



Original Article

The short-term effects of thoracic spine thrust manipulation on patients with shoulder impingement syndrome[☆]

Robert E. Boyles^{a,*}, Bradley M. Ritland^b, Brian M. Miracle^b, Daniel M. Barclay^b, Mary S. Faul^b, Josef H. Moore^b, Shane L. Koppenhaver^b, Robert S. Wainner^{c,d}

^aSchool of Physical Therapy, University of Puget Sound, 1500N Warner St, Tacoma, WA 98416, United States

^bUS Army-Baylor University Doctoral Program in Physical Therapy, Ft. Sam Houston, TX, United States

^cTexas State University, Physical Therapy Department, San Marcos, TX, United States

^dTexas Physical Therapy Specialists, PC, United States

ARTICLE INFO

Article history:

Received 17 May 2007

Received in revised form 5 May 2008

Accepted 19 May 2008

Keywords:

Shoulder impingement

Shoulder pain

Thoracic spine thrust manipulation

Manual physical therapy

ABSTRACT

The study was an exploratory, one group pretest/post-test study, with the objective of investigating the short-term effects of thoracic spine thrust manipulations (TSTMs) on patients with shoulder impingement syndrome (SIS).

There is evidence that manual physical therapy that includes TSTM and non-thrust manipulation and exercise is effective for the treatment of patients with SIS. However, the relative contributions of specific manual therapy interventions are not known. To date, no published studies address the short-term effects of TSTM in the treatment of SIS.

Fifty-six patients (40 males, 16 females; mean age 31.2 ± 8.9) with SIS underwent a standardized shoulder examination, immediately followed by TSTM techniques. Outcomes measured were the Numeric Pain and Rating Scale (NPRS) and the Shoulder Pain and Disability Index (SPADI), all collected at baseline and at a 48-h follow-up period. Additionally, the Global Rating of Change Scale (GRCS) was collected at 48-h follow-up to measure patient perceived change.

At 48-h follow-up, the NPRS change scores for Neer impingement sign, Hawkins impingement sign, resisted empty can, resisted external rotation, resisted internal rotation, and active abduction were all statistically significant ($p < 0.01$). The reduction in the SPADI score was also statistically significant ($p < 0.001$) and the mean GRCS score = 1.4 ± 2.5 .

In conclusion, TSTM provided a statistically significant decrease in self reported pain measures and disability in patients with SIS at 48-h follow-up.

© 2008 Elsevier Ltd. All rights reserved.

1. Introduction

Shoulder impingement syndrome (SIS) is a common shoulder diagnosis that accounts for 44–65% of all shoulder related medical visits to general practitioners (Price et al., 1994; Michener and Leggin, 2001). Neer (1972) described SIS as impingement of the rotator cuff beneath the coracoacromial arch. Fu et al. (1991) summarized SIS as a poorly defined term for a variety of shoulder disorders. While the etiology and location of SIS have been disputed, the emerging consensus has been that it is a multifactorial mechanical syndrome characterized by a compromise of the subacromial soft tissues. Common etiological factors of SIS are

weakness, decreased activity of the rotator cuff muscles, anatomic variation of the acromion, spurring, trauma, or other underlying conditions (Wilk and Arrigo, 1993; Bak and Faunl, 1997; Morrison et al., 1997; Prato et al., 1998; Bang and Deyle, 2000; Paley et al., 2000; Yanai et al., 2000; Almekinders, 2001; Armfield et al., 2003; Kim and McFarland, 2004).

Frequent complaints with SIS are pain, weakness, crepitus, and stiffness which may result in loss of activity and sleep disturbances (Lo et al., 1990; van der Windt et al., 1996). Reproduction of pain occurs with movements that compress the subacromial bursa and the supraspinatus muscle between the acromion and the humeral head (Neer and Welsh, 1977; Hawkins and Kennedy, 1980). Pain is common when the arm is elevated above the height of the shoulder while being internally rotated (Warner et al., 1990; Fu et al., 1991; Kamkar et al., 1993; Wilk and Arrigo, 1993; van der Windt et al., 1996; Yanai et al., 2000).

Although earlier systematic reviews of randomized controlled trials (RCTs) found little support for physical therapy intervention

[☆] This study was approved by the Institutional Review Boards of Brooke Army Medical Center, Wilford Hall Medical Center, and Keller Army Community Hospital.

* Corresponding author. +1 253 879 3633; fax: +1 253 879 2933.

E-mail address: bboyles@ups.edu (R.E. Boyles).

in patients with SIS, more recent high quality RCTs have shown that manual physical therapy and exercise are effective for reducing pain and disability in patients with disorders of the rotator cuff when compared to competing interventions (Winters et al., 1999; Bang and Deyle, 2000; Bergman et al., 2004). In several studies, patients who received manual physical therapy and exercise directed at the cervicothoracic spine and ribs in addition to Primary Care Medicine (PCM) had improved success rates when compared to patients receiving PCM care alone or exercise alone intervention (Winters et al., 1999; Bang and Deyle, 2000; Bergman et al., 2004). In addition, these effects were still maintained at 1 year (Winters et al., 1999; Bergman et al., 2004). While manual therapy to the thoracic spine and ribs appears to be an important treatment component in patients with SIS, the individual contribution of manipulative intervention or which patients may benefit is not known. Given the positive results of these trials in which thrust manipulation was a treatment component, further studies investigating the specific contributions of thrust manipulation are warranted.

While manual physical therapy and local corticosteroids have been shown to be of similar effectiveness for treating unilateral shoulder pain in primary care, patients receiving manual physical therapy had fewer co-interventions at 6 months (Bergman et al., 2004). Traditional passive interventions and modalities have not been shown to be effective for significantly reducing shoulder symptoms and disability associated with SIS (Leduc et al., 2003) and the use of non-steroidal anti-inflammatory drugs (NSAIDs) have not been demonstrated to provide clinically meaningful relief (Green et al., 2003; Petri et al., 2004).

Patients with SIS may develop functional impairments with chronic symptoms. Therefore, it is essential to explore treatment options for SIS that extend beyond the glenohumeral joint and subacromial space. The clinical rationale for the use thoracic spinal thrust manipulation on SIS patients is based upon regional interdependence (Wainner et al., 2001), or the theory that dysfunction of one body part imparts dysfunction upon another. The concept of regional interdependence is supported by evidence demonstrating the effectiveness of spinal manipulation in the treatment of upper and lower extremity disorders (Williams et al., 1995; Bergman et al., 2004). More specifically, mobilization and manipulation of the thoracic spine and upper quarter structures were components of combined intervention protocols demonstrated to be effective for the treatment of patients with SIS (Bang and Deyle, 2000; Bergman et al., 2004). However, the studies did not standardize the manual therapy techniques that each patient received and the relative contribution of manual therapy intervention of the thoracic spine is unknown.

To date, there are no published studies that address the short-term benefits of treating SIS patients with only thoracic thrust manipulation. Therefore, the purpose of our study was to investigate the short-term effects of thoracic spine thrust manipulations (TSTMs) on patients with SIS symptoms.

2. Methods

Three faculty members and four doctoral students in the US Army-Baylor University Doctoral Program in Physical Therapy were responsible for all study procedures. In addition to regular classroom instruction, faculty members trained the students in all examination and intervention procedures used in this study during four separate training sessions. Subject enrollment commenced once faculty judged that students were proficient with all study procedures. Students performed the shoulder examination and intervention after initial screening by the primary investigator for inclusion/exclusion criteria.

2.1. Subjects

Fifty-six meeting the inclusion criteria participated in the study (age 31.2 years, ± 8.9 ; 40 males, 71.4%). Subjects were recruited by referral from physical therapists, advertising, group announcements, or word-of-mouth contact. Subjects were screened by licensed physical therapists for the diagnosis of impingement syndrome according to the established inclusion criteria. All subjects were informed of the purpose of the study and signed an informed consent and Health Insurance and Portability and Accountability Act (HIPAA) forms approved by the Institutional Review Boards at Brooke Army Medical Center, Keller Army Community Hospital, and Wilford Hall Air Force Medical Center.

The inclusion criteria used in this study were modified from those used by Bang and Deyle (Bang and Deyle, 2000; Deyle et al., 2000). Subjects were between the ages of 18 and 50 years old, reported a two or greater pain rating on a 10-point Numeric Pain Rating Scale (NPRS) with either test in Category 1 and score an NPRS of two or greater in either Category 2 or on any resisted test in Category 3 (Table 1). In addition, all patients were required to be TRICARE beneficiaries (military health care insurance affiliate).

Patients were excluded from the study if they had a positive result on a cervical distraction, or Spurling's test as described by Wainner et al. (2003), reported primary complaint of neck or thoracic pain, received previous treatment of shoulder mobilization or thoracic manipulation since the onset of current shoulder pain, received a cortisone or other fluid injection into the shoulder joint within the last 30 days, a history of osteoporosis or fracture of shoulder girdle bones, a neurologic deficit, received any hormone replacement therapy, had contraindications to thrust manipulations, unwillingness to participate in the study, or inability to attend a 48-h follow-up. Refer to Fig. 1 for subject flow diagram.

2.2. Outcome measures

Intensity of shoulder pain was measured utilizing the NPRS. The NPRS is an 11-point pain rating scale ranging from 0 (no pain) to 10 (worst imaginable pain) used to assess pain intensity in the shoulder (Jensen et al., 1994). This scale has been demonstrated to be reliable, generalizable, and an internally consistent measure of clinical and experimental pain sensation intensity (Price et al., 1994). A two-point change on the NPRS has been identified as the minimally clinically important change needed to be confident that a change has actually occurred (Farrar et al., 2001; Childs et al., 2005). The NPRS was explained verbally and recorded prior to the shoulder evaluation and treatment and at the 48-h follow-up. The patient rated their pain during the following tests: Neer impingement test, Hawkins impingement test, active shoulder abduction, resisted external rotation, resisted internal rotation, and empty can.

Table 1
Inclusion criteria.

TRICARE beneficiary
Age 18–50
Plus ^a
Category I: impingement signs
Neer's sign
Hawkins sign
Category II: active shoulder abduction
Category III: resisted break tests
Internal rotation
External rotation
Empty can

^a Required to have NPRS of ≥ 2 with one of the two tests. In Category I and NPRS of ≥ 2 with one test from either Category II or III.

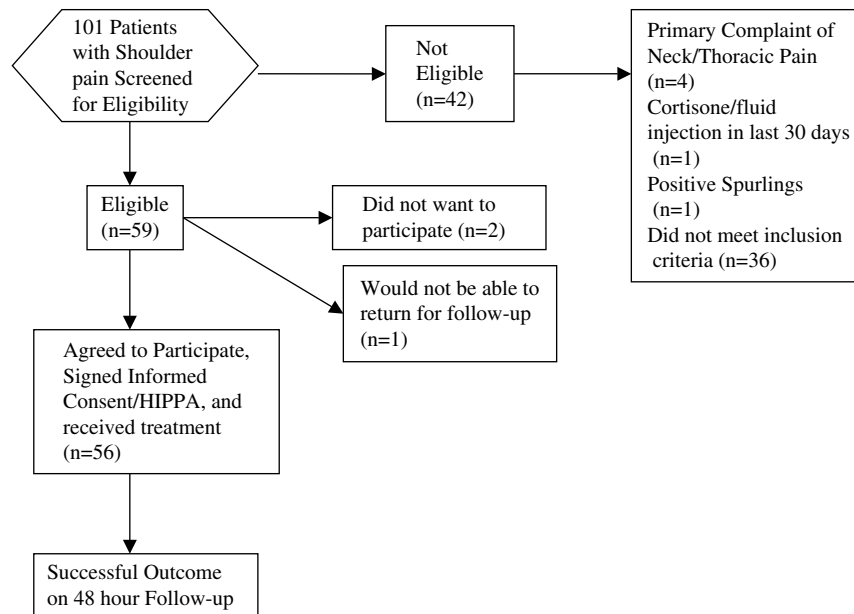


Fig. 1. Flow diagram showing subject recruitment and retention.

Pain and disability associated with the patient's shoulder were measured using the Shoulder Pain and Disability Index (SPADI). The SPADI is a 100-point, 13-item self-administered questionnaire which is divided into two subscales: a five-item pain subscale and an eight-item disability subscale. Williams et al. (1995) have shown that the SPADI is responsive to change and accurately discriminates between patients who are improving or worsening. Michener and Leggin (2001) also reported a high test-retest reliability and internal consistency for this instrument. A 10-point change on the SPADI has been identified as the minimally clinically important change needed to be confident that a change has actually occurred (Heald et al., 1997). The SPADI was administered prior to the shoulder evaluation and treatment and at the 48-h follow-up.

Change in the perception in the quality of life after the treatment was measured by a Global Rating of Change Scale (GRCS) (Jaeschke et al., 1989). The GRCS is a 15-point global rating scale ranging from -7 ("a very great deal worse") to 0 ("about the same") to +7 ("a very great deal better"). The use of a GRCS is a common, feasible, and useful method for assessing outcome (Fritz and Irrgang, 2001) and has been shown to be a valid measurement of change in patient status in other pain populations. It has been reported that scores of +4 and +5 are indicative of moderate changes in patient status and scores of +6 and +7 indicate large changes in patient status (Jaeschke et al., 1989). The GRCS was administered at the 48-h follow-up. The patient selected a number from 0 to ± 7 which corresponded to their perceived change in quality of life.

2.3. Examination procedure

Patients completed a form listing the inclusion and exclusion criteria of the study and were questioned with regard to the duration, mode of onset, distribution of symptoms, nature of symptoms, aggravating/easing factors, and any prior shoulder treatments. The physical examination measures consisted of shoulder range of motion (ROM), cervical ROM, Spurling's test, distraction test, cervical and thoracic posterior to anterior (PA) and unilateral mobility testing, and special tests for the shoulder. After a standardized shoulder examination was conducted, the examiner performed the standardized treatment.

2.4. Treatment

Upon completion of the physical exam, all patients received a high velocity low amplitude TSTM focusing on the mid-thoracic spine (Fig. 2A) and cervicothoracic junction (Fig. 2B). Care is taken to protect the shoulders and minimize force through the shoulders. No patients complained of shoulder pain during the set-up or actual manipulation. Only subjects with rib angle tenderness on the exam received a rib manipulation (Fig. 2C) at the level of tenderness. Manipulations were performed in the following order for all patients: mid-thoracic, cervicothoracic junction, and rib manipulation (if required). A description of all three techniques can be reviewed in Appendix A. If a cavitation, or "pop", was experienced, the researcher proceeded to the next technique. If no cavitation was heard by the examiner or felt by the patient, on the first attempt, the patient was repositioned, and a second manipulation was attempted. A maximum of two attempts per technique were administered. At the end of the examination and treatment session, patients were instructed to maintain normal daily living activities within their pain tolerance, to avoid activities that exacerbate symptoms, and instructed to perform an active ROM exercise for the thoracic spine two or three times daily.

2.5. Follow-up

Patients followed up with the same provider 48 h later. In order to determine the short-term effects of the treatment, follow-up SPADI, NPRS, and GRCS outcome measurements were conducted. No treatment/examination was conducted at the follow-up and the patient was considered to have completed the study at this time.

2.6. Data analysis

Statistical analysis was performed utilizing SPSS version 12.0. Data were analyzed using paired *t*-tests with an alpha level set at 0.01. The alpha level adjusted taking into account the overly conservative nature of a Bonferroni correction and concern for a Type II error. The SPADI scores as well as the NPRS values were analyzed in the same manner.



Fig. 2. Thoracic and rib manipulations used in this study. A: Seated mid-TSTM. B: Seated cervicothoracic spine thrust manipulation. C: Supine rib opening manipulation used in this study. Please see Appendix A for complete description of each.

3. Results

Between August 2005 and January 2006, 56 patients were recruited for the study. The total number of patients screened and reasons for exclusion can be seen in Fig. 1. Initial and follow-up NPRS and SPADI scores results can be found in Table 2. Significant differences between baseline and 48-h follow-up NPRS scores were found for all provocative shoulder tests, resisted tests, and SPADI scores, Table 2. Mean scores for all are depicted in Table 2. The mean SPADI change score was 6.85, Table 2. The mean GRCS value was $1.4 + (-2.5)$, frequency of GRCS can be found in Fig. 3.

4. Discussion

Due to the limitations of this study, we want to make it clear to readers that this is an exploratory study from which no cause and effect relationship can be inferred. There was no control group, nor randomization of subjects. Other significant limitations include a short-term follow-up, limited sample size and lack of outcomes assessor blinding. This study was based on previous research (Bang and Deyle, 2000; Flynn et al., 2007) from the literature and clinical observations and we endeavored to lay ground work for a future line of inquiry and high quality research regarding the influence of thoracic thrust manipulation on SIS.

Based on the results of this study, the use of TSTM in patients may have an impact on short-term pain and disability resulting in statistically significant changes. However, the changes observed did not reach the level of clinically meaningful significance. According to Heald et al. (1997), the SPADI requires a reduction of at least 10 points to be considered a clinically meaningful change. Childs et al. (2005) reported that a two-point reduction is needed for the NPRS. One possible reason why clinically significant change was not realized was that some patients in this study with shoulder complaints were not actively seeking care for their symptoms. This may explain the relatively lower NPRS and SPADI scores (Bang and Deyle, 2000; Bergman et al., 2004) which could have resulted in a floor effect and two different patient type populations represented. The mean GRCS was not large. Because the GRCS assesses a more global construct than pain and disability, longer-term follow-up may be required to adequately assess this variable.

We have included the mean differences between the outcome scores in Table 2. While the mean differences we observed were all statistically significant, none meet the minimal clinically important difference MCID for NPRS (Childs et al., 2005) or SPADI scores (Williams et al., 1995). However, all score differences were not only statistically significant, but they were consistently lower and were measured 48 h after a single intervention. Therefore, we believe the meaning of these results may be clinically important and could be further clarified in a future study of stronger design that includes repeated application of the intervention.

Another possible reason for the lack of clinical significance is that any effect TSTM contributed to the change observed was

Table 2
Results.

	Initial	48-h FU	Mean difference	p-Value
NPRS				
Neer	4.0 ± 2.5	2.9 ± 2.5	1.1	0.001
Hawkins	4.5 ± 2.2	3.3 ± 2.6	1.2	<0.001
EC, resisted	3.3 ± 2.5	2.5 ± 2.3	0.80	0.007
IR, resisted	2.4 ± 2.4	1.8 ± 2.4	0.63	0.008
ER, resisted	2.9 ± 2.6	1.9 ± 2.5	1.0	<0.001
Active ABD	3.1 ± 2.5	2.3 ± 2.6	0.8	0.001
SPADI				
	34.7 ± 17.4	27.9 ± 21.4	6.8	<0.001

Initial and 48-h follow-up NPRS and SPADI (mean values + SD).

FU = follow-up, EC = empty can, IR = internal rotation, ER = external rotation, ABD = abduction.

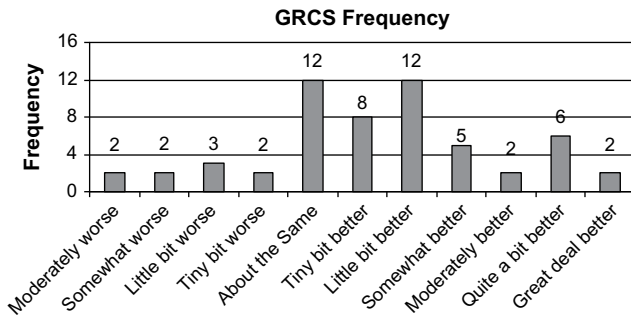


Fig. 3. GRCS frequency.

assessed in isolation from other interventions such as exercise and manual therapy of the shoulder girdle complex. These other interventions are often combined with TSTM and included in overall plan of care for patients with TSTM (Winters et al., 1999; Bang and Deyle, 2000; Bergman et al., 2004). While the relative contribution of specific manual therapy procedures is of interest, it has been demonstrated in patients with cervical spine disorders that the combined intervention of manual therapy and exercise is superior to either intervention alone (Bronfort et al., 2001; Jull et al., 2002). This would imply there is an interaction effect between manual therapy procedures and exercise.

The individual responses of subjects to TSTM varied. Of the 56 subjects in this study, one-third of them had a reduction of at least 10 points on their SPADI scores and approximately one-third had a clinically meaningful reduction in their NPRS scores for various provocative tests and movements. Thirteen subjects had a GRCS of four or greater. It is possible that if TSTM had an effect that patients may respond differentially to the intervention. A clinical prediction rule has been established for determining which patients with back pain and neck pain respond best to manipulation (Childs et al., 2004; Cleland et al., 2006). Similarly, the development of a clinical prediction rule for determining which patients with SIS respond best to TSTM may be possible. Because of the design of this study, we were unable to demonstrate a cluster of either subjective or objective signs, symptoms, or clinical findings that might lead the physical therapist to a decision to manipulate. Again, this is where the development of a clinical prediction rule would be beneficial.

As stated earlier, the clinical rationale for the use thoracic spinal thrust manipulation on SIS patients is based upon regional interdependence (Wainner et al., 2001), or the theory that dysfunction of one body part imparts dysfunction upon another. This rationale may be acceptable at this point, however, to truly understand the relationship between manipulative interventions effects on adjacent areas, rigorous mechanistic studies need to be conducted.

Another possible explanation for the changes that occurred are biomechanical in nature. Two studies (Bullock et al., 2005; Lewis et al., 2005) have been able to show the effects of thoracic posture on shoulder pain. Specifically the relationship of postural corrections in the thoracic spine and its effects of decreasing pain and increasing shoulder motion. There has also been research that has shown a relationship between scapular positional dysfunction and shoulder pathology (Kibler, 1998; Lukasiewicz et al., 1999; Ludewig and Cook, 2000; Laudner et al., 2006). It is possible that the TSTM administered in this study had effected the scapular position on the thoracic spine, thus bringing about the changes reported. Again, this is speculation as the design of this study does not allow for cause and effect.

The exploratory nature and design of this study do not permit us to establish a cause and effect relationship between TSTM and the findings observed in this study, or whether an interaction effect exists between TSTM and exercise in the management of patients

with SIS. Given the relatively short follow-up time, it is not likely that maturation or history effects were solely responsible for the changes observed in this study. Although TSTM may be of benefit in the management of patients with SIS, future work should consider a multifactorial, RCT of patients with moderate to severe finding of SIS that includes a standardized, evidence-based exercise program (Bang and Deyle, 2000) as well as manual therapy procedures to the shoulder girdle complex and thoracic spine. This would allow the questions of efficacy and interaction with regard to TSTM to be addressed.

As this was an exploratory study, we wanted to emulate the clinical experience as close as possible. Therefore, each subject had the same provider perform the initial evaluation, the treatment, and the follow-up. Similarly, we chose outcome measures that are commonly used to assess a patient's response to treatment or progression of pain/symptoms. One could argue that by having the same provider performing both the evaluation and the treatment, the results may have been impacted one way or another. Arguments could be made either way, but we believed the effects of having one provider, as opposed to two providers; one performing the treatment and another performing the evaluation, were negligible in this specific exploratory study.

While statistically significant, the results did not represent clinically meaningful change. The type of thrust techniques used was based on region rather than specific joint(s) treated. Other than rib palpation, no attempt was made to attempt to clinically determine the type or location of manipulation. Although this study has significant threats to internal validity which limits interpretation of our results and any clinical inference made from them, it does provide an initial look at a research frame work and clinical model of manual therapy regional interventions for patients with SIS. We look forward to seeing future studies of manual therapy intervention in patients with SIS which include a control group and blinded collection of outcome measures.

5. Conclusion

Subjects with SIS who received TSTM demonstrated statistically significant changes in pain and disability scores at 48 h. The efficacy of TSTM in isolation or combined with exercise and other manual therapy interventions is not known, nor can we identify which patients may benefit most. Further research with a more complex design is needed to determine questions of efficacy, relative contribution and predicted outcome.

The opinions and assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Departments of the Army, Air Force, or Defense.

Acknowledgments

CAPT Edward Kane, PT, PhD, ECS, SCS, ATC, for his valuable input during conception and initial write-up of the original research proposal.

Appendix A

Mid thoracic spine thrust manipulation

With patient sitting, researcher stands behind the patient and tells patient to slide all the way to the edge of the table. Researcher places upper right or left pectoral region on the area of the spine to be thrust. Researcher reaches around the patient and grasps subject's elbows, with knees slightly flexed. Researcher then tells the patient to relax and take a deep breath. When patient is on a natural breathing relaxation after exhaling, the researcher will then

compress the patient's upper body through patient's arms. Simultaneously, researcher extends knees to lift subject's body slightly up and over the fulcrum established by chest making a J-stroke with the patient's arms (Fig. 2a).

Cervicothoracic junction thrust manipulation

With patient sitting, have him/her inter-lock fingers behind lower cervical spine. Researcher stands behind patient with shoulders at same height as patients shoulders. Researcher then threads arms through patients so that hands are on top and inferior to the patient's hands at the CT Junction. Patient is told to move hands as low on the neck as possible and to relax his/her arms. Care is taken not to hyperextend the patients shoulder, but rather use the researchers forearms in a compressive manner anterior to the shoulder. Recline patient slightly so that C-Spine is oriented perpendicular to floor. When the patient is on a natural breathing relaxation after exhaling the researcher uses legs and lumbar extension to apply a high velocity, short amplitude force against gravity to distract (Fig. 2b).

Rib opening manipulation

Patient is supine with arms folded across chest, positioned as close to edge of plinth as possible. Examiner stands on the side of the patient ipsilateral to the pain and rolls patient over just far enough to get his/her hand under patient to get a skin lock on the affected rib angle. Examiner rolls patient supine so examiner's hand is still underneath patient and skin is still locked. Examiner moves patient's body into trunk flexion, ipsilateral side bend and rotation. Patient told to breathe deeply. At the natural relaxation after the exhale, examiner applies thrust with own body over the hand that's under the patient. If there is no cavitation, reposition patient and repeat the manipulation once (Fig. 2c).

References

- Almekinders LC. Impingement syndrome. *Clinics in Sports Medicine* 2001; 20:491–504.
- Armfield DR, Stickle RL, Robertson DD, Towers JD, Debski RE. Biomechanical basis of common shoulder problems. *Seminars in Musculoskeletal Radiology* 2003;7:5–18.
- Bak K, Faunl P. Clinical findings in competitive swimmers with shoulder pain. *American Journal of Sports Medicine* 1997;25:254–60.
- Bang MD, Deyle GD. Comparison of supervised exercise with and without manual physical therapy for patients with shoulder impingement syndrome. *Journal of Orthopaedic and Sports Physical Therapy* 2000;30:126–37.
- Bergman GJ, Winters JC, Groenier KH, Pool JJ, Meyboom-de Jong B, Postema K, et al. Manipulative therapy in addition to usual medical care for patients with shoulder dysfunction and pain: a randomized, controlled trial. *Annals of Internal Medicine* 2004;141:432–9.
- Bullock MP, Foster NE, Wright CC. Shoulder impingement: the effect of sitting posture on shoulder pain and range of motion. *Manual Therapy* 2005;10:28–37.
- Bronfort G, Evans R, Nelson B, Aker PD, Goldsmith CH, Vernon H. A randomized clinical trial of exercise and spinal manipulation for patients with chronic neck pain. *Spine* 2001;26:788–97 [Discussion 798–789].
- Childs JD, Fritz JM, Flynn TW, Irrgang JJ, Johnson KK, Majkowski GR, et al. A clinical prediction rule to identify patients with low back pain most likely to benefit from spinal manipulation: a validation study. *Annals of Internal Medicine* 2004;141:920–8.
- Childs JD, Piva SR, Fritz JM. Responsiveness of the numeric pain rating scale in patients with low back pain. *Spine* 2005;30:1331–4.
- Cleland JA, Fritz JM, Childs JD, Kulig K. Comparison of the effectiveness of three manual physical therapy techniques in a subgroup of patients with low back pain who satisfy a clinical prediction rule: study protocol of a randomized clinical trial [NCT00257998]. *BMC Musculoskeletal Disorders* 2006;7:11.
- Deyle GD, Henderson NE, Matekel RL, Ryder MG, Garber MB, Allison SC. Effectiveness of manual physical therapy and exercise in osteoarthritis of the knee. A randomized, controlled trial. *Annals of Internal Medicine* 2000;132:173–81.
- Farrar JT, Young Jr 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.
- Flynn TW, Wainner RS, Whitman JM, Childs JD. The immediate effects of thoracic spine manipulation on cervical range of motion and pain in patients with a primary complaint of neck pain – a technical note. *Orthopaedic Division Review* 2007 March/April:31–6.
- Fritz JM, Irrgang JJ. A comparison of a modified Oswestry Low Back Pain Disability Questionnaire and the Quebec Back Pain Disability Scale. *Physical Therapy* 2001;81:776–88.
- Fu FH, Harner CD, Klein AH. Shoulder impingement syndrome. A critical review. *Clinical Orthopaedics and Related Research* 1991:162–73.
- Green S, Buchbinder R, Hetrick S. Physiotherapy interventions for shoulder pain. *Cochrane Database of Systematic Reviews* 2003:CD004258.
- Hawkins RJ, Kennedy JC. Impingement syndrome in athletes. *American Journal of Sports Medicine* 1980;8:151–8.
- Heald SL, Riddle DL, Lamb RL. The shoulder pain and disability index: the construct validity and responsiveness of a region-specific disability measure. *Physical Therapy* 1997;77:1079–89.
- Jaeschke R, Singer J, Guyatt GH. Measurement of health status. Ascertain the minimal clinically important difference. *Controlled Clinical Trials* 1989;10:407–15.
- Jensen MP, Turner JA, Romano JM. What is the maximum number of levels needed in pain intensity measurement? *Pain* 1994;58:387–92.
- Jull G, Trott P, Potter H, Zito G, Niere K, Shirley D, et al. A randomized controlled trial of exercise and manipulative therapy for cervicogenic headache. *Spine* 2002;27:1835–43 [Discussion 1843].
- Kamkar A, Irrgang JJ, Whitney SL. Nonoperative management of secondary shoulder impingement syndrome. *Journal of Orthopaedic and Sports Physical Therapy* 1993;17:212–24.
- Kibler WB. The role of the scapula in athletic shoulder function. *American Journal of Sports Medicine* 1998;26:325–37.
- Kim TK, McFarland EG. Internal impingement of the shoulder in flexion. *Clinical Orthopaedics and Related Research* 2004:112–9.
- Laudner KG, Myers JB, Pasquale MR, Bradley JP, Lephart SM. Scapular dysfunction in throwers with pathologic internal impingement. *Journal of Orthopaedic and Sports Physical Therapy* 2006;36:485–94.
- Leduc BE, Caya J, Tremblay S, Bureau NJ, Dumont M. Treatment of calcifying tendinitis of the shoulder by acetic acid iontophoresis: a double-blind randomized controlled trial. *Archives of Physical Medicine and Rehabilitation* 2003;84:1523–7.
- Lewis JS, Wright C, Green A. Subacromial impingement syndrome: the effect of changing posture on shoulder range of motion. *Journal of Orthopaedic and Sports Physical Therapy* 2005;35:72–87.
- Lo YP, Hsu YC, Chan KM. Epidemiology of shoulder impingement in upper arm sports events. *British Journal of Sports Medicine* 1990;24:173–7.
- Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Physical Therapy* 2000;80:276–91.
- Lukasiewicz AC, McClure P, Michner L, Pratt N, Sennett B. Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. *Journal of Orthopaedic and Sports Physical Therapy* 1999;29:574–83.
- Michener LA, Leggin BG. A review of self-report scales for the assessment of functional limitation and disability of the shoulder. *Journal of Hand Therapy* 2001;14:68–76.
- Morrison DS, Frogameni AD, Woodworth P. Non-operative treatment of subacromial impingement syndrome. *Journal of Bone and Joint Surgery American Volume* 1997;79:732–7.
- Neer 2nd CS. Anterior acromioplasty for the chronic impingement syndrome in the shoulder: a preliminary report. *Journal of Bone and Joint Surgery American Volume* 1972;54:41–50.
- Neer 2nd CS, Welsh RP. The shoulder in sports. *Orthopedic Clinics of North America* 1977;8:583–91.
- Paley KJ, Jobe FW, Pink MM, Kvitne RS, El Attrache NS. Arthroscopic findings in the overhand throwing athlete: evidence for posterior internal impingement of the rotator cuff. *Arthroscopy* 2000;16:35–40.
- Petri M, Huffman SL, Waser G, Cui H, Snabes MC, Verburg KM. Celecoxib effectively treats patients with acute shoulder tendinitis/bursitis. *The Journal of Rheumatology* 2004;31:1614–20.
- Prato N, Peloso D, Franconeri A, Tegaldo G, Ravera GB, Silvestri E, et al. The anterior tilt of the acromion: radiographic evaluation and correlation with shoulder diseases. *European Radiology* 1998;8:1639–46.
- Price DD, Bush FM, Long S, Harkins SW. A comparison of pain measurement characteristics of mechanical visual analogue and simple numerical rating scales. *Pain* 1994;56:217–26.
- van der Windt DA, Koes BW, Boeke AJ, Deville W, De Jong BA, Bouter LM. Shoulder disorders in general practice: prognostic indicators of outcome. *The British Journal of General Practice* 1996;46:519–23.
- Wainner RS, Flynn TW, Whitman J. Spinal and extremity manipulation: the basic skill set for physical therapists. ed. *Manipulations, I. Manipulations, Inc.* 2001.
- Wainner RS, Fritz JM, Irrgang JJ, Boninger ML, Delitto A, Allison S. Reliability and diagnostic accuracy of the clinical examination and patient self-report measures for cervical radiculopathy. *Spine* 2003;28:52–62.
- Warner JJ, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Patterns of flexibility, laxity, and strength in normal shoulders and shoulders with instability and impingement. *American Journal of Sports Medicine* 1990;18:366–75.
- Wilk KE, Arrigo C. Current concepts in the rehabilitation of the athletic shoulder. *Journal of Orthopaedic and Sports Physical Therapy* 1993;18:365–78.
- Williams Jr JW, Holleman Jr DR, Simel DL. Measuring shoulder function with the Shoulder Pain and Disability Index. *Journal of Rheumatology* 1995;22:727–32.
- 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. *British Medical Journal* 1999;318:1395–6.
- Yanai T, Hay JG, Miller GF. Shoulder impingement in front-crawl swimming: I. a method to identify impingement. *Medicine and Science in Sports and Exercise* 2000;32:21–9.