Taylor & Francis
Taylor & Francis Group

Journal of Manual & Manipulative Therapy

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/yjmt20

In vivo measurements of glenohumeral distraction technique performed in three different joint positions

Diego Guerra-Rodríguez, Liliana Rozo, Daniel Basilio & Juan Guerrero-Henriquez

To cite this article: Diego Guerra-Rodríguez, Liliana Rozo, Daniel Basilio & Juan Guerrero-Henriquez (2021): *In vivo* measurements of glenohumeral distraction technique performed in three different joint positions, Journal of Manual & Manipulative Therapy, DOI: 10.1080/10669817.2021.1904350

To link to this article: https://doi.org/10.1080/10669817.2021.1904350

Published online: 25 Mar 2021.

JOURNAL OF MANUAL & MANIPULATIVE THERAPY
https://doi.org/10.1080/10669817.2021.1904350

Taylor & Francis
Taylor & Francis Group

In vivo measurements of glenohumeral distraction technique performed in three different joint positions

Diego Guerra-Rodríguez[a], Liliana Rozo[b], Daniel Basilio[c] and Juan Guerrero-Henriquez[d]

[a]Biomedical Department, Faculty of Health Sciences, University of Antofagasta, Antofagasta, Chile; [b]Postgraduate Department of Manual Therapy, Faculty of Rehabilitation Sciences, Andres Bello University, Santiago, Chile; [c]Kinetic-K Integral Therapy and Training Center, Antofagasta, Chile; [d]Rehabilitation and Human Movement Sciences Department, Faculty of Health Sciences, University of Antofagasta, Antofagasta, Chile

ABSTRACT

Introduction: Distraction techniques are an important part of the manual approach in the glenohumeral joint; however, there is controversy regarding the initial joint position to maximize separation of joint surfaces.

Objective: To identify, through an *in vivo* exploration, the behavior of the coracohumeral distance (CHD) during the application of a short lever arm grade III distraction technique on the humeral head, executed in three different glenohumeral positions (zero position (P0), rest position (RP) and 90º abduction position with maximum external rotation (ABD+ER)).

Methods: 15 participants were selected. A physical therapist executed grade III distraction techniques in described joint positions. Ultrasound was used to visualize the differences in CHD. Statistical analysis included interclass correlation coefficients (ICC) and repeated measurements of ANOVA.

Results: The range of ICC values was 0.740 and 0.948. The differences in CHD were 5.74 ± 0.51 mm, 3.97 ± 0.24 mm, and 0.64 ± 0.02 mm, for P0, RP and ABD+ER during application of distraction technique, respectively. There were differences between P0 and RP with ABD+ER ($P < 0.001$), and no differences between P0 and RP.

Conclusion: Initial joint position of application influences the separation of the articular surfaces, being wider in the zero and rest positions.

KEYWORDS
Shoulder joint; Musculoskeletal manipulations; Ultrasonography

Introduction

Manual distraction techniques have been used in the context of rehabilitation of patients with glenohumeral (GH) pathologies for improving range of motion and decreasing pain [1–3]. These are defined as articular mobilization techniques [4] that separate one joint surface from the other in a perpendicular direction [5], being a relevant part of intervention in manual therapy practice [6,7]. Although its positive effects have been documented, an important part of its execution lies in the ideal initial joint position, defined as the one that allows a greater separation between joint surfaces, to maximize its clinical results [8]. Cadaveric research has shown that initial GH joint position influences the separation of its surfaces, mainly due to the stress offered by the periarticular soft tissue [9–11].

In vivo explorations methods in GH joint had been conducted using imaging methods [12,13], such as ultrasound imaging (US), which has been recognized as a convenient, economical, radiation-free and non-invasive method for measuring real-time joint movements. These reasons make US suitable for objective assessment of GH translation in laboratory and field-based research [14]. One of the variables used in this context is the coraco-humeral distance (CHD) [15–17], which has allowed to highlight the differences associated with joint position in the context of manual techniques, with moderate to good reliability [14] and it had shown correlation with GH pathologies [18,19].

However, findings as to which is the best initial position are controversial. Gokeler et al. analyzed the distance between the humeral head and the glenoid fossa during maximum distraction in resting and joint blocking positions, concluding that there are no differences between both positions [12]. On the contrary, Park et al. compared CHD in neutral, resting and final range of motion positions, identifying the latter as the position in which the greatest separation is achieved [8]. Also, Fareeha et al. showed similar results when comparing mobilizations in intermediate and final ranges of movement [20]. Against this background, the objective of this research is to identify, through an *in vivo* exploration of the CHD researched with ultrasound, the optimal

CONTACT Juan Guerrero-Henriquez juan.guerrero@uantof.cl Department of Rehabilitation and Human Movement Sciences, Faculty of Health Sciences, University of Antofagasta, Avda, Antofagasta, 1240000, Chile

joint position when applying a grade III distraction technique according to Kaltenborn on the GH joint.

Methods

This was a study with a cross-sectional descriptive design in healthy participants. The protocol of this research was approved by the Bioethics Committee of the Faculty of Rehabilitation Sciences of the Universidad Andrés Bello. All participants approved and signed an informed consent.

Participants

Fifteen male participants were selected (mean ± standard deviation; age: 20.93 ± 0.46 years; weight: 71.06 ± 3.16 kg; height: 1.73 ± 0.02 m; BMI: 23.84 ± 1.04), by means of a non-probabilistic sampling for convenience. Inclusion criteria included age between 18 and 25 years, BMI equivalent to normal weight, range of lateral shoulder rotation movement ≥70 degrees, flexion ≥160 degrees and abduction ≥160 degrees, in both upper extremities. A history of spine, shoulder and elbow trauma, previous shoulder surgery or manipulation under anesthesia, shoulder pain during the past three months and diagnosed ligament hyperlaxity were considered exclusion criteria.

Instruments

A diagnostic ultrasound unit, SonoScape (E2 Digital Color Doppler Ultrasound System) with a dynamic range of up to 200 dB, was used with a 13 MHz linear transducer with 128 piezoelectric crystals. The images were obtained by a single examiner, trained in ultrasound musculoskeletal imaging.

Protocol

Distance measurements were recorded in the following GH positions: zero (P0), rest (RP) and 90º of abduction with maximum external rotation of the GH joint (ABD+ER). P0 corresponds to the location of the arm parallel to the body, with the elbow in extension and thumb in the ventral direction [21]. RP corresponds to an abduction of 25° in the scapular plane (30 degrees of elevation in the scapular plane) with the elbow flexed and the forearm in the horizontal plane [22]. For ABD+ER, the recommendations of Joo Han et al. were used [19]. RP and ABD+ER positions were controlled by the clinician in charge of performing the distraction technique. For all procedures, participants were instructed to lie in supine position, to ensure scapular stabilization by bodyweight [17].

In each position, three initial and during-technique measures of a grade III distraction of the humeral head with short lever arm were registered. Techniques were carried out by a physical therapist with a master's degree in Orthopedic Manual Therapy, head teacher of Biomechanics and Clinical Traumatology classes and research in musculoskeletal area. He was given an explanatory guide of the distraction technique to improve the reliability of the execution. Kalteborn grade III distraction was defined as the force from the first stop when tension increases in formerly slack periarticular tissue to the last stop within the anatomic range [8]. Force direction was perpendicular to joint surface [5].

The clinician in charge of the distraction technique was in a bipedal position on the side of the shoulder to be evaluated and the physical therapist in charge of the ultrasound recording was seated on the opposite side of the shoulder evaluated (Figure 1). A 30-second rest period was given after each measurement with upper extremity in a resting position lateral to participant's body. The duration of the measurement was determined by the ultrasound operator once the

a b c

Figure 1. Execution of distraction technique in zero position (column A), resting position (column B) and 90° abduction position with maximum external rotation (column C).

image of the technique was recorded in the corresponding position. The sonographer was blinded of joint position being tested.

The transducer was positioned over the anterior aspect of the shoulder in line with longitudinal axis. For CHD, the shortest straight line (in millimeters) drawn from the lateral aspect of the coracoid process up to the medial aspect of the lesser tubercle of the humerus was considered as CHD for P0 and RP [15,16]. For ABD+ER position, the cortical edge of humeral head was used as bony mark. All CHD were estimated from an image taken by the ultrasound screen at the same time of the measurement (Figure 2). For each image, the criterion used for the selection of an image was a correct delimitation of the cortical edge of coracoid process, lesser tubercule, and humeral head according to testing position.

Statistical analysis

The statistical analysis was carried out in the SPSS v25.0 program (IBM Corp., Armonk, NY). The Shapiro-Wilk test was used to determine the data distribution. Initially, paired t-Student test was applied to determine significant differences between the distance values categorized by position between right and left shoulder, with the objective of considering a total sample of 30 observations. Normalization of the CHD was carried out after the distraction made in each one of the positions, using as a parameter the initial position, expressing the result as a rate of change (ΔCHD).

A reliability analysis using the interclass correlation coefficient (ICC) was conducted on obtained CHD by

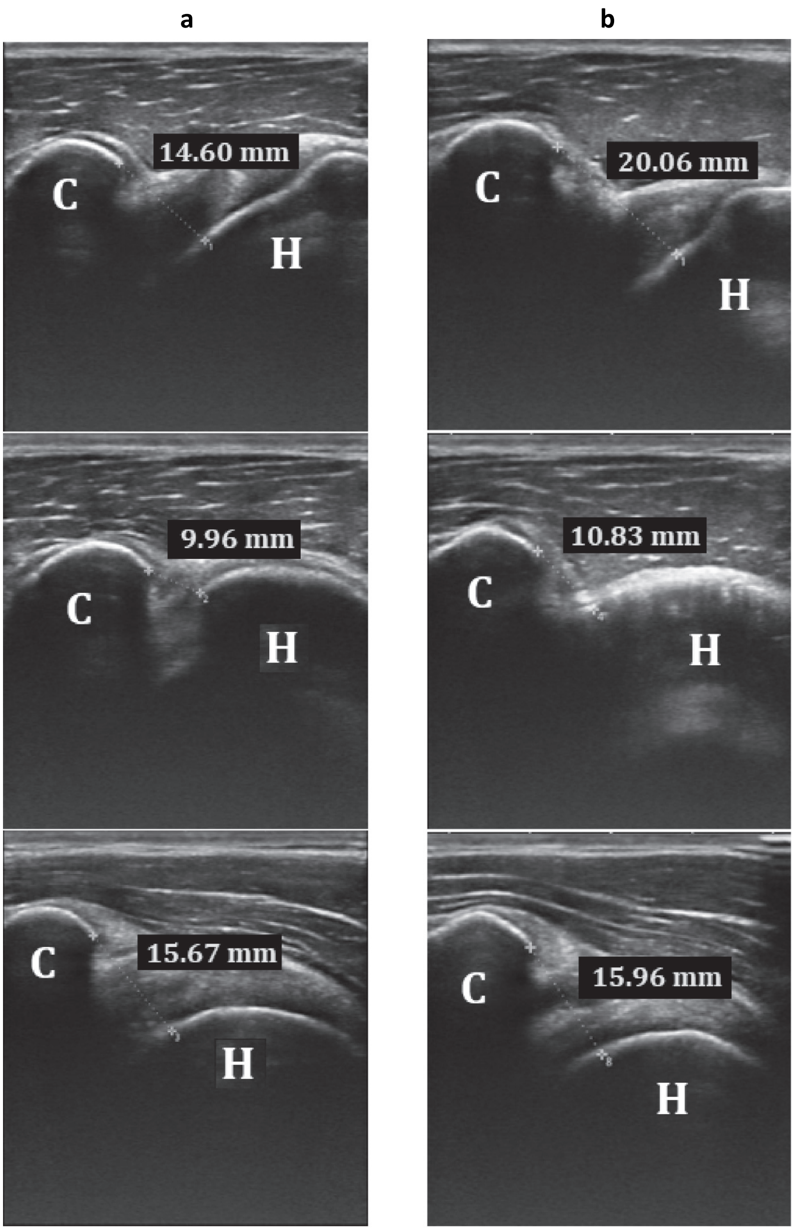

Figure 2. Initial (column A) and during distraction (column B) ultrasound images in zero position (row 1), resting position (row 2) and 90° abduction position with maximum external rotation (row 3) of one participant. C: coracoid process; H: humerus.

Table 1. Mean ± standard deviation values for each of upper extremity (UE) movements evaluated.

Movement	Right UE (n = 15)	Left UE (n = 15)	p value
Flexion (°)	174.87 ± 9.49	171.93 ± 9.29	0.079
External rotation (°)	96.20 ± 12.49	95.80 ± 12.36	0.348
Abduction (°)	181.20 ± 6.82	179.07 ± 9.77	0.182

Table 2. Initial (iCHD) and during (dCHD) technique application coracohumeral distance values. Δ indicates the standardized difference between the initial and during technique distance. P0: zero position; RP: resting position; ABD+ER: 90° of abduction with maximum external rotation; CHD: coracohumeral distance.

Position	iCHD (mm)	dCHD (mm)	ΔCHD (mm)	ΔCHD (%)
P0	13.60 ± 2.56	19.34 ± 3.07	5.74 ± 0.51	44.62 ± 0.23
RP	10.37 ± 3.29	14.34 ± 3.53	3.97 ± 0.24	43.80 ± 0.26
ABD+ER	16.42 ± 2.60	17.06 ± 2.62	0.64 ± 0.02	6.00 ± 0.05

position, where a value lower than 0.5 is indicative of poor reliability, values between 0.5 and 0.75 are indicative of moderate reliability, values between 0.75 and 0.9 are indicative of good reliability and values higher than 0.9 are indicative of excellent reliability [23].

To determine the differences between the three positions, the average of the three records per position was considered. The repeated measurements ANOVA test was applied using positions as an interaction effect. Subsequently, a multiple comparison test was applied with Bonferroni's *post hoc* correction. For all statistical tests, an $\alpha = 0.05$ was considered.

Results

Upper extremity range of motion

Table 1 shows the ranges of motion evaluated (flexion, external rotation, and abduction) of both upper extremities. No differences were observed for range of movement when grouping by right or left upper extremity.

Reliability analysis

The ICCs for CHD values in the three initial joint positions were in the range of 0.740 and 0.948, this finding being interpreted as moderate, good, and excellent reliability for ABD+ER, P0 and PR, respectively.

Differences in distraction technique

Table 2 shows initial and during the application of the distraction technique CHD values. While ABD+ER position shows greater initial CHD, the highest rates of change are observed when applying the distraction technique in the P0 and RP positions.

Table 3 shows the comparisons of normalized percentage difference between groups (P0, RP and ABD +ER). The main findings are significant differences between the P0 and ER positions with respect to the

Table 3. Results of multiple comparison tests. CI: 95% confidence interval; LB: lower bound; UP: upper bound. P0: zero position, RP: resting position, ABD+ER: 90° of abduction with maximum external rotation, and CHD: coraco-humeral distance. * indicates statistically significant differences.

Pairs		Mean difference (%)	CI [LB UB]	p
P0	RP	0.008	−0.118 0.134	1.000
	ABD+ER*	0.387	0.275 0.498	0.001
RP	P0	−0.008	−0.134 0.118	1.000
	ABD+ER*	0.379	0.260 0.498	0.001
ABD+ER	P0*	−0.387	−0.498 − 0.275	0.001
	RP*	−0.379	−0.498 − 0.260	0.001

ABD+ER position; however, there are no differences between P0 and RP.

Discussion

Using *in vivo* ultrasound imaging of the GH joint, we analyzed the differences in CHD when performing a Kaltenborn grade III distraction of the humeral head from the glenoid fossa in zero (P0), resting (RP) and 90° abduction with maximum external rotation (ABD+ER) positions. Our results show that the wider initial and highest rates of CHD change (base and during distraction technique) are achieved in P0 (5.74 ± 0.51 mm, ΔCHD: 44.62 ± 0.23%) and in RP (3.97 ± 0.24 mm, ΔCHD: 43.8 ± 0.26%), contrasting with low rate of change in CHD for the ABD+ER position (0.64 ± 0.02 mm, ΔCHD: 6.0 ± 0.05%). These results are consistent with the theoretical background reported by Goetti et al. [24] and Kaltenborn [21], who consider that the initial joint position; together with tension of the periarticular soft tissues (both contractile and non-contractile) are a primary determinant in the development of a distraction joint technique.

The effect of initial joint position on shoulder distraction technique has been recognized by Hsu et al. [10] who, in a cadaveric set up, analyzed the displacement of the humeral head during an axial distraction of the GH joint performed in three different positions. They reported displacement was greater in resting position (27.38 mm) followed by neutral position (22.01 mm), and at the end of the range of motion (9.34 mm) with significant differences for both humeral head displacement ($p < 0.002$) and distraction forces used ($p < 0.015$) among the three joint positions, which agree with the results of our study where significant differences are highlighted in the P0 and RP positions with respect to ABD+ER position. Authors concluded that during the distraction technique, the force applied by the therapist and the displacement of the humeral head depend on the tested joint position. Also, Oh et al. [19], through an *in vivo* exploration, described the differences between the values of CHD, using ultrasound in different shoulder rotations (full external rotation, in neutral rotation with the arm at the side of the body and in full internal rotation with the shoulder in

90º flexion). They reported that CHD varies significantly according to shoulder rotation; finding greater CHD in external rotation, which is consistent with this research.

As stated, the initial distance in ABD+ER position is greater than P0 and RP; however, its rate of change is lower when applying the grade III distraction technique, as evidenced by repeated measures testing, due in part to the greater tension found in the surrounding active and passive stabilizing elements and generating less joint separation, therefore; producing less impact on the mobility of the GH joint. The greater the relaxation of the passive structures of the articular complex, the greater the separation of the articular surfaces and probably due to a lower resistance of the tissues to the manipulative force on the joint capsule.

Regarding soft tissue changes by mechanical forces, Bialosky et al. [25] highlights the effects of manual therapy techniques on periarticular tissues, increased joint space, decreased joint pressure, changes in the elasticity of the joint capsule and surrounding muscles, among others. Several studies have suggested that changes in the elasticity of the joint capsule and surrounding muscles during a distraction mobilization could explain the effects of the technique in relieving pain and improving joint mobility. For contractile soft tissue, it has been described that there is a reactive contraction against any load applied to the GH joint by the rotator cuff [14] and immediate effects of passive joint mobilization on local muscle function [26].

In the case of ABD+ER position lower rate of CHD change, both contractile and non-contractile soft tissue may be involved. Kanazawa et al. showed a negative correlation between the elasticity of the coracohumeral ligament and the position of abduction with external rotation [27]. Also, increased tension of the lower GH ligament has been described in abduction and external rotation positions [24].

Differences can also be attributed to the type of distraction technique selected (short lever), which ensures a better grasp of the proximal humerus and allows a better perpendicular separation of the GH joint, adjusting better to the direction in which a distraction should be performed (perpendicular to the glenoid surface).

Our results suggest that both P0 and RP positions achieved a significant increase in the GH space during the execution of a grade III mobilization technique, leading to a change at arthrokinematic level that may favor the osteokinematic articular range, and thus be able to guide the therapist to select the most specific position during the clinical practice. These results allow to grow evidence on manual therapy intervention regarding GH joint. Future research should explore whether there are differences in the clinical effects of applying a grade III distraction in P0 or RP and consider different lever arm applications and its implication on GH joint separation.

Limitations

There are several limitations of this research. Only young and healthy males were selected with inclusion and exclusion criteria, using a non-probabilistic method for convenience, so findings cannot be extrapolated to individuals with shoulder mobility restrictions. Also, no randomization was applied, but we enrolled and applied all distraction techniques consecutively without an intentional selection [28].

Regarding CHD, measures were used from both shoulders, not considering dominance, although this generalization could be carried out since statistical tests were applied to determine the independence of each upper limb. We would also like to mention that between baseline measurements and during the execution of the technique, CHD distance measurement points vary, however, the bony eminences do not. The reasons for such changes are attributable to changes in the position of the scapula during the distraction technique; however, the subject's body weight was used for this purpose and the ICC values indicate the reliability of the measurements.

Finally, force application during the grade III distraction technique, RP and ABD+ER positions during distraction technique were not controlled. Also, manipulation of the ultrasound equipment was operator-dependent, so data recording may be biased; however, both professionals have training in both orthopedic manual therapy and ultrasound imaging procedures, moderate to excellent reliability evidenced by ICC values and blinded ultrasound operator mitigates bias associated to procedure.

Conclusion

We can conclude that the initial position of application of a grade III distraction technique in the GH joint influences the separation of the articular surfaces, with zero and resting positions being wider. These results allow us to orientate the therapist to select the most optimal position during the clinical practice.

Acknowledgments

This research was promoted by the Nucleus of Research in Rehabilitation and Human Movement Sciences (Decree 1076/2015).

Disclosure statement

The authors have no conflicts of interest to declare.

Notes on contributors

Diego Guerra-Rodríguez, PT, MSc, currently works as an academic in the Biomedical Department at University of Antofagasta, Chile. He has a master's degree in Orthopedic

Manual Therapy from Andres Bello University, Chile. His research lines are human anatomy, musculoskeletal science and clinical practice.

Liliana Rozo, PT, MSc, currently works at the Master of Orthopedic Manual Therapy Program in Andres Bello University in Santiago, Chile. She completed the Certification Specialty in Orthopedic Manual Therapy at St. Augustine University, FL, USA. She has a master's degree in Manual Therapy from Andres Bello University, Chile. His research interests include limb dysfunctions and motor control with the integrative approach to manual therapy and clinical reasoning. She is active in COLKINE Chile, RIG TMO CHILE, RIG TMO Colombia where she is an honorary member.

Daniel Basilio, PT, currently works as head physical therapist at Kinetic-K Integral Therapy and Training Center and master ´s degree in Physical Activity, Sport and Health of the University of Antofagasta candidate. He completed advanced training in upper extremity ultrasound in the International Society of Musculoskeletal Ultrasound (Musculoskeletal Ultrasound in Physical Therapy) and completed formation of eco-guided musculoskeletal electrolysis of Physioinvasiva Chile with MVClinic and the CEU University of San Pablo, Spain collaboration.

Juan Guerrero-Henriquez, PT, MSc, currently works as an academic in the Rehabilitation and Human Movement Sciences Department at University of Antofagasta, Chile. He has a master's degree in Orthopedic Manual Therapy from Andres Bello University, Chile. His research lines are biomechanics, musculoskeletal science, and data science.

ORCID

Juan Guerrero-Henriquez http://orcid.org/0000-0002-9071-3586

References

[1] Camarinos J, Marinko L. Effectiveness of manual physical therapy for painful shoulder conditions: a systematic review. J Manual Manipulative Ther. 2009;17(4):206–2015.
[2] Desjardins-Charbonneau A, Roy J-S, Dionne C, et al. The efficacy of manual therapy for rotator cuff tendinopathy: a systematic review and meta-analysis. J Orthop Sports Phys Ther. 2015;45(5):330–350.
[3] Kachingwe AF, Phillips B, Sletten E, et al. Comparison of manual therapy techniques with therapeutic exercise in the treatment of shoulder impingement: a randomized controlled pilot clinical trial. J Manual Manipulative Ther. 2008;16(4):238–247.
[4] Estébanez-de-miguel E, López-de-celis C, Caudevilla-Polo S, et al. The effect of high, medium and low mobilization forces applied during a hip long-axis distraction mobilization on the strain on the inferior ilio-femoral ligament and psoas muscle: a cadaveric study. Musculoskeletal Sci Pract. 2020;47 (September2019):3–7.
[5] Do MG, Kim TH, Lim JY. Changes in joint space width during kaltenborn traction according to traction grade in healthy adults. J Phys Ther Sci. 2016;28(1):246–249.
[6] Agarwal S, Raza S, Moiz J, et al. Effects of two different mobilization techniques on pain, range of motion and functional disability in patients with adhesive capsulitis: a comparative study. J Phys Ther Sci. 2016;28 (12):3342–3349.
[7] Heiser R, O'Brien VH, Schwartz DA. The use of joint mobilization to improve clinical outcomes in hand therapy: a systematic review of the literature. J Hand Ther. 2013;26(4):297–311.
[8] Park SS, Kim BK, Moon OK, et al. Effects of joint position on the distraction distance during grade III glenohumeral joint distraction in healthy individuals. J Phys Ther Sci. 2015;27(10):3279–3281.
[9] Ho KY, Hsu AT. Displacement of the head of humerus while performing "mobilization with movements" in glenohumeral joint: a cadaver study. Manual Ther. 2009;14(2):160–166.
[10] Hsu AT, Chiu JF, Chang JH. Biomechanical analysis of axial distraction mobilization of the glenohumeral joint - A cadaver study. Manual Ther. 2009;14 (4):381–386.
[11] Muraki T, Aoki M, Uchiyama E, et al. Strain on the repaired supraspinatus tendon during manual traction and translational glide mobilization on the glenohumeral joint: a cadaveric biomechanics study. Manual Ther. 2007;12(3):231–239.
[12] Gokeler A, Van Paridon-Edauw GH, DeClercq S, et al. Quantitative analysis of traction in the glenohumeral joint. In vivo radiographic measurements. Manual Ther. 2003;8(2):97–102.
[13] Vermeulen H, Obermann W, Burger B, et al. End-range mobilization techniques in adhesive capsulitis of the shoulder joint: a multiple-subject case report. Phys Ther. 2000;80(12):1204–1213.
[14] Rathi S, Taylor NF, Gee J, et al. Measurement of glenohumeral joint translation using real-time ultrasound imaging: a physiotherapist and sonographer intra-rater and inter-rater reliability study. Manual Ther. 2016;26:110–116.
[15] Navarro-Ledesma S, Struyf F, Labajos-Manzanares M, et al. Is coracohumeral distance associated with pain-function, and shoulder range of movement, in chronic anterior shoulder pain? BMC Musculoskelet Disord. 2017;18(136):1–6.
[16] Talbott NR, Witt DW. In vivo measurements of humeral movement during posterior glenohumeral mobilizations. J Manual Manipulative Ther. 2016;24 (5):269–276.
[17] Witt DW, Talbott NR. In-vivo measurements of force and humeral movement during inferior glenohumeral mobilizations. Manual Ther. 2016;21:198–203.
[18] Hekimoğlu B, Aydin H, Kizilgöz V, et al. Quantitative measurement of humero-acromial, humero-coracoid, and coraco-clavicular intervals for the diagnosis of subacromial and subcoracoid impingement of shoulder joint. Clin Imaging. 2013;37(2):201–210.
[19] Joo Han O, Byung Wook S, Jung-Ah C, et al. Measurement of coracohumeral distance in 3 shoulder positions using dynamic ultrasonography: correlation with subscapularis tear. Arthoscopy – J Arthoscopic Relat Surg. 2016;32(8):1502–1508.
[20] Fareeha K, Abdul Ghafoor S, Sumera A, et al. Effects of Kaltenborn mobilization in mid-range and

end-range in patients with adhesive capsulitis. Rawal Med J. 2017;42(4):559–562.

[21] Kaltenborn F. Fisioterapia manual: extremidades. 2004. McGraw-Hill Interamericana de España S.L.

[22] Lin HT, Hsu AT, Chang GL, et al. Determining the resting position of the glenohumeral joint in subjects who are healthy. Phys Ther. 2007;87(12):1669–1682.

[23] Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med. 2016;15(2):155–163.

[24] Goetti P, Denard PJ, Collin P, et al. Shoulder biomechanics in normal and selected pathological conditions. EFORT Open Rev. 2020;5(8):508–518.

[25] Bialosky JE, Bishop MD, Price DD, et al. The mechanisms of manual therapy in the treatment of musculoskeletal pain: a comprehensive model. Manual Ther. 2009;14(5):531–538.

[26] Pfluegler G, Kasper J, Luedtke K. The immediate effects of passive joint mobilisation on local muscle function. A systematic review of the literature. Musculoskeletal Sci Pract. 2020;45:102106.

[27] Kanazawa K, Hagiwara Y, Sekiguchi T, et al. Correlations between range of motion and elasticity of the coracohumeral ligament evaluated with shear-wave elastography. J Sport Rehabil. 2021;30(1):9–15.

[28] Oh JH, Song BW, Choi JA, et al. Measurement of coracohumeral distance in 3 shoulder positions using dynamic ultrasonography: correlation with subscapularis tear. BMC Musculoskelet Disord. 2016;32(8):1–7.