Immediate Effects of Thoracic Spine Manipulation Upon Shoulder Functionality in Patients With Sutured Rotator Cuff Repair: A Prospective Study

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Abstract

Objectives: The purpose of this study was to evaluate the immediate effect of thoracic spine manipulation upon active flexion and abduction mobility of the shoulder, spine temperature, and the size of the subacromial space as measured by ultrasound in 3 positions (internal, neutral, and external rotation) of the glenohumeral joint in patients who have undergone surgery because of subacromial impingement.

Methods: Quasi-experimental, prospective, short-term effect study with consecutively sampled participants. Thirty-two patients had undergone subacromial decompression together with supraspinatus tendon suture. The following variables were studied: age, sex, dominant shoulder, presurgery evolution time, working status, surface temperature of dorsal segment with limited mobility, premanipulation functional assessment using the Spanish version of the Upper Limb Functional Index Scale, goniometric range of motion measurement at glenohumeral joint before and after manipulation, and ultrasound measurement of subacromial space before and after manipulation.

Results: Significant differences and small effect size were found in measurements for flexion and abduction movements after thoracic spine manipulation ($P > .001$; ES > 0.2) and subacromial space measurements in neutral rotation and external rotation ($P > .001$), but without clinical relevance effect size (<0.2).

Conclusions: Active shoulder flexion and abduction mobility increase after manipulation of thoracic spine in patients who have undergone surgery for rotator cuff suture. Subacromial space increases significantly with shoulder in neutral and external rotation position after manipulation. No differences were found regarding surface temperature of manipulated area. (J Manipulative Physiol Ther 2018;41:589-595)

Key Indexing Terms: *Thoracic Vertebrae; Shoulder; Ultrasonography; Rotator Cuff; Manipulation, Spinal*

Introduction

Rotator cuff tendinopathy is a common disorder representing 10% of shoulder pain complaints and is directly related with what is known as "subacromial impingement" because of the wedging and rubbing undergone by the supraspinatus tendon against the inferior side of the acromion.[1] Impingement causes are still unknown[2,3]; all that is well known are the risk factors[4,5] and that tendon tears appear in more advanced cases.[6]

The only treatment for a fully torn rotator cuff capable of giving the supraspinatus back its shoulder start-off function and avoiding arthrosis development is surgery,[7] performed by arthroscopy technique or open surgery.[8] Treatment then continues with physiotherapy focused on functional recovery comprising early postoperative passive mobilization.[8]

Active mobility not only depends on muscle power but also on adequate scapular mobility in conjunction with sternocostoclavicular and acromioclavicular joints as well as with dorso-lumbar spine segment to achieve a full active articular range of the glenohumeral joint.[9]

The scapula is closely related to the thorax and the thoracic spine via numerous muscular structures. A reduced articular range of the dorsal portion could very well have an effect on the onset and aggravating of a subacromial syndrome.[10-12]

According to Theisen et al, the presence of restricted mobility range in the dorsal spine in patients with subacromial entrapment syndrome has been estimated. In

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fact, these have shown to have a significant difference in articular range of movement of the dorsal spine on a sagittal plane when compared with patients with healthy shoulders.[13]

High-velocity, low-amplitude technique manipulation applied to the thoracic spine is a common therapeutic procedure among manual therapists.[14] Vertebral manipulation of the thoracic region has shown to have a neuromuscular activation reflex effect in those muscles related with the manipulated vertebrae.[15] Other research studies and systematic revisions showing high-quality methodology have proven that high-speed, short-amplitude manipulations on dorsal segments have short-term effects on the shoulder joint in different ways, such as in articular motion range increase, diminished pain, and overall improvement of perceived sensations by patients.[16,17]

Other studies describe pain lessening in patients with subacromial entrapment syndrome after receiving manual therapy on dorsal vertebrae.[18] This could easily be understood if we consider the "regional interdependence" model described by Wainner, according to whom many musculo-skeletal disorders would improve further if a less localized and more region-focused diagnosis and treatment of the condition was carried out.[19] Recent studies have shown the effect of this kind of manipulation on shoulder range of motion (ROM), measured with goniometer, in patients who had not undergone surgery.[20,21]

Although measurements of subacromial space by echography have shown to be reliable in the diagnosis of subacromial syndrome, no studies showing echography measurements of changes occurring in the subacromial space after manipulation of dorsal spine have been found.[22-24] Likewise, no studies describing immediate effects of dorsal spine manipulation upon either shoulder functionality or subacromial space variations measured by echography in patients with surgically repaired subacromial syndrome were found either.

The purpose of this study was to carry out research on the immediate effect of dorsal manipulation upon active flexion and abduction mobility of the shoulder and spine temperature and on the size of the subacromial space as measured by echography in 3 positions (internal, neutral, and external rotation) of the glenohumeral joint in patients who have undergone surgery because of subacromial impingement.

Methods

Design

Quasi-experimental, prospective, short-term effect study with consecutively sampled participants. All patients had been diagnosed of subacromial impingement and undergone subacromial decompression together with supraspinatus tendon suture at Clínica CEMTRO (Madrid, Spain) and were also following a physiotherapy program at Clínica CEMTRO's Physiotherapy Unit during research.

Participants

Thirty-two patients (19 women, 13 men) aged 37 to 62 years were chosen between March and June 2013. All had interrupted medication for postsurgical pain and were no longer using a sling. Surgery had taken place 6 weeks before rehabilitation, so as to respect the necessary biological period to allow the supraspinatus tendon to sustain active shoulder drills without experiencing injury. This way, premanipulation and postmanipulation active mobility could be compared to determine any increase in active shoulder mobility range after manipulation.

Patient eligibility criteria were subacromial syndrome diagnosis by trauma specialist showing partial or total tear of supraspinatus tendon, surgical repair by subacromial decompression protocol, and supraspinatus tendon suture. Patient ineligibility criteria were over 65 years old; having absolute or relative contraindications to manipulation using thrust techniques, such as tumors or fractures; infections; atherosclerosis in main arteries; aneurisms; grade 2-3 spondylolisthesis; serious psychological disorders; osteopenia; osteoporosis; rheumatoid polyarthritis; coagulation disorders or neurologic complications; attending physiotherapy or manual therapy centers, other than that in which the present study was being carried out; and being absent from the center 24 to 48 hours after receiving the last therapy session, thus hindering any control of possible adverse side effects after manual therapy.

Ethics

The study had ethics approval from the Comite de Etica de la Investigacion Clínica at CEMTRO (Madrid, Spain). All participants gave their written consent after receiving explanatory instructions from the researcher and signing the corresponding informed consent. The principles of the Declaration of Helsinki were respected.

Procedure

Studied variables were age, sex, dominant shoulder, presurgery evolution time, working status, surface temperature of dorsal segment with limited mobility, premanipulation functional assessment using ULFI-Sp scale,[25] goniometric ROM measurement at glenohumeral joint before and after manipulation, and echography measurement of subacromial space before and after manipulation

Patients were duly informed of procedure, consents signed, and individual descriptive data were registered (ie, age, sex, dominant shoulder, presurgery symptom evolution time); they were then assessed using the functional ULFI-Sp scale, followed by a goniometric measurement of active-assisted mobility for shoulder flexion and abduction. Finally, echography measurement of subacromial space and localization of dorsal segments with limited mobility and skin temperature of this same zone were taken and registered. After performing the mobilization technique, active-assisted mobility was measured once again for flexion and abduction together with echography measurement and skin temperature of affected area.

To assess any possible increase in articular ROM, goniometric measurements were used for active-assisted mobility of the glenohumeral joint for both flexion and abduction, a method which has shown to have a reliability value of $r = 0.94$ according to a study by Kolber and Hanney.[26]

Shoulder functionality and patient perception were assessed using the "Upper Limb Functional Index" consisting of 25 questions, each offering 3 possible answers out of a value of 100, where 100 was the worst functional state, and 0 was the best functional state for the shoulder. We used the Spanish version of the ULFI scale, named ULFI-Sp, with a reliability value of 0.92 to 0.95 when compared with the original questionnaire reliability value (0.90-0.96).[26] This index, which is consistently used as a specific scale to assess shoulder functionality in presence of rotator cuff pathologies,[26] was handed to patients before receiving thoracic manipulation. The questionnaire was not handed back to patients immediately after manipulation because such closeness in time would mean their ability to remember previous answers would bias the measured variable.

A 7.5 to 13 Mhz LOGIQ-e ultrasound probe (General Electric, New York, New York) was used to measure subacromial space at 12 Mhz as standard frequency. After revealing subacromial space, the probe's exact position was outlined with a pen on the patient's skin to place the probe in exactly the same place for the postmanipulation measurement.

Echography was performed with the patient comfortably seated and his or her shoulder in a relaxed, neutral position. The images captured in external rotation were measured by goniometer, with the elbow flexed to 90°, the arm beside the body, and the shoulder at 15° external rotation. The same procedure and position (with opposite direction of rotation internal) was followed for 15° internal rotation images.

The protocol followed for patient positioning when obtaining echography images was taken from study by Wang et al (intraclass correlation coefficient 0.91),[27] and subacromial space measurements were performed according to measurements taken by Girometti et al,[28] considering a continous line from acromion to humeral head, following the black line created for the echographic acoustic shadowing under the acromion, and taking the measure in centimeters (Fig 1).

Temperature measurements were taken 2 cm from above the skin, covering the area considered as having limited mobility, following Hershler et al's protocol[29] with CEM DT-8806s (Shenzhen, China) digital, infrared gun-thermometer, which is often used for noncontact body-temperature measurements, having a reliability value of $r = 0.937$, before and after manipulation.

Fig 1. *Subacromial space measuring performed according to measurements taken by Girometti et al.*[28]

Intervention

The therapist was instructed to perform the usual clinical assessment (with postgraduate training in manipulative therapy and 15 years of clinical experience) to identify the stiffest level and primarily used posteroanterior passive accessory intervertebral movements applied with the heel of the hand with the participant positioned prone.[30]

Manipulation was as follows: the heel of 1 of the therapist's hands was placed directly over the treatment-receiving vertebra, over its transverse apophysis. During the manipulation process, the therapist's other hand flexes the thoracic spine far enough to produce a maximum degree of tension in the mentioned level spinal joints. While maintaining this tension, the therapist briefly, but firmly, presses their chest against the patient in the direction of the hand holding the vertebra at the same time the patient finishes his exhalation. The hand holding the affected level spinal joints was placed with its fingers bent just under the spinous process. Regarding the manipulation technique itself, a flexion movement was applied to the hand in extension injuries and an extension movement in flexion injuries.[31]

The therapist who performed such techniques has ample experience and training in manual therapy, and inertial sensors were used to confirm that the correct technique had been applied.[32-35] All interventions were developed in the same room with the temperature set at 24°C.

The patient was placed in supine lying position because it has proven to be more effective than other positions at distal levels,[36] while also modifying a classical technique[30] by maintaining the operated upper limb in full extension to avoid any pain during maneuvers (Fig 2).

Data Collection and Analysis

For statistical analyses, all data were assessed for normality with the Shapiro-Wilk test,[37] which determined all data were normally distributed. The paired Student t test was used to compare averages of related samples. All data were analyzed with the SPSS software (version 22.00 for Windows) (IBM Corp, Armonk, New York). The effect

Fig 2. *Thoracic spine manipulation maintaining the operated upper limb in full extension so as to avoid any pain during maneuvers.*

size (ES) was determined for precomparisons vs post-comparisons using an online ES calculator (http://www.uccs.edu/~lbecker/). The ES values of 0.2, 0.5, and 0.8 were interpreted as small, moderate, and large, respectively.[38]

Previous research on thoracic spine manipulation for use with shoulder disorders was evaluated to calculate sample size.[22] Considering a moderate effect, statistical power of 80%, and an α of 5%, the calculated sample size for the experimental condition was 27 participants.

Results

Table 1 shows basal and descriptive results, and Table 2 shows result differences for the measured variable before and after interventions.

Significant differences and small ES were found in measurements for flexion and abduction movements after thoracic spine manipulation ($P > .001$; ES > 0.2) and subacromial space measurements in neutral rotation and external rotation ($P > .001$), but without clinical relevance ES (<0.2). Increase in subacromial space was significant for internal rotation ($P > .01$), and differences in temperature were not significant. More details of mean, variance, and mean differences results of each outcome can be found in Table 2.

Discussion

After manipulation of thoracic spine, active shoulder flexion and abduction mobility increase in patients who have undergone surgery for rotator cuff suture. Subacromial space does increase after the manipulation, although the 1 mm increase cannot be considered clinically relevant. When manipulating thoracic segments in supine decubitus position, a 7° flexion and 8° active abduction of the shoulder was achieved together with a 1 mm subacromial space increase in neutral position, a 0.8 mm increase for external rotation, and a 0.7 mm for internal rotation. Changes in surface temperature of manipulated area were not significant.

Changes in active shoulder mobility after manipulation have already been studied by other authors. Michener[21] showed a 3° increase in internal rotation after thoracic manipulation; Haik[38] studied changes in scapular kinematics, obtaining nonstatistically significant findings. The present study focused on active shoulder flexion and abduction. Our patients received manipulation treatment 6 weeks after surgery. This is the time at which more conservative physiotherapy protocols recommend starting with totally active motion and internal rotation glenohumeral passive

Table 1. *Basal and Descriptive Results of the Sample (n = 32)*

Variables	
Sex n (%)	Men 13 (40.6) Women 19 (59.4)
Right dominant shoulder n (%)	21 (65.6)
Age years (mean)	50.09
Symptom presence before surgery (mo)	12.85
Working status n (%)	Housewife 46.85 Office 31.25 Others 21.9

Table 2. *Descriptive and Mean Differences for Measured Variable Before and After Interventions*

	Pre (mean ± SD)	Post (mean ± SD)	Lower	Upper	t	*P*	SE
Pair 1 Neutro (cm)	1.46 ± 0.34	1.57 ± 0.30	-.139	-.072	-6.49	.001	-0.161
Pair 2 External rotation (cm)	1.59 ± 0.35	1.67 ± 0.35	-.108	-.044	-4.86	.001	-0.106
Pair 3 Internal rotation (cm)	1.38 ± 0.51	1.45 ± 0.46	-.127	-.017	-2.66	.01	0.121
Pair 4 Flex (°)	143.35 ± 15.62	150.45 ± 17.06	-9.00	-5.19	-7.60	.001	-0.212
Pair 5 Abd (°)	142.16 ± 19.2	150.55 ± 17.37	-10.50	-6.27	-8.09	.001	-0.222
Pair 6 T (°C)	35.35 ± 1.49	35.48 ± 1.69	-.369	.117	-1.05	NS	-0.040

NS, nonsignificant; *SD*, standard deviation; *SE*, standard error.

movements. They based it in a low rate of post-surgery tears[39] because of the fact of biological repair of reinserted tendon has been completed 4-6 weeks after surgery.[40]

The research by Strunce et al[41] appears to be in line with the results in the present study concerning mobility increase, finding a 3.9° increase in flexion and a 3.7° increase in abduction after manipulation dorsal segment and ribs with limited mobility in patients who had not been operated and who had not been diagnosed of specific pathologies. Further biomechanical studies would be of interest to provide information concerning the exact mechanisms, which causes an increase in glenohumeral joint mobility after performing such treatment on the thoracic spine.

Although other authors have considered variables, such as improvement of pain in patients with subacromial impingement after manipulation of thoracic spine without obtaining statistically-significant results,[42] such a variable was not considered in the present study owing to the fact that repair by arthroscopy would have solved the pain originated by the impingement after liberating this space during the operation.

Measuring the subacromial space by echography and relating any changes in measurements taken with effectiveness of physiotherapy treatment has also been done by other authors. Savoie et al[43] prove there is a significant increase in subacromial space with a treatment based on active exercises for 6 weeks, as well as improving shoulder functionality, both observations being in-line with this study's main objective. Luque et al[44] have carried out measurements of the subacromial space before and after applying a neuromuscular taping in neutral position and at 60° of shoulder elevation in scapular plane and have obtained similar results to those of this study, showing a 1 mm increase in neutral position of the shoulder.

This is the first ever study to use diagnosis by echography imaging to assess thoracic manipulation on the increase of subacromial space in patients who have undergone surgery for rotator-cuff repair, which is why we believe that our results may provide other patients who were operated on for the same condition with benefits if they undergo postsurgical physiotherapy programs, which include other techniques also shown to be effective when it comes to increasing subacromial space. Likewise, we propose further research on the combination of several techniques, such as active exercises, stretching drills, Kinesio Taping, and thoracic spine manipulation to assess their combined effect on a possible greater increase in subacromial space diameter.

Several studies[45,46] have shown local temperature variations after performing manipulation techniques, establishing a relationship with a possible direct sympathetic-excitatory effect by manipulation, which would increase local peripheral vascularization. Another study has taken local temperatures to allocate those segments with limited mobility, which would be more likely to receive treatment,[47] but our results are not in agreement with the that study, possibly owing to the more advanced temperature-measurement technique used in our study or to variations in the manipulation technique, which was adapted to the type of patient treated in this study.

Limitations

Considering this study was a nonrandomized yet highly pragmatic clinical trial, we were not able to compare results with a control group. It is nevertheless an innovative study, establishing promising results concerning the increase in postoperative active shoulder mobility and accelerating the recovery period in patients who need to follow long-term physiotherapy programs, thus creating opportunities for future research in which control groups may be included in addition to new techniques, such as those previously described. It must also be noted that patients included in the current study had previously started a physiotherapy program, leaving researchers no option to bias sample selection. An additional advantage was that the same team operated on all patients, thus avoiding the weakness of results obtained, had differences in surgical techniques existed.

Conclusion

Active shoulder flexion and abduction mobility increase after manipulation of thoracic spine in patients who have undergone surgery for rotator cuff suture. Subacromial space increases significantly with shoulder in neutral and external rotation position after manipulation. No differences were found regarding surface temperature of manipulated area.

Funding Sources and Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): P.B.-P., A.I.C.-V.
Design (planned the methods to generate the results): P.B.-P., A.I.C.-V.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): A.I.C.-V.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): P.B.-P.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): P.B.-P., A.I.C.-V.
Literature search (performed the literature search): P.B.-P., A.I.C.-V.
Writing (responsible for writing a substantive part of the manuscript): P.B.-P., A.I.C.-V.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): A.I.C.-V.

Practical Applications

- Manipulation of thoracic spine immediately improves active shoulder flexion and abduction mobility in patients who have undergone surgery for rotator cuff suture.
- No differences were found regarding surface temperature of manipulated area.
- Subacromial space increases significantly with shoulder in neutral and external rotation position after manipulation.

References

1. Dabija DI, Gao C, Edwards TL, Kuhn JE, Jain NB. Genetic and familial presdisposition to rotator cuff disease: a systematic review. *J Shoulder Elbow Surg.* 2017;26(6):1103-1112.
2. Almekinders LC. Impingement syndrome. *Clin Sports Med.* 2001;20(3):491-504.
3. Cohen RB, Williams Jr GR. Impingement syndrome and rotator cuff disease as repetitive motion disorders. *Clin Orthop.* 1998;351:95-101.
4. Hawkins RJ, Kennedy JC. Impingement syndrome in athletes. *Am J Sports Med.* 1980;8(3):151-158.
5. Soslowsky LJ, An CH, Johnston SP, Carpenter JE. Geometric and mechanical properties of the coracromial ligament and their relationship to rotator cuff disease. *Clin Orthop Relat Res.* 1994;304:10-17.
6. Morrison DS, Bigliani LU. The clinical significance of variations in acromial morphology. *Orthop Trans.* 1987;11:234.
7. Neer II CS. Anterior acromioplasty for the chronic impingement syndrome in the shoulder: a preliminary report. *J Bone Joint Surg Am.* 1972;54(1):41-50.
8. Fernandez Sabaté A, Armengol Barallat J. El hombro doloroso. In: Cáceres Palou E, ed. *Manual SECOT de Cirugia Ortopedica y Traumatologica*. Madrid, Spain: Editorial Medica Panamericana; 2004:458-472.
9. Kapandji AI. In: Kapandji AI, ed. El hombro. Fisiologia Articular. Madrid, Spain: Editorial Medica Panamericana; 2007:60-69.
10. Greenfield B, Catlin PA, Coats P, Green E, Mc Donald JJ, North C. Posture in patients with shoulder overuse injuries and healthy individuals. *J Orthop Sports Phys Ther.* 1995;21(5):287-295.
11. Nicholson GG. Rehabilitation of common shoulder injuries. *Clin Sports Med.* 1989;8(4):633-655.
12. Betz U, Grober J. AM: Ist die Thoraxbeweglichkeit bei patienten mit einem impingement-syndrom der schulter verandert? – vergleich mit gesunden probanden. *Manuelle Therapie.* 2005:2-10.
13. Theisen C, Wagenswald A, Timmesfeld N, et al. Co-occurrence of outlet impingement syndrome of the shoulder and restricted range of motion in the thoracic spine. A prospective study with ultrasound-based motion analysis. *BMC Musculoskelet Disord.* 2010;11:135.
14. American Physical Therapy Association. Guide to Physical Therapist Practice. Second Edition. American Physical Therapy Association. *Phys Ther.* 2001;81(1):9-746.
15. Herzog W, Conway PJ, Zhang YT, Gál J, Guimaraes AC. Reflex responses associated with manipulative treatments on the thoracic spine: a pilot study. *J Manipulative Physiol Ther.* 1995;18(4):233-236.
16. Strunce JB, Walker MJ, Boyles R, 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(4):230-236.
17. Walser RF, Meserve BB, Boucher TR. The effectiveness of thoracic spine manipulation for the management of musculoskeletal conditions: a systematic review and meta-analysis of randomized clinical trials. *J Man Manip Ther.* 2009;17(4):237-246.
18. 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(4):375-380.
19. Wainner RS, Whitman JM, Cleland JA, Flynn TW. Regional interdependence: a musculoskeletal examination model whose time has come. *J Orthop Sports Phys Ther.* 2007;37(11):658-660.
20. Kardouni JR, Pidcoe PE, Shaffer SW, et al. Thoracic spine manipulation in individuals with subacromial impingement syndrome does not immediately alter thoracic spine kinematics, thoracic excursion, or scapular kinematics: a randomized controlled trial. *J Orthop Sports Phys Ther.* 2015;45(7):527-538.

21. Michener LA, Kardouni JR, Lopes Albers AD, Ely JM. Development of a sham comparator for thoracic spinal manipulative therapy for use with shoulder disorders. *Man Ther.* 2013;18(1):60-64.
22. Seitz AL, Michener LA. Ultrasonographic measures of subacromial space in patients with rotator cuff disease: a systematic review. *J Clin Ultrasound.* 2011;39(3):146-154.
23. McCreesh K, Adusumilli P, Evans T, Riley S, Davies A, Lewis J. Validation of ultrasound measurement of the subacromial space using a novel shoulder phantom model. *Ultrasound Med Biol.* 2014;40(7):1729-1733.
24. Azzoni R, Cabitza P. Sonographic versus radiographic measurement of the subacromial space width. *Chir Organi Mov.* 2004;89(2):143-150.
25. Cuesta-Vargas AI, Gabel PC. Cross-cultural adaptation reliability and validity of the Spanish version of the Upper Limb Functional Index. *Health Qual Life Outcomes.* 2013;11:126.
26. Kolber MJ, Hanney WJ. The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: a technical report. *Int J Sports Phys Ther.* 2012;7(3):306-313.
27. Wang HK, Lin JJ, Pan SL, Wang TG. Sonographic evaluations in elite college baseball athletes. *Scand J Med Sci Sports.* 2005;15(1):29-35.
28. Girometti R, De Candia A, Sbuelz M, et al. Supraspinatus tendon US morphology in basketball players: correlation with main pathologic models of secondary impingement syndrome in young overhead athletes. Preliminary report. *Radiol Med (Torino).* 2006;111(1):42-52.
29. Hershler C, Conine TA, Nunn A, Hannay M. Assessment of an infra-red non-contact sensor for routine skin temperature monitoring: a preliminary study. *J Med Eng Technol.* 1992;16(3):117-122.
30. Campbell BD, Snodgrass SJ. The effects of thoracic manipulation on posteroanterior spinal stiffness. *J Orthop Sports Phys Ther.* 2010;40(11):685-693.
31. González-Iglesias J, Fernández-de-las-Peñas C, Cleland JA, Gutiérrez-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(1):20-27.
32. Cuesta-Vargas AI, Galán-Mercant A, Williams JM. The use of inertial sensors system for human motion analysis. *Phys Ther Rev.* 2010;15(6):462-473.
33. Williams JM, Cuesta-Vargas AI. An investigation into the kinematics of 2 cervical manipulation techniques. *J Manipulative Physiol Ther.* 2013;36(1):20-26.
34. Williams JM, Cuesta-Vargas A. Quantification of prone thoracic manipulation using inertial sensor-derived accelerations. *J Manipulative Physiol Ther.* 2014;37(4):230-235.
35. Cuesta-Vargas AI, Williams J. Inertial sensor real-time feedback enhances the learning of cervical spine manipulation: a prospective study. *BMC Med Educ.* 2014;14:120.
36. Karas S, Olson Hunt MJ. A randomized clinical trial to compare the immediate effects of seated thoracic manipulation and targeted supine thoracic manipulation on cervical spine flexion range of motion and pain. *J Man Manip Ther.* 2014;22(2):108-114.
37. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: Erlbaum Associates; 1988.
38. Haik MN, Alburquerque-Sendín 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(7):475-487.
39. Abtahi A, Granger E, Tashjian R. Factors affecting healing after arthroscopic rotator cuff repair. *World J Orthop.* 2015;6(2):211-220.
40. Kim CW, Kim JH, Kim DG. The factors affecting pain pattern after arthroscopic rotator cuff repair. *Clin Orthop Surg.* 2014;6(4):392-400.
41. Strunce J, Walker M, Boyles R, Young B. The immediate effects of thoracic spine and rib manipulation on subjects with primary complaints of shoulder pain. *J Man Manip Ther.* 2009;17(4):230-236.
42. Kardouni JR, Shaffer SW, Pidcoe PE, Finucane SD, Cheatham SA, Michener LA. Immediate changes in pressure pain sensitivity after thoracic spinal manipulative therapy in patients with subacromial impingement syndrome: a randomized controlled study. *Man Ther.* 2015;20(5):540-546.
43. Savoie A, Mercier C, Desmeules F, Frémont P, Roy JS. Effects of a movement training-oriented rehabilitation program on symptoms, functional limitations and acromiohumeral distance in individuals with subacromial pain syndrome. *Man Ther.* 2015;20(5):703-708.
44. Luque-Suarez A, Navarro-Ledesma S, Petocz P, Hancock MJ, Hush J. Short-term effects of kinesiotaping on acromiohumeral distance in asymptomatic subjects: a randomised controlled trial. *Man Ther.* 2013;18(6):573-577.
45. Vicenzino B, Collins D, Benson H, Wright A. An investigation of the interrelationship between manipulative therapy-induced hypoalgesia and sympathoexcitation. *J Manipulative Physiol Ther.* 1998;21(7):448-453.
46. Chiu TW, Wright A. To compare the effects of different rates of application of a cervical mobilisation technique on sympathetic outflow to the upper limb in normal subjects. *Man Ther.* 1996;1(4):198-203.
47. Triano JJ, Budgell B, Bagnulo A, et al. Review of methods used by chiropractors to determine the site for applying manipulation. *Chiropr Man Therap.* 2013;21(1):36.