67.3 (89.3) days. Baseline characteristics of the 10 patients in this case series can be found in Table 1. This study was approved by the Ethics Committee of Universidad Rey Juan Carlos (URJC 12-1065), and all patients provided informed consent before their participation in the study.

To be eligible for inclusion, patients had to (1) exhibit a primary complaint of unilateral, posterior "shoulder girdle" pain[12,24]—that is, "pain between the neck and the elbow at rest or during movement of the upper arm"[10]—with or without brachial pain of any duration; (2) demonstrate findings on physical examination linking "shoulder pain with dysfunction of the cervicothoracic spine and the adjacent ribs"[10]; (3) be between 18 and 70 years of age;

Table 1. *Baseline Variables: Demographics and Outcome Measures*

Baseline Variable	Patients With Rib 2-3 Syndrome (n = 10)
Age (y)	33.6 (13.4)
Sex: male, n (%)	5 (50%)
Duration of symptoms (d)	67.3 (89.3)
BMI (kg/m^2)	24.1 (3.4)
NPRS (0-10)	6.5 (1.8)
SPADI (0-100)	50.3 (17.9)

Data are expressed as mean (SD) except for sex.
BMI, Body Mass Index in kg/m^2; *NPRS*, Numeric Pain Rating Scale, 0–10, lower scores indicate less pain; *SPADI*, Shoulder Pain and Disability Index, 0–100, lower scores indicate greater function.

(4) have an NPRS score of 2 or greater (on a 0-to-10 scale) at rest; (5) have a baseline Shoulder Pain And Disability Index (SPADI) score of 20% or greater[23] (on a 0-to-100 scale); (6) have a negative Neer impingement test[23]; and (7) have familiar pain recognition during firm manual posterior-to-anterior palpation over the second and/or third ribs[25] lateral to the transverse processes but medial to the vertebral border of the scapula.

A negative Neer impingement test was used as one of the inclusion criteria because it has been found to be sensitive but not specific for shoulder impingement syndrome[43,44]; thus, the Neer impingement test appears to be a useful screening test for ruling out synovial disorders of the glenohumeral, subacromial, and coracoacromial articulations. Furthermore, a negative Neer impingement test was recently found by Mintken et al[23] to be 1 of 5 prognostic variables in predicting success in individuals with shoulder pain after HVLA thrust manipulation targeted to the cervicothoracic, upper, and middle thoracic spines.

Patients were excluded if they (1) exhibited any contraindications to manipulative therapy; (2) had red flags (ie, tumor, metabolic diseases, osteoporosis, resting blood pressure greater than 140/90 mm Hg, prolonged history of steroid use, etc); (3) presented with 2 or more positive neurologic signs consistent with a herniated cervical disc and/or nerve root compression (muscle weakness involving a major muscle group of the upper extremity, diminished upper extremity deep tendon reflex, or diminished or absent sensation to pinprick in any upper extremity dermatome); (4) presented with specific rheumatic disorders (polymyalgia rheumatica, rheumatoid arthritis, systemic lupus erythematosus, and fibromyalgia); (5) presented with a diagnosis of cervical spinal stenosis; (6) exhibited bilateral upper extremity symptoms; (7) had evidence of central nervous system involvement (hyperreflexia, sensory disturbances in the hand, intrinsic muscle wasting of the hands, unsteadiness during walking, nystagmus, loss of visual acuity, impaired sensation of the face, altered taste, and presence of pathologic reflexes); (8) had a shoulder disorder due to general internal disease of the thoracic or abdominal organs; (9) had physical examination findings consistent with adhesive capsulitis (ie, active and passive physiologic motion limitations in multiple planes with a capsular pattern); (10) had received a cortisone injection or other fluid injection into the shoulder joint within the last 30 days; (11) had a history of whiplash injury within the previous 6 weeks; (12) had a history of fracture, dislocation, or rotator cuff rupture; (13) had prior surgery to the neck, thoracic spine, or shoulder; (14) had received treatment for neck or shoulder pain from any practitioner within the previous month; (15) had a history of dementia or other psychiatric disorder; or (16) had pending legal action regarding their shoulder pain.

Treating Practitioners

Three manipulative physiotherapists performed all of the HVLA thrust manipulations to the upper thoracic and upper rib articulations on all study participants. At the time of data collection, each of the physiotherapists had completed a postgraduate Master's degree in orthopedic manipulative therapy, had worked in clinical practice for greater than 3 years, and routinely used HVLA thrust manipulation in daily clinical practice. To ensure that all examination, treatment, and outcome procedures were standardized, all therapists were required to study a manual of standard operating procedures and to participate in two 15-hour training sessions.

Examination Procedures

Demographic information and clinical history including age; weight; height; sex; medical history; and the location, nature, and duration of symptoms were collected. This was followed by a physical examination that included, but was not limited to, the following testing procedures. The cervical spine was examined by administering active and passive range of motion testing in all 6 planes, the cervical lateral glide test, the quadrant test, the median nerve upper limb neurodynamic test, and upper limb neurologic testing (reflexes, sensation, and muscle strength representing C5-T1). Screening for periscapular myofascial trigger points was conducted using manual palpation to assess whether myofascial trigger points were a contributing factor to the patient's reported shoulder girdle and/or upper arm pain; however, the presence of myofascial trigger points alone was not used to disqualify inclusion in the study if familiar pain recognition also occurred during firm manual posterior-to-anterior palpation over the second and/or third ribs lateral to the transverse processes but medial to the vertebral border of the scapula.[25] The following special tests for screening of subacromial and/or coracoacromial shoulder impingement[45] were administered on each subject: the Full and Empty Can test,[46,47] the Hawkins-Kennedy test,[48] the Neer impingement test,[49] and the painful arc test.[50] Pain and weakness[51] were assessed

during the administration of the "shoulder impingement" special tests. Arthrogenic assessments included passive accessory motion testing of the glenohumeral joint in supine,[52] unilateral posterior-to-anterior passive accessory mobility testing of the C2-C7 facet joints in prone,[53] cervical lateral glide passive motion testing of C3-7 facet joints in supine,[54] and central PAs over T1-T6 spinous processes.[53]

Although the Hawkins-Kennedy and Empty Can tests were included as part of a comprehensive shoulder examination for all subjects,[46,49,55] we did not use the results of these 2 tests to determine whether patients were included or excluded from the study. That is, the outcome on the Hawkins-Kennedy and Empty Can tests has not been shown to be predictive of success in patients with shoulder pain receiving spinal manipulation. Rather, we used a negative Neer impingement test as 1 of the 7 inclusion criteria because it has previously been found by Mintken et al[23] to predict successful outcomes in individuals with shoulder pain receiving spinal manipulation.

Outcome Measures

The primary outcome measures were the perceived level of shoulder girdle pain as measured by the NPRS[56] and shoulder disability as captured with the SPADI.[57-59] The global rating of change (GROC) was used as a secondary outcome measure.[60]

The NPRS was used to capture the patient's level of pain. Patients were asked to indicate the intensity of their current shoulder girdle pain using an 11-point scale, ranging from 0 (no pain) to 10 (worst pain imaginable).[56] The MCID for the NPRS in a broad population of patients with various musculoskeletal conditions has been reported to be 1.74 points[61]; in addition, and according to Dworkin et al,[62] raw score changes of 1 point or percentage changes of approximately 15% to 20% represent the MCID for the NPRS in subjects with chronic pain. More specifically, the NPRS exhibited a minimal detectable change of 2.5 points[63] and an MCID between 1.1[63] and 2.17[64] points in patients with shoulder pain, which is consistent with the findings in heterogeneous groups of patients with musculoskeletal pain conditions.[61,62]

The SPADI is a self-report questionnaire developed to assess the pain and disability associated with shoulder pathology in people with shoulder pain of musculoskeletal, neurogenic, or undetermined origin.[59] The SPADI contains 13 items that assess 2 domains: a 5-item subscale that measures pain and an 8-item subscale that measures disability. The items of both domains are scored on a Likert scale ranging from 0 to 10, where 0 represents no pain/no difficulty and 10 represents worst pain imaginable/ so difficult required help. Each subscale is summed and transformed to a percentage score out of 100, and then the mean is taken of the 2 subscales (both subscale percentage

scores are weighted equally) to give a total SPADI score out of 100, with higher scores indicating greater impairment or disability. The SPADI has been found to possess excellent reliability, validity, and responsiveness.[59,65] When the SPADI is used more than once on the same subject (ie, at initial consultation and again at discharge), the minimal detectable change has been reported to be 18 points.[66,67] The MCID for the SPADI has been found to be 10 points[65]; however, in a recent systematic review, Roy et al[68] concluded that changes between 8 and 13 points in the SPADI score should be considered clinically meaningful. Michener and Leggin[69] reported a high test-retest reliability and internal consistency for the SPADI.

In addition, at 48 hours, 4 days, 1 month, and 3 months, patients completed a 15-point GROC scale. The GROC was first described by Jaeschke et al[60] and has been used in many studies[70-73] to grade the subject's own perception of overall functional change. The scale ranges from −7 (a very great deal worse) to 0 (about the same) and to +7 (a very great deal better).[60] Intermittent descriptors of worsening or improving are assigned values from −1 to −6 and +1 to +6, respectively. The NPRS was the only outcome measure reassessed immediately postintervention; however, the SPADI and the NPRS were both assessed at baseline, 48 hours, 4 days, 1 month, and 3 months after the first HVLA thrust manipulation session.

Second/Third Ribs and Upper Thoracic HVLA Thrust Manipulation Techniques

All patients were treated for 1 session and then returned 48 hours later to complete outcome measurements and receive a second treatment session. The treatment program consisted of 3 components: (1) an HVLA thrust manipulation targeting the second and third costotransverse rib articulations on the first treatment session; (2) an upper thoracic HVLA thrust manipulation targeted bilaterally to the T2-T3 facet articulations on the second treatment session; and (3) advice to maintain usual activity within the limits of pain. Other interventions (eg, exercises, massage, advice about posture, and treatment directly to the glenohumeral joint or rotator cuff muscles) were considered deviations[10] from the manipulative protocol and, therefore, were discouraged from being implemented. No further treatment was delivered by the manipulative physiotherapist after 48 hours. All follow-up assessments on day 4, 1 month, and 3 months were conducted onsite at the respective clinic. All 10 participants denied receiving other interventions during their respective 3-month follow-up period.

After the initial examination and at the first treatment session, subjects received a single HVLA thrust manipulation targeting the costotransverse articulation of the second rib and third ribs on the symptomatic side. For this technique,[74] the patient's arms were folded horizontally across their chest. Contact was made onto the second

and/or third ribs by hooking the operator's volar aspect of the first carpometacarpal joint perpendicular to the upper ribs just lateral to transverse processes of T2-T3 but medial to the respective rib angles. The operator's underside forearm was prepositioned in mid pronation/supination, and to tension the costotransverse articulation, a caudad directed "pulling down" on the second rib was initiated as the patient was rolled over on to their back. Cephalad and posterior traction was introduced via the operator's own costochondral margin against the patient's forearms. Gentle posterior compression toward the table over the lateral infraclavicular and lateral pectoral region was provided. The patient was then asked to lift their head off the pillow, and at that moment, the following 3 levers of HVLA thrust were simultaneously delivered: (1) a cephalad and posterior traction thrust via the operator's epigastric region, (2) an anterior-to-posterior compression thrust over the infraclavicular and superolateral pectoral region with the operator's cephalad hand, and (3) a pronation and caudad traction thrust of the operator's caudad or underside hand (Fig 1).

Forty-eight hours after the first treatment session, a single HVLA thrust manipulation directed bilaterally to the upper thoracic (T2-T3) spine with the patient supine was performed. For this technique,[74] the patient held her/his arms and forearms across the chest with the elbows aligned in a superoinferior direction. The physiotherapist contacted the transverse processes of the lower vertebrae of the target motion segment with the thenar eminence and middle phalanx of the third digit. The upper lever was localized to the target motion segment by adding the secondary levers of rotation away and side bend toward the therapist and the lower lever or underside hand used pronation and radial deviation to achieve rotation toward and side bend away moments, respectively. The space inferior to the xiphoid process and costochondral margin of the therapist was used as the contact point against the patient's elbows to deliver an HVLA thrust manipulation in an anterior to posterior direction targeting T2-T3 bilaterally (Fig 2).

For both the upper thoracic (T2-T3) and second rib thrust manipulations, if no popping or cracking sound was heard on the first attempt, the therapist repositioned the patient by adjusting the secondary levers and performed a second HVLA thrust manipulation. A maximum of 2 attempts were performed on each patient.[71,73,75-77]

Statistical Analysis

Data analysis was performed using SPSS 21.0 (IBM, Armonk, NY). Descriptive statistics, including frequency counts for categorical variables and measures of central tendency and dispersion for continuous variables, were calculated to summarize the data. A normal distribution of quantitative data for the 2 primary outcome measures (ie, NPRS for pain and SPADI for disability) was assessed using the Kolmogorov-Smirnov test; both outcomes were

Fig 1. *High-velocity low-amplitude thrust manipulation targeting the second and third costotransverse rib articulations.*

normally distributed ($P > .05$). A 1-way analysis of variance (ANOVA) for repeated measures, with a Greenhouse-Geisser epsilon correction, was used to compare the intragroup scores of each variable (1 for the NPRS data and 1 for the SPADI data) during postintervention assessments. Post hoc pairwise comparisons (paired t tests) were performed, examining the difference between baseline and each of the follow-up periods using the Bonferroni correction at an α level of .05. The statistical analysis was conducted at a 95% confidence level. All 10 participants completed outcomes through 3-month follow-up. To quantify the treatment magnitude, within-group effect sizes were calculated using Cohen's d coefficient. An effect size of greater than 0.8 was considered large, close to 0.5 was considered moderate, and less than 0.2 was considered small.

RESULTS

Shoulder Girdle Pain (NPRS)

Using the Greenhouse-Geisser epsilon correction, a 1-way repeated-measures ANOVA revealed a significant ($F = 63.439$; $P = .001$) decrease in shoulder girdle pain (NPRS) after 2 sessions of HVLA thrust manipulation targeting the second and third ribs on the symptomatic side and the upper thoracic spine (T2-T3) bilaterally (Fig 3). Post hoc pairwise comparisons showed significant differences between the pretreatment pain scores and each of the 5 postintervention pain scores ($P < .05$); however, no significant differences in shoulder pain (NPRS) were found between immediately postmanipulation and 48 hours ($P = .279$), day 4 and 1 month ($P = .591$), and 1 month and 3 months ($P = .081$). Table 2 provides the mean and SDs for rest shoulder girdle pain intensity (NPRS) scores at all assessment periods between baseline and 3-month follow-up. Table 3 provides the preintervention and

Fig 2. *High-velocity low-amplitude thrust manipulation directed bilaterally to the upper thoracic (T2-T3) spine.*

Fig 3. *Mean shoulder girdle pain scores (NPRS 0-10) from baseline to 3 months. Mean and 95% confidence interval for shoulder girdle pain scores (NPRS 0-10) at rest from baseline to 3 months after an initial session of HVLA thrust manipulation directed to the costotransverse articulations of the second and third ribs on the symptomatic side and a second session of HVLA thrust manipulation targeting the upper thoracic spine (T2-3) bilaterally (P = .001).*

postintervention scores for shoulder pain (NPRS) on each of the subjects at all time points.

A significant ($P = .001$) decrease, with large (ie, Cohen's $d = 0.8$ or greater) within-group effect sizes were found between preintervention data and all 5 postintervention assessments in shoulder girdle pain (Cohen's $d = 2.33$ [baseline to immediately posttreatment]; Cohen's $d = 2.63$ [baseline to 48 hours]; Cohen's $d = 4.07$ [baseline to day 4]; Cohen's $d = 4.01$ [baseline to 1 month]; Cohen's $d = 4.61$ [baseline to 3 months]) after 2 sessions of HVLA thrust manipulation targeting the upper thoracic spine (T2-T3) bilaterally and the second and third costotransverse articulations on the symptomatic side.

Shoulder Pain and Disability (SPADI)

Using the Greenhouse-Geisser epsilon correction, a 1-way repeated measures ANOVA found a significant ($F = 59.997$; $P = .001$) decrease in disability (SPADI score) after 2 sessions of HVLA thrust manipulation targeting the second and third ribs on the symptomatic side and the upper thoracic spine (T2-T3) bilaterally (Fig 4). Post hoc pairwise comparisons showed significant differences between the pretreatment disability scores and each of the 4 postintervention disability scores ($P < .05$); however, no significant differences in disability (SPADI) were found between day 4 and 1 month ($P = .474$), and 1 month and 3 months ($P = .084$). Table 2 provides the mean and SDs for shoulder disability (SPADI) scores at all assessment periods between baseline and 3-month follow-up. Table 4 provides the preintervention and postintervention scores for disability (SPADI) on each of the subjects at all time points.

A significant ($P = .001$) decrease, with large (ie, Cohen's $d \geq 0.8$) within-group effect sizes (ie, the strength of association or treatment magnitude) were found between preintervention data and all 4 postintervention assessments
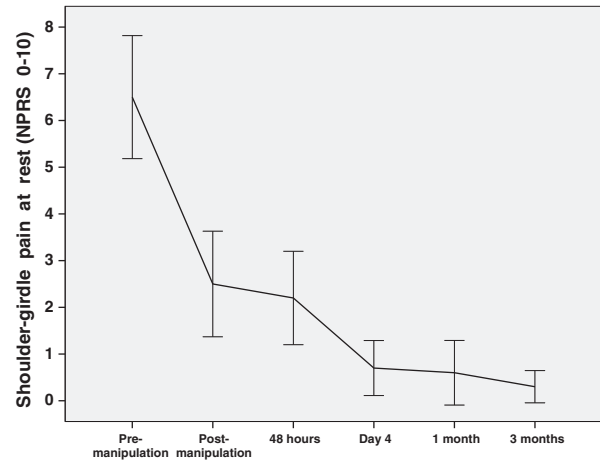
in disability (Cohen's $d = 2.68$ [baseline to 48 hours]; Cohen's $d = 3.77$ [baseline to day 4]; Cohen's $d = 3.80$ [baseline to 1 month]; Cohen's $d = 3.91$ [baseline to 3 months]) after 2 sessions of HVLA thrust manipulation targeting the upper thoracic spine (T2-T3) bilaterally and the second and third costotransverse articulations on the symptomatic side.

Global Rating of Change

In 10 patients with shoulder pain secondary to second and third rib syndrome and after 1 to 2 sessions of HVLA thrust manipulation targeting the upper thoracic (T2-T3) spine bilaterally and the costotransverse articulations of ribs 2 and/or 3 on the symptomatic side, the mean (SD) GROC scores were +5.4 (1.1) at 48 hours, +6.2 (0.8) at day 4, +6.8 (0.4) at 1-month follow-up, and +6.8 (0.4) at 3-month follow-up, indicating "moderately better" and "a great deal better" outcomes in the immediate and short terms and "a very great deal better" outcome in the long term at 3-month follow-up. For all assessment periods, the mean and SD for posttreatment GROC scores can be found in Table 2.

Discussion

In this prospective study of 10 patients with shoulder girdle pain secondary to second and third rib syndrome, a statistically significant and clinically meaningful reduction in resting shoulder pain (NPRS) and disability (SPADI) was demonstrated after 2 sessions of HVLA thrust manipulation directed to the upper thoracic zygapophyseal articulations

Table 2. *Preintervention and Postintervention Scores for Shoulder Pain, Disability, and GROC*

Variable	Preintervention	Immediately Postintervention	48 h	Day 4	1 mo	3 mo
NPRS (0-10)	6.5 (1.8)	2.5 (1.6)	2.2 (1.4)	0.7 (0.8)	0.6 (0.9)	0.3 (0.5)
SPADI (0-100)	50.3 (17.9)	NA	11.1 (10.2)	1.9 (2.5)	1.5 (2.4)	0.5 (0.8)
GROC (−7 to +7)	NA	NA	+5.4 (1.1)	+6.2 (0.8)	+6.8 (0.4)	+6.8 (0.4)

Data are expressed as mean (SD).
GROC, Global Rating of Change, -7 to +7, higher scores indicate greater overall improvement; *NPRS*, numeric pain rating scale, 0–10, lower scores indicate less pain; *SPADI*, Shoulder Pain and Disability Index, 0–100, lower scores indicate greater function.

bilaterally and the costotransverse articulations of the second and third ribs on the symptomatic side. Large (ie, Cohen's $d \geq 0.8$) within-group effect sizes were found between preintervention data and all postintervention assessments in resting shoulder pain (NPRS) and disability (SPADI), suggesting a strong clinical effect that was retained at the 3-month follow-up.

Our findings are in agreement with several studies that have previously investigated the effectiveness of HVLA thrust manipulation and/or nonthrust mobilization to the cervicothoracic junction, middle thoracic spine, upper thoracic spine, and/or upper ribs in patients with shoulder pain.[6,7,10,23,24,42] In contrast, a recent randomized controlled trial[41] found no statistically significant between-group difference in shoulder pain after thoracic HVLA thrust manipulation when compared with sham manipulation; however, unlike our study, the midthoracic (T3-T7) region was targeted rather than the upper thoracic spine and upper ribs, the longest outcome measure was taken just 3 minutes after the treatment, and the symptomatic portion of the sample only included individuals that met a specific diagnostic protocol for shoulder impingement syndrome—that is, not second and third rib syndrome.

Over a 12-week period and after a mean of 3.8 sessions of HVLA thrust manipulation and/or nonthrust mobilization to the cervical spine, upper thoracic spine, and adjacent ribs, Bergman et al[10] found 43% of the patients with shoulder pain assigned to the usual medical care combined with manipulative therapy group reported full recovery compared with 21% of the control group (ie, usual medical care alone). The study by Bergman et al[10] appears to be the first trial that evaluated the effectiveness of adding manipulative therapy to the cervicothoracic spine and upper ribs with usual medical care for the treatment of specifically shoulder girdle syndrome, not subacromial impingement or rotator cuff tendonitis. Compared with the study conducted by Winters et al,[13,24] the trial by Bergman et al[10] and our prospective case series only included patients with shoulder symptoms thought to originate from cervicothoracic spine and upper rib dysfunction (ie, shoulder girdle syndrome, not synovial syndrome).[12,13,24] Nevertheless, in the trial by Bergman et al,[10] it remains unknown as to how many of the patients in the combined manipulative therapy and usual medical group actually received HVLA thrust manipulation vs nonthrust mobilization alone or a combination of both. In addition, no description of the actual HVLA thrust manipulation or nonthrust mobilization techniques or the target levels were

provided in the trial by Bergman et al.[10] Nevertheless, like the findings of our case series and as stated in the very last sentence of the article by Bergman et al,[10] "For patients with shoulder symptoms in whom dysfunction of the cervicothoracic spine and adjacent ribs is found, referral to an manual therapist should be considered."[10]

This study found a 61.5% (6.5-2.5 points) reduction in rest shoulder girdle pain immediately after a single session of HVLA thrust manipulation to the upper thoracic spine and upper ribs. Similarly, in an observational study of 21 patients with shoulder pain and immediately after a single session of "HVLA thrust manipulation to the upper thoracic spine and/or ribs," Strunce et al[7] reported a 51% (63.1-31.2 mm) reduction in resting pain intensity scores and a mean GROC score of +4.2. Similar to the +4.2 GROC score immediately after the intervention in the study of Strunce et al,[7] our mean GROC score was +5.4 at 48-hour follow-up. However, unlike Strunce et al[7] that only measured preoutcomes and immediately postoutcomes, we tracked pain and disability up to 3 months out. In addition, unlike the present case series that targeted specifically ribs 2 and 3, it remains unknown if ribs 1, 2, 3, or lower were manipulated in the study by Strunce et al.[7]

According to the findings of the trial by Winters et al[24] that compared physiotherapy (exercise, massage, and physical modalities twice per week), manipulation (up to 6 sessions of nonthrust mobilization and/or HVLA thrust manipulation to the cervical spine, upper thoracic spine, upper ribs, acromioclavicular joint, and glenohumeral joint), and corticosteroid injections (1-3 injection sessions over 3 weeks directed to the subacromial space, glenohumeral joint capsule, and/or acromioclavicular joint), manipulation was found to be superior ($P < .001$) to physiotherapy in the shoulder girdle group. More specifically, 5 weeks after randomization, 70% of the patients in the manipulation group considered that they were "cured" compared with 10% of the physiotherapy group. In contrast, for patients in the "synovial" group and 5 weeks after randomization, 75% of the patients in the injection group (average number of injections was 1.8) reported being cured compared with 20% in the physiotherapy group and 40% in the manipulation group. In agreement with the findings of the present case series, Winters et al[24] concluded, "For treating shoulder girdle disorders, manipulation seems to be the preferred treatment. For the synovial disorders, corticosteroid injection seems the best treatment."
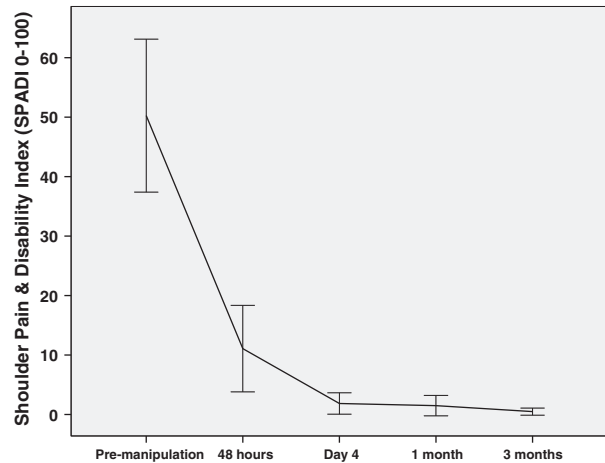
Table 3. *Preinterventon and Postintervention Scores for Shoulder Pain*

NPRS	Preintervention	Immediately Postintervention	48 h	Day 4	1 m	3 mo
Subject 1	5	2	2	1	0	0
Subject 2	8	3	2	1	0	0
Subject 3	7	4	4	2	2	1
Subject 4	3	0	0	0	0	0
Subject 5	5	3	2	0	0	0
Subject 6	8	2	3	0	0	0
Subject 7	5	1	0	0	0	0
Subject 8	8	4	3	0	0	0
Subject 9	8	1	2	2	2	1
Subject 10	8	5	4	1	2	1

NPRS, numeric pain rating scale, 0-10, lower scores indicate less pain.

Fig 4. *Mean shoulder pain and disability scores (SPADI 0-100) from baseline to 3 months. Mean and 95% confidence interval for SPADI (0-100) scores from baseline to 3 months after an initial session of HVLA thrust manipulation directed to the costotransverse articulations of the second and third ribs on the symptomatic side and a second session of HVLA thrust manipulation targeting the upper thoracic spine (T2-3) bilaterally (P = .001).*

Nevertheless, although Winters et al[24] were the first to publish a randomized clinical trial describing the positive effects of manipulation in treating shoulder pain, no descriptions of the actual cervical, thoracic, rib, acromio-clavicular, or glenohumeral joint manipulation techniques were reported; furthermore, it was not disclosed how many of the subjects in the "manipulation group" received nonthrust mobilization vs HVLA thrust manipulation. In addition, no subjects in the trial by Winters et al[24] received HVLA thrust manipulation targeting exclusively the second and third costotransverse rib articulations and/or upper thoracic zygapophyseal articulations. Notably, although Winters et al[24] found short-term (ie, 11 weeks) effectiveness for corticosteroid injection therapy and cervical, thoracic, upper rib, acromioclavicular, and/or glenohumeral joint manipulation (or nonthrust joint mobilization) for shoulder pain, no significant differences were found between the 3 treatment groups (physiotherapy, manipulation, and injections) 2 to 3 years later in the long-term follow-up study.[13] Therefore, although the significant reductions in pain and disability in our prospective case series were found to not decay between the 1- and 3-month interval, it remains unknown if these changes would still be present 1 to 2 years later.[2,13]

Although the mean duration of symptoms was 67 days, 1 of the 10 patients reported symptoms for just 1 day before seeking treatment from the physiotherapist. Rather than describing a specific traumatic event or insidious onset, this particular patient reported waking one morning with unilateral, posterior shoulder girdle pain that was sharp in nature and 8/10 on the NPRS. In addition, this patient also met the other 6 inclusion criteria that were used in this prospective case series. Musculoskeletal physiotherapy practices that are functioning in a direct access model frequently evaluate and treat individuals the day after the initial injury or pain presentation—that is, the inclusion of an individual with just 1 day of symptoms should not be considered unusual.[78-82] In addition and like the present case series, there are several studies in the manual therapy literature that have used pain "of any duration" or "mixed duration"—that is, acute (1-30 days), subacute (31-89 days), or chronic (>90 days)—as an inclusion criterion.[71,83-85] Moreover, Boyle[25] was the first to publish a peer-reviewed article on second rib syndrome, and notably, he described the effect of rib manipulation on 2 separate patients: 1 acute (just a few days) and 1 chronic (18 months).

There are several studies that have found an interaction between myofascial trigger points and underlying joint dysfunction.[86-90] More specifically, deactivation of myofascial trigger points after manipulative therapy or intraarticular injections to segmentally related facet joints,[87,88,90] improved muscular feed forward activation timing or motor performance after HVLA thrust manipulation,[71,91-94] and reductions in pain and disability after HVLA thrust manipulation in patients with myofascial trigger points and/or myofascial pain syndrome[87,89] have previously been demonstrated. Nevertheless, we did not use the presence of trigger points as one of our inclusion or exclusion criterion because high-quality evidence suggests that manual examination for the identification of the specific location of the "trigger point" is not a valid[95-97] or reliable[95,98-100] process between examiners.

Biomechanical,[30,31,41,56,101-106] spinal or segmental,[94,107-111] and central descending inhibitory pain pathway[112-115] models have all been suggested as possible explanations for the immediate hypoalgesic effects observed after HVLA thrust manipulation. Recently, the biomechanical effects of HVLA thrust manipulation have been under scientific scrutiny,[109] and it is plausible that the clinical benefits found in our study are associated with a neurophysiological response involving temporal sensory summation at the dorsal horn of the spinal cord[107]; however, this proposed model is

Table 4. *Preintervention and Postintervention Scores for Disability*

SPADI	Preintervention	48 h	Day 4	1 mo	3 mo
Subject 1	28.3	6.9	0.6	0.0	0.0
Subject 2	71.8	6.1	2.6	0.0	0.0
Subject 3	51.1	20.5	6.1	4.5	1.6
Subject 4	24.1	0.0	0.0	0.0	0.0
Subject 5	49.0	16.0	0.0	0.0	0.0
Subject 6	59.4	4.0	1.0	0.0	0.0
Subject 7	25.9	5.3	0.0	0.0	0.0
Subject 8	65.0	25.0	0.0	0.0	0.0
Subject 9	63.1	0.0	6.5	5.5	2.3
Subject 10	65.0	27.0	1.6	4.9	1.0

SPADI, Shoulder Pain and Disability Index.

currently supported only by findings from transient, experimentally induced pain in healthy subjects[107,108,110,116,117] and not in patients with shoulder pain. In summary, there is currently insufficient evidence to support a dominant role of any of these 3 hypoalgesic mechanisms.

Limitations

The sample size was small, and no comparison group was included. To make inferences on cause-and-effect relationships, future studies should use larger sample sizes and use a comparison group with random allocation to the experimental and control groups. An observational, descriptive case series was designed to explore whether manual therapy could be useful in patients with shoulder pain associated with second and third rib syndrome. We believe that this study may be the stimulus for future randomized controlled trials on this topic. In addition, although randomized controlled trials are considered to be the "gold standard" for experimental designs, observational, descriptive case series do have a place in clinical research and are appropriately ranked as level III evidence on the hierarchy.[118,119] By definition, descriptive studies (eg, prospective case series) are observational and do not have a comparison group.[118] The benefits of using a descriptive study are for trend analysis and hypothesis generation[120,121]; moreover, "descriptive studies are often a springboard into more rigorous studies with comparison groups."[122] Therefore, considering only 1 case report[25] has been published on second rib syndrome, we believe that a grouping of 10 patients in a prospective, single-arm study is a progression of the evidence surrounding this topic. We do, however, realize that cause-and-effect inferences cannot be made from observational studies,[122] and we have been very careful not to make such inferences. Second, we did not take any outcome measures beyond 3 months after the intervention; therefore, it is unknown if the changes in pain and disability that we found would still be present at 1 year after the intervention. Third, standardizing the treatment to just 2 specific manipulative procedures is not pragmatic and does not represent the common clinical practice of being able to alter the manipulation technique, target level, line of drive, or patient position during different treatment sessions based on clinical reasoning and response to the previous treatment session. Fourth, the results of our study cannot be generalized to individuals with shoulder pain secondary to synovial disorders of the subacromial cavity, glenohumeral joint, acromioclavicular joint, or coracoacromial structures. We attempted to screen out synovial disorders by only including subjects with a negative Neer impingement test. Fifth, we did not use a validated diagnostic protocol to determine whether the patients in this study actually had second and third rib syndrome or some other shoulder disorder. Finally, another limitation of this study is that 3 different practitioners administered all of the upper thoracic and upper rib HVLA thrust manipulations; hence, it cannot be assumed that individual and subtle nuances to technique delivery adopted with time and experience would be identical in different practitioners administering the same procedure. Future research should determine whether second and third rib syndrome is a valid diagnostic subgroup of patients with shoulder pain and whether these patients respond any different to HVLA thrust manipulation or other interventions than those currently categorized as having a "shoulder girdle disorder."

CONCLUSION

The results of the current study demonstrated that patients with shoulder pain secondary to second and third rib syndrome who received the combination of 2 sessions of HVLA thrust manipulation directed to the upper thoracic zygapophyseal articulations bilaterally and the second and third rib costotransverse articulations on the symptomatic side experienced significant reductions in pain and disability and showed significant improvements in perceived level of recovery, at 48-hour, 1-month, and 3-month follow-ups.

CONTRIBUTORSHIP INFORMATION

Concept development (provided idea for the research): J.D., F.M.d., G.G., F.M.i.

Design (planned the methods to generate the results): J.D., F.M.d., G.G., F.M.i.

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): J.D., F.M.d.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): J.D., F.M.d., G.G., F.M.i.

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): J.D., F.M.d., T.P., C.F.d.l.P.

Literature search (performed the literature search): J.D., F.M.d., T.P.

Writing (responsible for writing a substantive part of the manuscript): J.D., F.M.d., G.G., FM.i., T.P., C.F.d.l.P.

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): J.D., FM.d., G.G., F.M.i., T.P., C.F.d.l.P.

Other (list other specific novel contributions): J.D., F.M.d., G.G., F.M.i., T.P., C.F.d.l.P.

Practical Applications

- Patients with shoulder pain secondary to second and third rib syndrome who received the combination of HVLA thrust manipulation targeted to the upper thoracic spine bilaterally and the second and third ribs on the symptomatic side experienced statistically significant reductions in pain and disability and showed significant improvements in perceived level of recovery.
- Large within-group effect sizes were found between preintervention data and all postintervention assessments in both shoulder pain and disability.
- At 3-month follow-up, a statistically significant and clinically meaningful decrease in shoulder pain and disability was observed; furthermore, the mean GROC score indicated "a very great deal better."

REFERENCES

1. van der Windt DA, Koes BW, Boeke AJ, Deville W, De Jong BA, Bouter LM. Shoulder disorders in general practice: prognostic indicators of outcome. Br J Gen Pract 1996;46: 519-23.
2. Winters JC, Sobel JS, Groenier KH, Arendzen JH, Meyboom-de Jong B. The long-term course of shoulder complaints: a prospective study in general practice. Rheumatology (Oxford) 1999;38:160-3.
3. Goodman CC. Screening for gastrointestinal, hepatic/biliary, and renal/urologic disease. J Hand Ther 2010;23:140-56 [quiz 157].
4. Michener LA, McClure PW, Karduna AR. Anatomical and biomechanical mechanisms of subacromial impingement syndrome. Clin Biomech (Bristol, Avon) 2003;18:369-79.
5. Vecchio P, Kavanagh R, Hazleman BL, King RH. Shoulder pain in a community-based rheumatology clinic. Br J Rheumatol 1995;34:440-2.
6. Boyles RE, Ritland BM, Miracle BM, et al. The short-term effects of thoracic spine thrust manipulation on patients with shoulder impingement syndrome. Man Ther 2009;14: 375-80.
7. Strunce JB, Walker MJ, Boyles RE, Young BA. The immediate effects of thoracic spine and rib manipulation on subjects with primary complaints of shoulder pain. J Man Manip Ther 2009;17:230-6.
8. Ostor AJ, Richards CA, Prevost AT, Speed CA, Hazleman BL. Diagnosis and relation to general health of shoulder disorders presenting to primary care. Rheumatology (Oxford) 2005;44: 800-5.
9. Picavet HS, Schouten JS. Musculoskeletal pain in the Netherlands: prevalences, consequences and risk groups, the DMC(3)-study. Pain 2003;102:167-78.
10. Bergman GJ, Winters JC, Groenier KH, et al. Manipulative therapy in addition to usual medical care for patients with shoulder dysfunction and pain: a randomized, controlled trial. Ann Intern Med 2004;141:432-9.
11. Sobel JS, Kremer I, Winters JC, Arendzen JH, de Jong BM. The influence of the mobility in the cervicothoracic spine and the upper ribs (shoulder girdle) on the mobility of the scapulohumeral joint. J Manipulative Physiol Ther 1996;19: 469-74.
12. Sobel JS, Winters JC, Groenier K, Arendzen JH, Meyboom de Jong B. Physical examination of the cervical spine and shoulder girdle in patients with shoulder complaints. J Manipulative Physiol Ther 1997;20:257-62.
13. Winters JC, Jorritsma W, Groenier KH, Sobel JS, Meyboom-de Jong B, Arendzen HJ. Treatment of shoulder complaints in general practice: long term results of a randomised, single blind study comparing physiotherapy, manipulation, and corticosteroid injection. BMJ 1999;318:1395-6.
14. Davidovic L, Lotina S, Kostic D, Pavlovic S, Jakovljevic N, Djoric P. The upper thoracic outlet vascular syndrome. Acta Chir Iugosl 2001;48:31-6.
15. Davidovic LB, Lotina SI, Vojnovic BR, et al. Treatment of the thoracic outlet vascular syndrome. Srp Arh Celok Lek 1998;126:23-30.
16. DeFranca GG, Levine LJ. The T4 syndrome. J Manipulative Physiol Ther 1995;18:34-7.
17. Dzieciuchowicz L, Wlodarczyk W, Oszkinis G. Critical upper limb ischemia caused by initially undiagnosed thoracic outlet syndrome—case report. Pol Przegl Chir 2012;84: 158-62.
18. Menck JY, Requejo SM, Kulig K. Thoracic spine dysfunction in upper extremity complex regional pain syndrome type I. J Orthop Sports Phys Ther 2000;30:401-9.
19. Nichols AW. The thoracic outlet syndrome in athletes. J Am Board Fam Pract 1996;9:346-55.
20. Rogers L. Upper-limb pain due to lesions of the thoracic outlet; the scalenus syndrome, cervical rib, and costoclavicular compression. Br Med J 1949;2:956-8.
21. Shepherd J. Thoracic outlet compression syndrome: a rare cause of upper extremity symptoms in children. J Am Board Fam Pract 1999;12:403-5.
22. Tucker AM. Shoulder pain in a football player. Med Sci Sports Exerc 1994;26:281-4.
23. Mintken PE, Cleland JA, Carpenter KJ, Bieniek ML, Keirns M, Whitman JM. Some factors predict successful short-term outcomes in individuals with shoulder pain receiving cervicothoracic manipulation: a single-arm trial. Phys Ther 2010;90:26-42.
24. Winters JC, Sobel JS, Groenier KH, Arendzen HJ, Meyboom-de Jong B. Comparison of physiotherapy, manipulation, and corticosteroid injection for treating

shoulder complaints in general practice: randomised, single blind study. BMJ 1997;314:1320-5.

25. Boyle JJ. Is the pain and dysfunction of shoulder impingement lesion really second rib syndrome in disguise? Two case reports. Man Ther 1999;4:44-8.

26. Lindgren KA, Leino E. Subluxation of the first rib: a possible thoracic outlet syndrome mechanism. Arch Phys Med Rehabil 1988;69:692-5.

27. Yeager D. First rib fixation and "dead arm" in baseball pitchers. Baseball Strength Coaching; 20121-7.

28. Zatocil Z, Gregor Z, Leypold J, Roubal P. Resection of the first rib for the upper thoracic outlet syndrome—long-term experience. Rozhl Chir 1997;76:242-5.

29. Zatocil Z, Koristek V, Gregor Z, Cerny J. Personal experience with resection of the first rib for the upper thoracic outlet syndrome using the transaxillary approach. Cas Lek Cesk 1987;126:641-3.

30. Norlander S, Gustavsson BA, Lindell J, Nordgren B. Reduced mobility in the cervico-thoracic motion segment—a risk factor for musculoskeletal neck-shoulder pain: a two-year prospective follow-up study. Scand J Rehabil Med 1997;29: 167-74.

31. Norlander S, Aste-Norlander U, Nordgren B, Sahlstedt B. Mobility in the cervico-thoracic motion segment: an indicative factor of musculo-skeletal neck-shoulder pain. Scand J Rehabil Med 1996;28:183-92.

32. Grieve GP. Common vertebral joint problems. 2nd ed. Edinburgh, NY: Churchill Livingstone; 1988.

33. Jirout J. X-ray studies on the dynamics of the first rib. Manuelle Med 1983;21:20-2.

34. Sobel JS, Winters JC, Arendzen JH, Groenier K, Meyboom de Jong B. Schouderklachten in de Huisartspraktijk. Huisarts Wet 1995;38:342-7.

35. Maigne JY, Maigne R, Guerin-Surville H. Upper thoracic dorsal rami: anatomic study of their medial cutaneous branches. Surg Radiol Anat 1991;13:109-12.

36. Durkovicova C, Holomanova A, Cierny G. Localization of motor cells for the first and second anterior thoracic nerves and the long thoracic nerve of the cat [proceedings]. Folia Morphol (Praha) 1977;25:311-4.

37. Ishizuka K, Sakai H, Tsuzuki N, Nagashima M. Topographic anatomy of the posterior ramus of thoracic spinal nerve and surrounding structures. Spine (Phila Pa 1976) 2012;37: E817-22.

38. Moore DC. Anatomy of the intercostal nerve: its importance during thoracic surgery. Am J Surg 1982;144:371-3.

39. Nakamura Y, Iino Y, Fujisawa Y, Kawachi Y, Otsuka F. Intraneural granular cell tumor of the dorsal ramus of a thoracic nerve. Indian J Dermatol Venereol Leprol 2013;79: 258-60.

40. Weddell G. The anatomy of the thoracic outlet in relation to "irritation" and compression of nerve trunks. Proc R Soc Med 1945;38:601-4.

41. Haik MN, Alburquerque-Sendin F, Silva CZ, Siqueira-Junior AL, Ribeiro IL, Camargo PR. Scapular kinematics pre- and post-thoracic thrust manipulation in individuals with and without shoulder impingement symptoms: a randomized controlled study. J Orthop Sports Phys Ther 2014;44:475-87.

42. Bang MD, Deyle GD. Comparison of supervised exercise with and without manual physical therapy for patients with shoulder impingement syndrome. J Orthop Sports Phys Ther 2000;30:126-37.

43. Calis M, Akgun K, Birtane M, Karacan I, Calis H, Tuzun F. Diagnostic values of clinical diagnostic tests in subacromial impingement syndrome. Ann Rheum Dis 2000;59:44-7.

44. MacDonald PB, Clark P, Sutherland K. An analysis of the diagnostic accuracy of the Hawkins and Neer subacromial impingement signs. J Shoulder Elbow Surg 2000;9:299-301.

45. Michener LA, Walsworth MK, Doukas WC, Murphy KP. Reliability and diagnostic accuracy of 5 physical examination tests and combination of tests for subacromial impingement. Arch Phys Med Rehabil 2009;90:1898-903.

46. Itoi E, Kido T, Sano A, Urayama M, Sato K. Which is more useful, the "full can test" or the "empty can test," in detecting the torn supraspinatus tendon? Am J Sports Med 1999;27: 65-8.

47. Jobe FW, Moynes DR. Delineation of diagnostic criteria and a rehabilitation program for rotator cuff injuries. Am J Sports Med 1982;10:336-9.

48. Hawkins RJ, Kennedy JC. Impingement syndrome in athletes. Am J Sports Med 1980;8:151-8.

49. Park HB, Yokota A, Gill HS, El Rassi G, McFarland EG. Diagnostic accuracy of clinical tests for the different degrees of subacromial impingement syndrome. J Bone Joint Surg Am 2005;87:1446-55.

50. Kessel L, Watson M. The painful arc syndrome. Clinical classification as a guide to management. J Bone Joint Surg (Br) 1977;59:166-72.

51. Kelly BT, Kadrmas WR, Speer KP. The manual muscle examination for rotator cuff strength. An electromyographic investigation. Am J Sports Med 1996;24:581-8.

52. Hengeveld E, Banks K, Maitland GD. Maitland's peripheral manipulation. 4th ed. Edinburgh, New York: Elsevier/ Butterworth Heinemann; 2005.

53. Maitland GD, Edwards BC. Vertebral manipulation. 5th ed. London, Boston: Butterworths; 1986.

54. Fernandez-de-las-Penas C, Downey C, Miangolarra-Page JC. Validity of the lateral gliding test as tool for the diagnosis of intervertebral joint dysfunction in the lower cervical spine. J Manipulative Physiol Ther 2005;28:610-6.

55. Magee DJ. Orthopedic physical assessment. 5th ed. St. Louis, MO: Saunders Elsevier; 2008.

56. Norlander S, Nordgren B. Clinical symptoms related to musculoskeletal neck-shoulder pain and mobility in the cervico-thoracic spine. Scand J Rehabil Med 1998;30: 243-51.

57. Breckenridge JD, McAuley JH. Shoulder Pain and Disability Index (SPADI). J Physiother 2011;57:197.

58. MacDermid JC, Solomon P, Prkachin K. The Shoulder Pain and Disability Index demonstrates factor, construct and longitudinal validity. BMC Musculoskelet Disord 2006;7: 12.

59. Roach KE, Budiman-Mak E, Songsiridej N, Lertratanakul Y. Development of a shoulder pain and disability index. Arthritis Care Res 1991;4:143-9.

60. Jaeschke R, Singer J, Guyatt GH. Measurement of health status. Ascertaining the minimal clinically important difference. Control Clin Trials 1989;10:407-15.

61. Farrar JT, Young JP, LaMoreaux L, Werth JL, Poole RM. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. Pain 2001;94:149-58.

62. Dworkin RH, Turk DC, McDermott MP, et al. Interpreting the clinical importance of group differences in chronic pain clinical trials: IMMPACT recommendations. Pain 2009;146: 238-44.

63. Mintken PE, Glynn P, Cleland JA. Psychometric properties of the shortened disabilities of the Arm, Shoulder, and Hand Questionnaire (QuickDASH) and Numeric Pain Rating Scale in patients with shoulder pain. J Shoulder Elbow Surg 2009; 18:920-6.

64. Michener LA, Snyder AR, Leggin BG. Responsiveness of the numeric pain rating scale in patients with shoulder pain and the effect of surgical status. J Sport Rehabil 2011;20: 115-28.

65. Heald SL, Riddle DL, Lamb RL. The shoulder pain and disability index: the construct validity and responsiveness of a region-specific disability measure. Phys Ther 1997;77: 1079-89.

66. Angst F, Goldhahn J, Drerup S, Aeschlimann A, Schwyzer HK, Simmen BR. Responsiveness of six outcome assessment instruments in total shoulder arthroplasty. Arthritis Rheum 2008;59:391-8.

67. Angst F, Goldhahn J, Pap G, et al. Cross-cultural adaptation, reliability and validity of the German Shoulder Pain and Disability Index (SPADI). Rheumatology (Oxford) 2007;46: 87-92.

68. Roy JS, MacDermid JC, Woodhouse LJ. Measuring shoulder function: a systematic review of four questionnaires. Arthritis Rheum 2009;61:623-32.

69. Michener LA, Leggin BG. A review of self-report scales for the assessment of functional limitation and disability of the shoulder. J Hand Ther 2001;14:68-76.

70. Cleland JA, Childs JD, Fritz JM, Whitman JM, Eberhart SL. Development of a clinical prediction rule for guiding treatment of a subgroup of patients with neck pain: use of thoracic spine manipulation, exercise, and patient education. Phys Ther 2007;87:9-23.

71. Dunning JR, Cleland JA, Waldrop MA, et al. Upper cervical and upper thoracic thrust manipulation versus nonthrust mobilization in patients with mechanical neck pain: a multicenter randomized clinical trial. J Orthop Sports Phys Ther 2012;42:5-18.

72. Whitman JM, Cleland JA, Mintken PE, et al. Predicting short-term response to thrust and nonthrust manipulation and exercise in patients post inversion ankle sprain. J Orthop Sports Phys Ther 2009;39:188-200.

73. Cleland JA, Glynn P, Whitman JM, Eberhart SL, MacDonald C, Childs JD. Short-term effects of thrust versus nonthrust mobilization/manipulation directed at the thoracic spine in patients with neck pain: a randomized clinical trial. Phys Ther 2007;87:431-40.

74. Hartman L. Handbook of osteopathic technique. 3rd ed. Cheltenham, UK: Nelson Thornes Ltd.; 2001.

75. Gonzalez-Iglesias J, Fernandez-de-las-Penas C, Cleland JA, Alburquerque-Sendin F, Palomeque-del-Cerro L, Mendez-Sanchez R. Inclusion of thoracic spine thrust manipulation into an electro-therapy/thermal program for the management of patients with acute mechanical neck pain: a randomized clinical trial. Man Ther 2009;14:306-13.

76. Gonzalez-Iglesias J, Fernandez-de-las-Penas C, Cleland JA, Gutierrez-Vega Mdel R. Thoracic spine manipulation for the management of patients with neck pain: a randomized clinical trial. J Orthop Sports Phys Ther 2009;39:20-7.

77. Lau HM, Wing Chiu TT, Lam TH. The effectiveness of thoracic manipulation on patients with chronic mechanical neck pain—a randomized controlled trial. Man Ther 2011; 16:141-7.

78. Kearns M, Ponichtera N, Rucker T, Ford G. Physical therapists as practitioners of choice: consumer knowledge of practitioner skills and training. J Phys Ther Educ 2014;28: 64-72.

79. Scheele J, Vijfvinkel F, Rigter M, et al. Direct access to physical therapy for patients with low back pain in the Netherlands: prevalence and predictors. Phys Ther 2014;94: 363-70.

80. Ojha HA, Snyder RS, Davenport TE. Direct access compared with referred physical therapy episodes of care: a systematic review. Phys Ther 2014;94:14-30.

81. Bury TJ, Stokes EK. A global view of direct access and patient self-referral to physical therapy: implications for the profession. Phys Ther 2013;93:449-59.

82. Deyle GD. Direct access physical therapy and diagnostic responsibility: the risk-to-benefit ratio. J Orthop Sports Phys Ther 2006;36:632-4.

83. McCarthy MJ, Grevitt MP, Silcocks P, Hobbs G. The reliability of the Vernon and Mior neck disability index, and its validity compared with the short form-36 health survey questionnaire. Eur Spine J 2007;16:2111-7.

84. Pool JJ, Ostelo RW, Hoving JL, Bouter LM, de Vet HC. Minimal clinically important change of the Neck Disability Index and the Numerical Rating Scale for patients with neck pain. Spine (Phila Pa 1976) 2007;32:3047-51.

85. Westaway MD, Stratford PW, Binkley JM. The patient-specific functional scale: validation of its use in persons with neck dysfunction. J Orthop Sports Phys Ther 1998;27:331-8.

86. Fernandez-de-Las-Penas C. Interaction between trigger points and joint hypomobility: a clinical perspective. J Man Manip Ther 2009;17:74-7.

87. Kuan TS, Wu CT, Chen SM, Chen JT, Hong CZ. Manipulation of the cervical spine to release pain and tightness caused by myofascial trigger points. Arch Phys Med Rehabil 1997;78:1042.

88. La Touche R, Fernandez-de-las-Penas C, Fernandez-Carnero J, et al. The effects of manual therapy and exercise directed at the cervical spine on pain and pressure pain sensitivity in patients with myofascial temporomandibular disorders. J Oral Rehabil 2009;36:644-52.

89. Mansilla-Ferragut P, Fernandez-de-Las Penas C, Alburquerque-Sendin F, Cleland JA, Bosca-Gandia JJ. Immediate effects of atlanto-occipital joint manipulation on active mouth opening and pressure pain sensitivity in women with mechanical neck pain. J Manipulative Physiol Ther 2009;32: 101-6.

90. Tsai CT, Hsieh LF, Kuan TS, Kao MJ, Hong CZ. Injection in the cervical facet joint for shoulder pain with myofascial trigger points in the upper trapezius muscle. Orthopedics 2009;32.

91. Marshall P, Murphy B. The effect of sacroiliac joint manipulation on feed-forward activation times of the deep abdominal musculature. J Manipulative Physiol Ther 2006; 29:196-202.

92. Keller TS, Colloca CJ. Mechanical force spinal manipulation increases trunk muscle strength assessed by electromyography: a comparative clinical trial. J Manipulative Physiol Ther 2000;23:585-95.

93. Metcalfe S, Reese H, Sydenham R. Effect of high-velocity low-amplitude manipulation on cervical spine muscle strength. J Man Manip Ther 2006;14:152-8.

94. Suter E, McMorland G. Decrease in elbow flexor inhibition after cervical spine manipulation in patients with chronic neck pain. Clin Biomech (Bristol, Avon) 2002;17:541-4.

95. Myburgh C, Larsen AH, Hartvigsen J. A systematic, critical review of manual palpation for identifying myofascial trigger points: evidence and clinical significance. Arch Phys Med Rehabil 2008;89:1169-76.

96. Myburgh C, Lauridsen HH, Larsen AH, Hartvigsen J. Standardized manual palpation of myofascial trigger points in relation to neck/shoulder pain; the influence of clinical experience on inter-examiner reproducibility. Man Ther 2011;16:136-40.

97. Tough EA, White AR, Richards S, Campbell J. Variability of criteria used to diagnose myofascial trigger point pain syndrome—evidence from a review of the literature. Clin J Pain 2007;23:278-86.

98. Lew PC, Lewis J, Story I. Inter-therapist reliability in locating latent myofascial trigger points using palpation. Man Ther 1997;2:87-90.

99. Lucas N, Macaskill P, Irwig L, Moran R, Bogduk N. Reliability of physical examination for diagnosis of myofascial trigger points: a systematic review of the literature. Clin J Pain 2009;25:80-9.

100. Sciotti VM, Mittak VL, DiMarco L, et al. Clinical precision of myofascial trigger point location in the trapezius muscle. Pain 2001;93:259-66.

101. Cassidy JD, Lopes AA, Yong-Hing K. The immediate effect of manipulation versus mobilization on pain and range of motion in the cervical spine: a randomized controlled trial. J Manipulative Physiol Ther 1992;15:570-5.

102. Clements B, Gibbons P, McLaughlin P. The amelioration of atlanto-axial rotation asymmetry using high velocity low amplitude manipulation: is the direction of thrust important? J Osteopath Med 2001;4:8-14.

103. Martinez-Segura R, Fernandez-de-las-Penas C, Ruiz-Saez M, Lopez-Jimenez C, Rodriguez-Blanco C. Immediate effects on neck pain and active range of motion after a single cervical high-velocity low-amplitude manipulation in subjects presenting with mechanical neck pain: a randomized controlled trial. J Manipulative Physiol Ther 2006;29:511-7.

104. Whittingham W, Nilsson N. Active range of motion in the cervical spine increases after spinal manipulation (toggle recoil). J Manipulative Physiol Ther 2001;24:552-5.

105. Rosa DP, Alburquerque-Sendin F, Salvini TF, Camargo PR. Effect of seated thoracic manipulation on changes in scapular kinematics and scapulohumeral rhythm in young asymptomatic participants: a randomized study. J Manipulative Physiol Ther 2013;36:546-54.

106. Muth S, Barbe MF, Lauer R, McClure PW. The effects of thoracic spine manipulation in subjects with signs of rotator cuff tendinopathy. J Orthop Sports Phys Ther 2012;42:1005-16.

107. Bialosky JE, Bishop MD, Price DD, Robinson ME, George SZ. The mechanisms of manual therapy in the treatment of musculoskeletal pain: a comprehensive model. Man Ther 2009;14:531-8.

108. Bialosky JE, Bishop MD, Robinson ME, Barabas JA, George SZ. The influence of expectation on spinal manipulation induced hypoalgesia: an experimental study in normal subjects. BMC Musculoskelet Disord 2008;9:19.

109. Bialosky JE, George SZ, Bishop MD. How spinal manipulative therapy works: why ask why? J Orthop Sports Phys Ther 2008;38:293-5.

110. Bishop MD, Beneciuk JM, George SZ. Immediate reduction in temporal sensory summation after thoracic spinal manipulation. Spine J 2011;11:440-6.

111. Dunning J, Rushton A. The effects of cervical high-velocity low-amplitude thrust manipulation on resting electromyographic activity of the biceps brachii muscle. Man Ther 2009;14:508-13.

112. Haavik-Taylor H, Murphy B. Cervical spine manipulation alters sensorimotor integration: a somatosensory evoked potential study. Clin Neurophysiol 2007;118:391-402.

113. Millan MJ. Descending control of pain. Prog Neurobiol 2002;66:355-474.

114. Skyba DA, Radhakrishnan R, Rohlwing JJ, Wright A, Sluka KA. Joint manipulation reduces hyperalgesia by activation of monoamine receptors but not opioid or GABA receptors in the spinal cord. Pain 2003;106:159-68.

115. Zusman M. Forebrain-mediated sensitization of central pain pathways: "non-specific" pain and a new image for MT. Man Ther 2002;7:80-8.

116. Bialosky JE, Bishop MD, Robinson ME, George SZ. The relationship of the audible pop to hypoalgesia associated with high-velocity, low-amplitude thrust manipulation: a secondary analysis of an experimental study in pain-free participants. J Manipulative Physiol Ther 2010;33:117-24.

117. George SZ, Bishop MD, Bialosky JE, Zeppieri G, Robinson ME. Immediate effects of spinal manipulation on thermal pain sensitivity: an experimental study. BMC Musculoskelet Disord 2006;7:68.

118. Grimes DA, Schulz KF. An overview of clinical research: the lay of the land. Lancet 2002;359:57-61.

119. Vandenbroucke JP, von Elm E, Altman DG, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. Ann Intern Med 2007;147:W163-94.

120. Lu CY. Observational studies: a review of study designs, challenges and strategies to reduce confounding. Int J Clin Pract 2009;63:691-7.

121. Benson K, Hartz AJ. A comparison of observational studies and randomized, controlled trials. N Engl J Med 2000;342:1878-86.

122. Grimes DA, Schulz KF. Descriptive studies: what they can and cannot do. Lancet 2002;359:145-9.