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DOCTORAL THESIS

REHABILITATIVE ULTRASOUND IMAGING (RUSI) IN THE PHYSICAL EVALUATION OF PATIENTS WITH SHOULDER PAIN

SANTIAGO NAVARRO LEDESMA

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AUTOR: Santiago Navarro Ledesma

http://orcid.org/0000-0002-4302-1106

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REHABILITATIVE ULTRASOUND IMAGING (RUSI) IN THE PHYSICAL EVALUATION OF PATIENTS WITH SHOULDER PAIN

THESIS SUBMITTED FOR THE FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR IN PHYSIOTHERAPY BY THE UNIVERSITY OF MALAGA AND DOCTOR IN MEDICAL SCIENCES BY THE UNIVERSITY OF ANTWERPEN

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DEFENDED BY: SANTIAGO NAVARRO LEDESMA

PROMOTORS:

Prof. Dr. Alejandro Luque Suárez

Prof. Dr. Filip Struyf

Prof. Dr. María Teresa Labajos Manzanares

Academic Year 2016-2017

Faculty of Health Sciences/ Faculty of Medicine and Health Sciences

Mr. Alejandro Luque Suarez, PhD in Physiotherapy at the University of Malaga, Spain

CERTIFY that the dissertation presented as Doctoral Thesis by Mr. Santiago Navarro Ledesma, entitled REHABILITATIVE ULTRASOUND IMAGING (RUSI) IN THE PHYSICAL EVALUATION OF PATIENTS WITH SHOULDER PAIN, has been carried

out under my supervision and I consider this Thesis fulfills the requirements in terms of substance and scientific rigour and is presented to be read

Hereby, I declare on my word of honor this declaration on the 12th of May, two thousand and seventeen

Faculty of Health Sciences/ Faculty of Medicine and Health Sciences

Mrs. María Teresa Labajos Manzanares, PhD in Medicine and Surgery at the University of Malaga, Spain

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Universiteit Antwerpen

Mr. Filip Struyf, PhD in Health Sciences and Physiotherapy at the Vrije University of Brussels

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DEDICATORIA:

A mis padres, quienes siempre me han apoyado y dado lo mejor de sí mismos. Sin ellos, no sería quien soy.

AGRADECIMIENTOS:

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A todos aquellos que participaron de algún modo en el proyecto.

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Glossary of acronyms

AHD: Acromiohumeral distance

CHD: Coracohumeral distance

CHI: Coracohumeral interval

GPs: General practitioners

LHBT: Long head biceps tendon

MRI: Magnetic resonance imaging

RC: Rotator cuff

RCRSP: Rotator cuff related shoulder pain

RCT: Rotator cuff tear

RUSI: Rehabilitative ultrasound imaging

ROM: Range of movement

SAPS: Subacromial pain syndrome

SIS: Subacromial impingement syndrome

SPADI: Shoulder Pain And Disability Index

US: Ultrasound

USI: Ultrasound imaging

Chapter I

General introduction

Chapter 1

1.1 Rehabilitative ultrasound imaging in the assessment of musculoskeletal system

Principles.

Ultrasound is defined as sound with a frequency greater than 20 000 Hz, which is the upper limit of the range registered by the human ear. Ultrasound imaging (USI) uses sound waves primarily in the range of 3.5 to 15 MHz. Ultrasound waves behave according to principles that apply to all sound waves, which at the most fundamental level are mechanical waves that travel via particle vibration. Specifically, the source of a sound creates oscillatory vibrations that affect particles in the medium that lies adjacent to it. These particles, in turn, affect their adjacent particles, and so on. This process is referred to as wave propagation. How far a sound wave propagates and whether an echo is produced depends on the strength of the sound source, the properties of the media through which the sound has to travel, and the number, shape, and properties of the objects it encounters. These behaviors can be summarized by the principles of penetration and attenuation.(Whittaker et al., 2007)

History.

From an historical point of view, ultrasound imaging (USI) has been used for medical purposes since 1950s(Whittaker et al., 2007). Although the first work related to rehabilitative sciences carried out by physiotherapists only started in the 1980s with the work of Dr Archie Young, a physician at the University of Oxford whose research team included physiotherapists(Teyhen, 2006).

Current applications of USI in rehabilitation go to two distinct areas of musculoskeletal imaging mainly: rehabilitative USI (RUSI) and diagnostic imaging (USI). With the purpose to define the role of RUSI, the US Army-Baylor University Doctoral Program in Physical Therapy hosted an international symposium on RUSI in May 2006 where included the development of a set of RUSI measurement standards for the assessment of muscle function and the exploration of future applications of RUSI(Teyhen, 2007). Rehabilitative ultrasound imaging (RUSI) has been described as "a procedure used by physiotherapists to evaluate muscle and related soft tissue morphology and function during exercise and physical tasks. RUSI is used to assist in the application of therapeutic interventions aimed at improving neuromuscular function. This includes providing feedback to the patient and physiotherapists to improve clinical outcomes. Additionally, RUSI is used in basic, applied, and clinical rehabilitative research to inform clinical practice"(Teyhen, 2006). On the other hand, the use of diagnostic USI involves the examination of injuries or diseases on soft tissues as ligament, tendon, and muscle, which requires different skills and training than those needed for RUSI(Whittaker et al., 2007).

Advantages and disadvantages.

In recent years, the use and knowledge of USI in the management of musculoskeletal disorders(Hides, Richardson, & Jull, 1998)(Teyhen & Koppenhaver, 2011)(Teyhen, 2006)(Hides, Stokes, Saide, Jull, 1994) has been growing thanks to its non-ionizing effect, non-invasive technique, low cost and the possibility of dynamic evaluation(Lee et al., 2007)(Hides et al., 1998). A good correlation with magnetic resonance imaging (MRI) is growing in different pathological entities(Lenza et al., 2013), furthermore when considering accuracy, cost, and safety, US is the best option(Roy et al., 2015). Thus, USI lets us carry out reiterated evaluations, which could play an important role in the prevention of injuries.

Also, USI enables professionals to attain major accuracy when the return to play is studied, reducing the number of injury possibilities.

On the other hand, USI also has disadvantages as it is highly operator dependent, so an inadequate use and understanding of USI could contaminate the study and its results. Because of that, researchers must take care during both the interpretation and reporting process.

Ultrasound imaging in shoulder disorders.

Regarding USI related to shoulder pain management, it has been shown that US is comparable to MRI regarding rotator cuff and bicep tendon integrity evaluation(Fischer,mAlexander, Weber, Neubecker, Clement, & Thomas, Tanner, Zeifang, 2015). There exists many studies documenting different shoulder injuries and structures such as tendon(Arend, Arend, & Da Silva, 2014), muscle(Juul-kristensen, Bojsen-møller, Holst, & Ekdahl, 2000) or bursa(Drakes, Thomas, Kim, Guerrero, & Lee, 2015) in healthy(Juul-kristensen et al., 2000) and shoulder pain populations measured by US. Furthermore, measuring tendon thickness(Schneebeli, Egloff, Giampietro, Clijsen, & Barbero, 2014) and spaces such as acromio-humeral(Desmeules, Minville, Riederer, Côté, & Frémont, 2004) (AHD) and coraco-humeral interval (CHI)(MR Tracy, TA Trella, LN Nazarian, CJ Tuohy, 2010) (CHD) have been also analyzed, in addition to the presence of tears as well as their progress related to age or pain(Yamaguchi et al., 2006),(Teunis, Lubberts, Reilly, & Ring, 2014).

This means that many different shoulder conditions have been studied, however no studies exist establishing a correlation between the size of the subacromial space with pain, function and disability in people suffering from chronic shoulder pain, and the same is true for the subcoracoid space in chronic pain conditions.

More extensive studies are needed to cover these gaps in the scientific literature to guide professionals to a better understanding both in the prognosis and in the best choice of physiotherapy treatment program. Thus, if a correlation between the AHD and pain-function and ROM is found in patients with chronic shoulder pain, clinicians could direct treatments on increasing such space. Equally, the same could be thought if a correlation between the CHD and pain-function and ROM is found. On the contrary, whether no correlations are found in the aforementioned situations, others factors such as psychosocial, intrinsic properties of tissue or central sensitization,should be considered when a patients with chronic shoulder pain is assessed.

Technique and scanning protocol.

Acromio-humeral distance (AHD).

The process to evaluate AHD has been previously used in different populations, such as healthy volunteers(Luque-Suarez, Navarro-Ledesma, Petocz, Hancock, & Hush, 2013) and patients with shoulder pain(McCreesh, Anjum, Crotty, & Lewis, 2015). Patients are seated upright without back support, their feet flat on the ground. AHD was defined as the shortest linear distance between the most inferior aspect of the acromion and the adjacent humeral head(Desmeules et al., 2004). The ultrasound transducer is placed on the most anterior aspect of the acromion edge, with the long axis of the transducer placed in the plane of the scapula and parallel to the flat surface of the acromion. AHD was measured in centimeters, using the calipers on the ultrasounds' screen.

Coraco-humeral distance (CHD).

The process followed to evaluate CHD has not been previously described in any US study. Hence, although there is one study which uses US measuring CHD it does not explain the method they followed as well as any landmarks. Patients are seated upright without back support, their feet flat on the ground. CHD was defined as the shortest linear distance between the coracoid and the adjacent humeral head(Gerber, Terrier, & Ganz, 1985). The ultrasound transducer is placed on the most anterior aspect of the shoulder, observing the coracoid process and the humeral head on the screen, taking the shortest distance between them. CHD was measured in centimeters, using the calipers on the ultrasounds' screen.

Long head biceps (LHBT).

Following Corazza (Corazza et al., 2015), the LHBT is the first structure to be examined, as the bicipital groove is a useful bony landmark during dynamic evaluation of the shoulder with US. The patient's forearm is placed with the elbow flexed 90 degrees in slight internal rotation, with the palm facing up and medially. This position allows for bringing the bicipital groove to an anterior position, allowing for a clear visualization of the LHBT. The bicipital groove is easily identified by placing the probe over the humeral head on an axial plane. Once localized the groove, the LHBT should be lying inside. Then, slide the probe cranially and caudally to evaluate the tendon along its extra-articular course. The evaluation should be commenced proximally from the rotator interval up to the myotendinous junction distally. The normal LHBT will appear as hyperechoic and fibrillar. As the tendon has an oblique course (i.e., more superficial cranially, deeper caudally), it is crucial to keep the transducer always as perpendicular as possible to the tendon course to avoid hypoechoic appearance due to anisotropy artifacts. Important information about LHBT stability can be obtained extrarotating the flexed forearm with elbow abducted while holding the probe on the bicipital groove. In normal conditions, the tendon must be seen within the groove during the entire maneuver. Then, the probe should be rotated 90 degrees clockwise to evaluate the LHBT on a long axis; again, due to its oblique course, optimal visualization of the tendon can be obtained by slightly pressing the distal edge of the probe on the skin to achieve maximal perpendicularity of the US beam to tendon fibers. The LHBT is usually evaluated for tendinosis, instability, or fluid fusion within the tendon sheath, with or without synovial hypertrophy. The proximal portion of the LHBT is contained within the rotator interval. As already mentioned, this is a triangular portion of the capsule through which the LHBT exits the intrarticular space and lies between the supraspinatus and the subscapularis tendons. Here, the LHBT is stabilized by the superior glenohumeral ligament (medially and deeply) and by one branch of the coracohumeral ligament (superficially). To evaluate this area, the arm should be externally rotated and the probe should be moved upwards and with the external tip slightly rotated medially, to follow the course of the tendon. In this position, the rotator interval appears as a layered hyperechoic area surrounding the cross sectioned LHBT. Distally, the myotendinous junction of the LHBT is located under the pectoralis major tendon. This area should be carefully assessed when a traumatic tear is suspected.

Subscapularis tendon.

To evaluate the subscapularis tendon, the probe is placed in the axial plane in the same position used to visualize the bicipital groove and the lesser tuberosity. The patient is asked to rotate the forearm externally, keeping the hand palm up and the elbow strictly close to the iliac crest. This will stretch laterally the subscapularis tendon, allowing for an easier examination in its entire extent. It is crucial to evaluate the tendon in short and long axis as, due to its width, lesions may affect one location even if other areas appear completely normal. In the long axis, the subscapularis tendon should be evaluated sliding the US transducer from the cranial to the caudal aspect. Then, the subscapularis tendon must be evaluated on its short axis, turning the probe 90 degrees clockwise. This scan shows the complex anatomy of the subscapularis tendon, with its multifascicular pattern formed by an alternation of hyperechoic tendons and hypoechoic muscular fibers. This appearance has remarkable variations among general population, as some subjects may present with thicker tendon fibers while in others muscular fibers are much more visible. In axial scan, the subscapularis tendon should be evaluated from medial to lateral border. Subscapularis tears mainly occur on the cranial aspect of the tendon. (Corazza et al., 2015)

Supraspinatus tendon.

The supraspinatus tendon can be evaluated using two different positions of the arm: the Crass position (i.e., with the elbow 90 degrees flexed and the forearm located behind patient's back) or the modified Crass or Middleton position (i.e., with patient's hand palm placed over his/her iliac wing or "back pocket" with the elbow flexed and directed medially). The modified Crass position has the advantage of showing the supraspinatus tendon more completely, extracting the full myotendinous junction. Once the patient is positioned, the supraspinatus tendon is visualized on its long axis first. The extra-articular portion of the LHBT can be used as a landmark to orientate the transducer properly over the supraspinatus. Indeed, these two tendons have a parallel course; once the LHBT is identified on its long axis on the anteromedial aspect of the shoulder, the transducer is shifted posteriorly over the greater tuberosity without changing orientation. This allow for a long-axis evaluation of the supraspinatus. A correct scan is obtained when the humeral head cartilage, the anatomical neck of the humerus, and the greater tuberosity are seen together on a single scan. The tendon should be evaluated from the anterior to the posterior aspect. Particular caution should be taken when evaluating the critical area of the supraspinatus tendon, as tendon fibers have a curvilinear course that make them almost parallel to the US beam. To avoid anisotropy artifacts that typically affect this area, the probe should be slightly tilted laterally to make the US beam as perpendicular as possible to those fibers(Martinoli, 2010). Of note, the critical area is the portion of the supraspinatus tendon more prone to tears. The structure of the supraspinatus tendon should be hyperechoic and fibrillar. As the probe is moved posteriorly to reach the junctional area between the supraspinatus and the infraspinatus, thin hypoechoic striations are seen. These are the anterior part of the infraspinatus, as its fibers run on a different plane compared to the supraspinatus. A hyperechoic fibrillar structure can be seen deep to the supraspinatus and infraspinatus tendons, tracking in a perpendicular fashion relative to the rotator cuff fibers. This is the so-called rotator cable, a thick deep bundle of fibers arising from the coracohumeral ligament, perpendicular to the supraspinatus and infraspinatus tendons, which can be seen in 47–99% of patients depending on age(Bennett, 2001). The distal portion of the tendon is also known as rotator crescent. After evaluating the supraspinatus tendon on the long axis, the probe should be rotated 90 degrees clockwise to assess the short axis. The tendonis evaluated from the lateral to the medial aspect, and will appear as an oval-shape structure overlying the greater tuberosity.

The size of supraspinatus tendon footplate has been reported to range between 11 and 18 mm(Karthikeyan et al., 2014). A similar range has been reported for the antero-posterior diameter (Jacobson, 2011). Dynamic scan of the supraspinatus tendon can be performed applying gentle pressure over the patient’s flexed elbow in medial direction. This allows for further exposing the supraspinatus tendon, also emphasizing the presence of tiny tears that may be undetectable during static evaluation. The subacriomial–subdeltoid bursa lies between the supraspinatus tendon and the deltoid muscle, and in physiologic conditions appears as a barely visible thin hypoechoic band.

Extrarotator tendons.

To evaluate the infraspinatus and the teres minor tendons, the patient is asked to put the hand's palm on the opposite shoulder. Another position that may avoid excessive anterior dislocation of tendons is with the forearm in supination on the ipsilateral thigh. The probe should be oriented vertically to localize the scapular spine, which separates the infraspinous fossa from the supraspinous fossa and can be used as a bony landmark. Then the probe should be shifted below the scapular spine over the infraspinous fossa, where infraspinatus and teres minor muscles can be seen as individual structures deep to the deltoid. The probe should then be moved laterally until the two tendons will be seen arising from the respective muscles bellies on their short axis, being the infraspinatus cranial and the teres minor caudal. These tendons have a similar appearance, and in some patients it can be difficult to separate one from the other, as they usually merge at their insertion over the greater tuberosity(Silvestri, Muda, & L. Sconfienza, 2012). After short axis evaluation, the probe should be positioned on the infraspinatus tendon and turned by 90 degrees clockwise to assess the tendons along its longitudinal axis till their insertional region on the posterior aspect of the greater tuberosity. For a better view of insertional region of the tendons, the patient's arm can be slightly externally rotated while keeping the elbow strictly adherent to the chest. Then, sliding the probe slightly caudally, the teres minor tendon can be assessed with a similar approach.

Impingement tests.

The use of RUSI has several advantages, as it has been referred previously. One of them is the dynamic capability of US, which is useful in the detection of impingement conditions.

The probe should be placed in a coronal scan over the superior aspect of the shoulder to visualize the acromion on the medial side of the image and a part of the supraspinatus tendon on the lateral side. With the forearm 90 degrees flexed over the arm, the upper limb of the patient is abducted to see the supraspinatus tendon disappearing under the acromion. Impingement of the supraspinatus tendon cannot be seen directly under the acromion, as US beam cannot penetrate cortical bone. However, impaired sliding and impingement of the subacromial–subdeltoid bursa under the acromion can be easily demonstrated, with fluid distending the bursal recesses(Jacobson, 2011)(Bureau, Beauchamp, Cardinal, & Brassard, 2006). The coracoacromial ligament is a thin triangular fibrous band, which connects the acromion with the lateral edge of the coracoid. To assess this ligament, the probe should be oriented on a coronal oblique plane, with one edge of the probe on the coracoid process and the other edge on the acromial tip .The coraco-acromial ligament appears as a thin fibrillar hyperechoic band in tension between the coracoid and the acromion. Also this structure may represent a site of impingement for the supraspinatus tendon(J. Brossmann, Preidler, K W, R. A. Pedowitz, L.M. White, D. Trudel, 1996). With the same manoeuver used to assess subacromial impingement, the supraspinatus muscle and tendon can be seen sliding under the ligament. If the ligament bows during this maneuver, subligamentous impingement can be reliably diagnosed. Far less common than subacromial and coracoacromial, antero-medial and posteromedial impingement can be detected using US. Anteromedial impingement (also known as subcoracoid impingment) occurs when the subscapularis tendon and/or the LHBT impinge over the tip of the coracoid when the arm is flexed forward and in maximal internal rotation. The evaluation of this condition can be performed reproducing this movement of the arm while placing the US transducer lateral to the coracoid process. Postero-superior impingement occurs when the junction of supraspinatus and infraspinatus is pinched between the greater tuberosity of the humerus and the postero-superior glenoid while the arm is in maximal abduction and external rotation. This impingement typically leads to degenerative tears of the undersurface of the supraspinatus tendon. This condition can be evaluated placing the US probe over the postero-superior glenoid rim while positioning the arm in abduction and external rotation.

1.2 Justification of the thesis

Because of acromiohumeral distance (AHD), defined as the shortest linear distance between the most inferior aspect of the acromion and the adjacent humeral head(Hébert, Moffet, Dufour, & Moisan, 2003), has been suggested to be related with the presence and severity of some shoulder disorders, such as subacromial impingement syndrome (SIS) and rotator cuff (RC) tendinopathy(L. a. Michener, Subasi Yesilyaprak, Seitz, Timmons, & Walsworth, 2013)(Kibler et al., 2013), a research project through this thesis was started, whose first study was designed with the aim of investigating whether the AHD, measured by ultrasonography, can be increased after a kinesio taping application. We chose to examine this issue initially in asymptomatic subjects, according to investigate the effects of kinesio taping on the AHD in the absence of pain, as well as to evaluate the capabilities of ultrasound imaging in the assessment of changes in AHD after application of a physiotherapy technique. A secondary aim was to investigate whether the direction in the application of the technique influences in the effects obtained on AHD.

Once the study mentioned above was carried out, a second study was designed with the aim of determining whether there is any association between AHD measured by ultrasonography, and pain-function and range of movement, in participants suffering from chronic rotator cuff related shoulder pain (RCRSP). If any association was found, clinical practice could be focused on improving AHD and, furthermore, AHD could be used for researchers as an outcome measure to report results of their interventions, as the same manner as pain, function and ROM are used nowadays. Moreover, if there was a correlation between AHD and pain, disability and ROM, it would be possible to determine populations at risk of suffering and/or perpetuating chronic rotator cuff related shoulder pain.

Finally, a third study was designed with the purpose of assessing the intrarater reliability of coracohumeral distance (CHD), measured by US, in patients suffering from chronic anterior shoulder pain, as well as to determine the association between CHD with shoulder pain, function and shoulder-ROM free of pain. If a strong relationship between a reduced CHD and high levels of pain, decreased shoulder function and limited shoulder ROM was identified, preventive and therapeutic efforts could be focused on increasing this space.

Chapter II

Aims of thesis

Chapter II

Aims of thesis

1. The first aim of the thesis was to investigate whether acromiohumeral distance (AHD) can be increased after a kinesio taping application. A secondary aim was to investigate whether the technique of kinesio taping application influences any effects on the AHD.
2. To investigate the level of association between acromiohumeral distance (AHD) measured by ultrasonography and pain disability and shoulder range of movement (ROM), in patients suffering from chronic shoulder pain.
3. To investigate the level of association between coracohumeral distance (CHD) measured by ultrasonography and pain, disability and shoulder range of movement (ROM), in patients suffering from chronic anterior shoulder pain.

Chapter III

Short term effects of kinesio taping on acromiohumeral distance in asymptomatic subjects: a randomized clinical trial

Chapter III

Short term effects of kinesio taping on acromiohumeral distance in asymptomatic subjects: a randomized clinical trial

3.1 Introduction

Maintenance of the subacromial space in the shoulder girdle is crucial for normal shoulder function. The subacromial space can be assessed by measurement of the acromiohumeral distance (AHD), which is the distance between the most cranial part of the humeral head and the acromion. Reduced AHD occurs when the humeral head migrates superiorly with inadequate external rotation, and correlates with shoulder impingement severity (Desmeules et al., 2004) (Mayerhoefer, Breitenseher, Wurnig, & Roposch, 2009) (Matsuki et al., 2012) and rotator cuff disease (Seitz & Michener, 2010) . The measure of AHD can also be used to identify patients who are most likely to benefit from active rehabilitation for shoulder impingement(Desmeules et al., 2004) or surgical repair of the rotator cuff (Saupe et al., 2006). In asymptomatic individuals, reduced AHD during shoulder abduction correlates with scapular dyskinesia (Silva, Hartmann, Laurino, & Biló, 2010) and may therefore be a useful pre-symptomatic indicator of subacromial impingement. AHD can be measured by radiography or magnetic resonance imaging (Saupe et al., 2006), although ultrasonography is a less expensive tool that has additional benefits (Azzoni, Cabitza, & Parrini, 2004) (Desmeules et al., 2004). For example, real-time ultrasonography enables the radiologist to measure AHD in different degrees of shoulder elevation or rotation (L. A. Michener, McClure, & Karduna, 2003). This approach has been used to detect subacromial space narrowing in young athletes as an early sign of shoulder impingement (Girometti et al., 2006).

In recent years, the use of a therapeutic taping technique known as kinesio taping has become increasingly popular for a range of musculoskeletal conditions and for sport injuries. For those with rotator cuff tendinopathy and shoulder impingement, kinesio taping has been found to improve self-reported outcomes such as pain and disability (Thelen, Dauber, & Stoneman, 2008) (Hsu, Chen, Lin, Wang, & Shih, 2009) (Kaya, Zinnuroglu, & Tugcu, 2011). However, the mechanism of action of kinesio taping is currently unknown and no studies have used diagnostic imaging to obtain quantitative measures of the effect of kinesio tape on the AHD. We hypothesize that kinesio taping increases the AHD.

The primary aim of this study was to investigate whether kinesio taping can increase the AHD. We chose to examine this initially in asymptomatic subjects to investigate the mechanism of action of kinesio taping in the absence of pain. A secondary aim was to investigate whether the technique of kinesio taping application influences any effects on the AHD.

3.2 Method

Design: randomized controlled trial

Participants

We recruited sixty-two participants, who volunteered from the student body of the Health Sciences School at Malaga University (Spain), and were screened for inclusion between January and March 2012. To be included, participants had to meet all of the following criteria: (i) no shoulder pain in the previous month, (ii) no previous shoulder surgery, (iii) negative Neer test: pain ≤3/10 when the upper limb is elevated in the plane between flexion and abduction with prevention of scapular rotation, (iv) no painful arc with shoulder flexion or abduction (pain ≤3/10 on a visual analogue scale), (v) between 18 and 40 years of age,

(vi) AHD ≥7mmwitharm at their side and (vii) able to provide informed, written consent. Exclusion criteria were as follows: (i) presence of a skin injury or condition on the shoulder that would contraindicate the use of KT, (ii) refusal to participate once the conditions of the study were known.

Forty-nine participants were enrolled into the study (Fig. 1).

Informed written and verbal consent were obtained from all participants before enrolment and baseline demographic and clinical data were collected. The study was approved by The Medical

Research Ethics Committee of the Faculty of Nursing, Physiotherapy, Podiatry and Occupational Therapy, University of Malaga and conducted in accordance with the Declaration of Helsink.

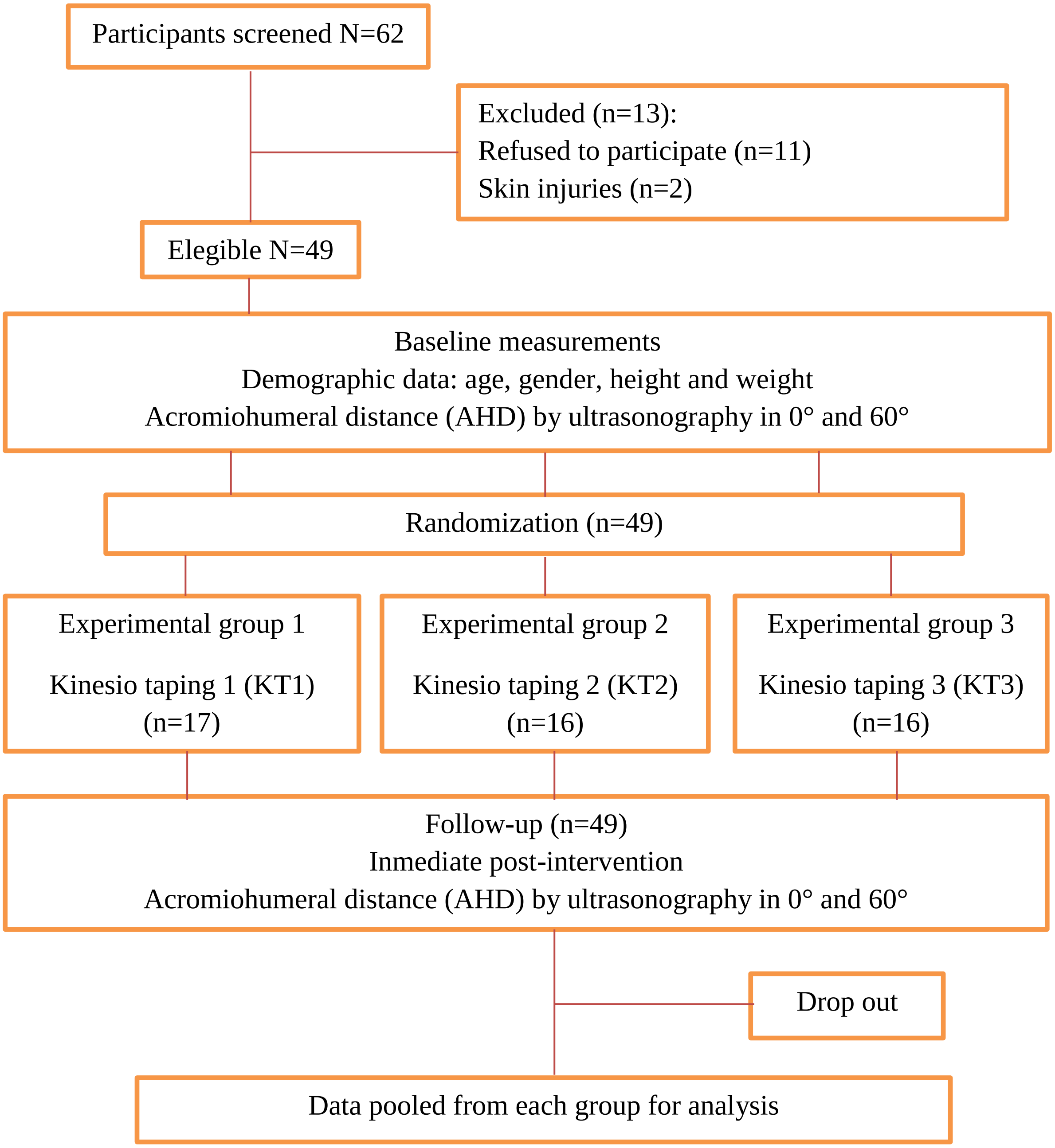

Figure 1: Participant flow diagram

Procedure

Participants were randomly assigned to 1 of 3 groups using a random-number generator and concealed allocation. Group 1 (KT1) received kinesiotape applied in the traditional manner from anterior to posterior. Group 2 (KT2) received kinesiotape applied from posterior to anterior and group 3 (KT3) received sham kinesiotape.

All participants received the kinesiotape application the day after the initial examination by the primary author. Each participant had ultrasound measures of AHD taken before and after the initial kinesiotape application, in 0° and 60° of active shoulder elevation in the scapular plane (Fig. 1).

Taping techniques

All taping was applied by the primary author who has 15 years of experience as a musculoskeletal physiotherapist (ALS), to the shoulder of the dominant upper limb of each participant. The skin was first cleaned with alcohol to aid adherence of the tape. Standard 5 cm wide blue k-tape was used for all taping techniques. The KT1 group received a kinesio tape application. The goal of taping in this group was to facilitate shoulder external rotation in order to increase AHD. A single strip was applied with the subject in erect standing, with the shoulder in maximal external rotation, palm facing forward (Fig. 2). The tape was applied from the coracoid process anteriorly to the superior scapular angle posteriorly, to maintain shoulder external rotation. The tape was stretched to 100% and immediately applied to the skin. Once applied, the adhesion of the tape to the skin was enhanced by rubbing the surface of the tape three times in an anterior to posterior direction.

The KT2 group received an identical treatment to the KT1 group, except that the tape was applied in the opposite direction: from the superior scapular angle to the coracoid process.

The KT3 group received a sham kinesio taping technique, whereby a single strip was applied in the same place as KT1 and KT2, but without tension and with the shoulder in neutral rather than external rotation (Fig. 2). All tape applications looked similar. In all groups, kinesio tape was removed by the physiotherapist after outcome data were collected.

Figure 2. KT1 (left), applied with 100% tension in maximal external rotation. KT3 (right) applied with no tension and in neutral rotation (sham taping).

Ultrasound measurements

The ultrasound examination of the shoulder was carried out by the second author (SNL). To reduce bias, the assessor was blinded to group allocation. Each participant was issued an identification number, and this was the only information provided to the examiner. Outcome data were collected for all participants. The ultrasound examinations were carried out using the MyLab_25Gold device (Esaote company, Genoa, Italy) with a 5e 12 MHz linear transducer. AHD was measured at 0° and 60° of shoulder elevation in the scapular plane, with the participant seated in an upright position(Kalra, Seitz, Boardman, & Michener, 2010). To achieve an upright position, with shoulder retraction and cervical and thoracic extension, subjects were instructed to sit against the back rest of the chair, sit up straight, pull their shoulders back and look straight ahead. We chose 60° of elevation because the AHD is smallest between 60° and 120°(Flatow et al., 1994). A hydro goniometer placed on the participant's arm was used to position the arm at 0° and 60° of scapular plane elevation(L.J. Hebert a, H. Moffet a, b, B.J. McFadyen a, b, 2000). To assist in positioning arm elevation in the scapular plane, a room divider was positioned at an angle of 30° forward from the subject's frontal plane, which was marked with tape on the floor(Theodoridis & Ruston, 2002). The participants were asked to maintain their arm elevated actively with enough tension to maintain the position of the hydro goniometer (Fig. 3). Between measurements, participants were instructed to bring their arm down to a resting position to minimize shoulder fatigue(Theodoridis & Ruston, 2002). To measure the AHD in 0° and 60° the ultrasound transducer was positioned along the major axis of the humerus and parallel to the flat superior aspect of the acromion, so that both the acromion and humerus could be visualized. The AHD was measured going straight down (vertically) from the acromion to the humeral head(Girometti et al., 2006), (Fig. 4). Measurements of the AHD were made at two locations: (1) at the most anterior part of the acromial arch and (2) 1 cm behind the first measure. The mean of the two measures was recorded(Desmeules et al., 2004). Excellent intrarater within-day reliability for ultrasonographic measurements of acromion-greater tuberosity distance in healthy individuals has been reported previously (ICC 0.97e0.99)(Kumar, Bradley, & Swinkels, 2010), (ICC 0.88e0.91) (Kumar et al., 2011).

We evaluated the intra-rater reliability of the ultrasound measurement of AHD. Three AHD measurements were taken for all participants by the same examiner, in 0° and 60° of shoulder elevation, prior to kinesio tape application. A time interval of 2 min was provided between each measurement. During that period, participants were encouraged to move out of the standardized position. Participants were then repositioned and the second set of measurements taken. The ultrasound examiner was blind to their initial measurements (values were obscured by placing a sticker on the ultrasound screen).

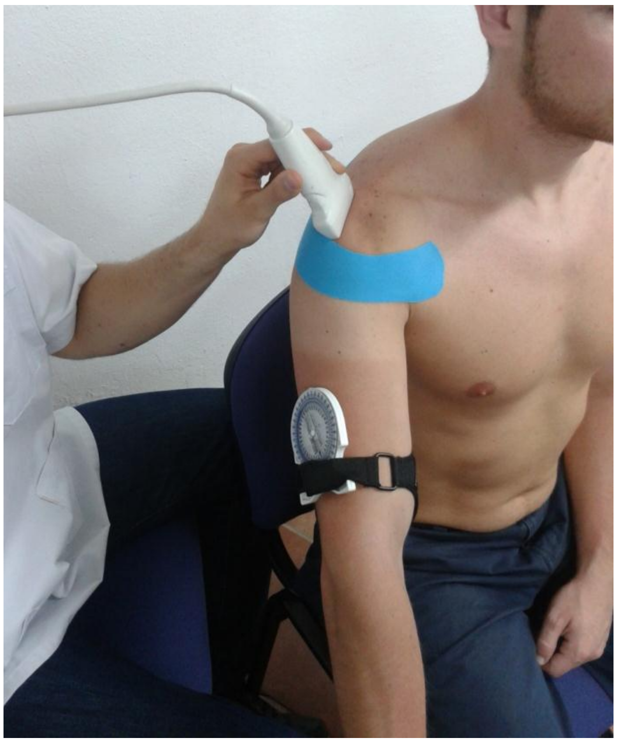

Figure 3 Participant's position for AHD assessment with ultrasonography.

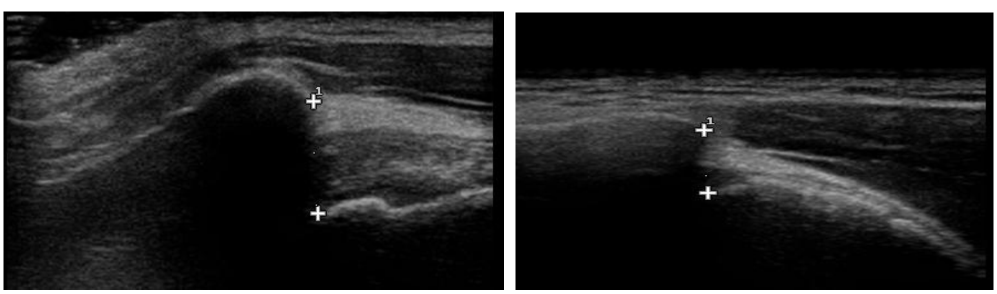

Figure 4 Ultrasound measurements of the AHD in 0° (left) and 60° (right) of scapular plane elevation. The area of subacromial space is equivalent to the distance between the two white cross symbols.

Data analysis

A power analysis was carried out using ΔAHD, (change in AHD = AHD after treatment minus AHD before treatment) as the primary response variable. A one-way analysis of variance with three groups required samples of size 17 in each group in order to identify between-group differences equal to 1 standard deviation of within-group values with a power of at least 70%. This approach was utilized as there was no prior information on variability of change values for AHD.

Analysis of variance models were constructed for ΔAHD, using the repeated measures nature of the data, with subject as a random factor (nested within group), and group and angle as fixed factors.

The three groups were compared pairwise with a Bonferroni adjustment for multiple comparisons. The data were analyzed using SPSS version 20. A p value of <0.05 was considered statistically significant.

Intrarater reliability of measuring AHD by ultrasound was estimated by calculating the intraclass correlation coefficient (ICC) for the second author, using a one-way random effect model

3.3 Results

Sixty-two participants were screened and 13 were excluded because of skin conditions or preference not to participate. This resulted in 49 participants who were enrolled into the study (Fig. 1): 17 in KT1 group and 16 participants each in KT2 and KT3 groups. Demographic characteristics and baseline ultrasound measures of AHD are shown in Table 1. The mean age of the participants was 23 years, 70 kg weight and 170 cm height, and 47% of the participants in the study were female. The mean baseline AHD was 10.5 mm at

0° and 7.2 mm at 60°. There were no significant differences in the demographic characteristic or AHD between the three groups at baseline.

Table 1 Baseline characteristics of subjects

	EXP. GROUP 1 (KT1) n=17	EXP. GROUP 2 (KT2) n=16	SHAM GROUP (KT3) n=16	P values
Age in years, mean (SD)	24.7 (5.3)	22.9 (4.1)	21.1 (2.6)	0.06
Females (n) %	(8) 47%	(10) 62%	(6) 37%	0.376
Weight (kgs), mean (SD)	68.6 (12.5)	70.2 (11.7)	72.3 (15.5)	0.726
Height (cms), mean (SD)	168.5 (8.6)	168.6 (9.7)	169.1 (18.5)	0.191
AHD (mm) in 0°, mean (SD)	11.2 (3.3)	10.3 (1.8)	10.1 (1.2)	0.298
AHD (mm) in 60°, mean (SD)	7.3 (1.9)	7.4 (1.5)	7.0 (1.6)	0.781

No adverse effects were reported by any of the participants during the treatment and follow-up periods.

The intra-rater reliability of the AHD measurements was excellent (ICC 0.94 (95% CI: 0.90, 0.96) at 0 degrees, and 0.87 (0.80, 0.92) at 60 degrees). The ANOVA model for ΔAHD found that groups were significantly different ($p = 0.001$), but angles were not significant ($p=0.72$), nor were inter-subject differences ($p = 0.30$). Group-by angle interaction was not required in the model, and its exclusion made no appreciable difference to the results. Each active group was significantly different to the control/sham group (KT1 $p < 0.001$, KT 2 $p = 0.006$) but the two active groups were not significantly different from each other (p=0.95, all with Bonferroni adjustment). Table 2 presents the ΔAHD for the 3 groups and Table 3 presents the effect sizes for comparisons between each of the 3 groups.

Table 2 ΔAHD (mm) for the 3 intervention groups; CI: confidence interval

GROUP	Mean	Standard error	95% CI
KT1	1.158[a]	0.208	(0.741 to 1.576)
KT2	0.856[a]	0.214	(0.426 to 1.287)
KT3	-0.128[a]	0.214	(-0.559 to 0.302)

[a]: Based on modified population marginal mean

Table 3 ΔAHD (mm) and effect size for comparisons between 3 intervention groups; CI: confidence interval

Group comparison	Effect size	95% CI	P value
KT1 vs KT3	1.28[*]	(0.55 to 2.03)	<0.001
KT2 vs KT3	0.98[*]	(0.23 to 1.74)	0.006
KT1 vs KT2	0.30	(-0.44 to 1.04)	0.95

[*]: indicates a statiscally significant difference between groups.

3.4. Discussion

This study investigated whether kinesio taping increases the AHD in asymptomatic individuals compared with sham taping. The results demonstrate that the AHD, measured by ultrasound, can be significantly increased by kinesio taping. Our results also suggest that there is no difference in the effect on the AHD if kinesio tape is applied in the anterior to posterior direction or the opposite direction.

The main strength of our study is methodological rigor. We used a randomized controlled trial design with true randomization and concealed allocation. We attained a follow-up of 100% of study participants and there was blinding of the assessor and statistician.

However, there are limitations of the current study that should be recognized. First, we only investigated short-term effects of kinesio taping so we cannot make inferences about long-term effects.

Second, these results inform us about the effects of kinesio taping on healthy individuals, and so the effects on AHD in people with subacromial impingement are unknown.

Our results that kinesio taping can increase the AHD in asymptomatic subjects provides a good foundation to further investigate the effects in those at risk of developing subacromial impingement or those with established pain and dysfunction. A further limitation is that measurements of AHD over 60° of abduction were not attained because of technical limitations with ultrasonography(Desmeules et al., 2004).

To the authors' knowledge, this is the first study to use diagnostic imaging to obtain quantitative measures of the effect of kinesio taping on AHD distance. Our results provide evidence for a possible mechanism by which kinesio taping may provide benefits for people with subacromial impingement, as one component of a multimodal treatment program.

It is not known whether changes in AHD of the magnitude attained by kinesio taping in this study are sufficient to be clinically important. DAHD and effect size between KT1 and KT3 were 1.28 (0.55, 2.03) and between KT2 and KT3 0.98 (0.23, 1.74). Future research needs to investigate the association between changes in AHD and changes in important clinical outcomes.

We are unaware of any other research about whether the direction of kinesio tape application influences outcomes. In the present study we did not find any significant differences between two application techniques, but it is unknown whether this would be the case in those with pathology. Based on our findings it does not seem that applying the tape in the direction of the movement that is desired is important.

We can only speculate about the physiological mechanisms by which kinesio taping increased the AHD in this study. One possibility is that kinesio taping caused a change in the firing pattern of the rotator cuff motor units, which could increase humeral head external rotation. There is some evidence that kinesio taping applied to the shoulder increases trapezius muscle activity in baseball players with shoulder impingement(Hsu et al., 2009).

However, in healthy individuals, traditional taping has been shown not to significantly increase muscular activity, measured with electromyography(Cools, Witvrouw, Danneels, & Cambier, 2002)(Alexander, Stynes, Thomas, Lewis, & Harrison, 2003). In future research it will be interesting to use electromyography to ascertain whether rotator cuff muscle activity is altered by kinesio taping.

3.5. Conclusion

Kinesio taping increases the AHD in individuals without shoulder pain immediately following application of tape, compared with sham kinesio tape. No differences were found with respect to the direction in which the tape was applied. It will be useful for future studies to investigate whether kinesio taping improves treatment outcomes in individuals at risk of or with subacromial impingement, and whether these changes are clinically meaningful.

Chapter IV

Does the acromiohumeral distance matter in rotator cuff related shoulder pain?

Chapter IV

Does the acromiohumeral distance matter in rotator cuff related shoulder pain?

4.1 Introduction

Shoulder pain is one of the most common musculoskeletal conditions in primary care(Urwin et al., 1998), with a prevalence fluctuating from 6.9 to 26% for point prevalence, 18.6–31% for 1-month prevalence, 4.7–46.7% for 1-year prevalence and 6.7–66.7% for lifetime prevalence(J. Luime et al., 2004) and with 12-month recurrence rates approximately twice the prevalence rates. In working population, prevalence for shoulder pain associated to musculoskeletal disorders is even higher(Roquelaure et al., 2006). The prevalence of shoulder pain is higher in women(Bergman et al., 2010), and increases with age(Linsell et al., 2006). Rotator cuff tendinopathy (RCT) is the most common cause of shoulder pain(J. S. Lewis, 2010).

Acromiohumeral distance (AHD), defined as the shortest linear distance between the most inferior aspect of the acromion and the adjacent humeral head(Hébert et al., 2003), has been suggested to be related with the presence and severity of some shoulder disorders, such as subacromial impingement syndrome (SIS) and rotator cuff (RC) tendinopathy (Kibler et al., 2013) (Michener et al., 2013) The use of ultrasound imaging in the determination of AHD(Hébert et al., 2003) (Desmeules et al., 2004)(Kalra et al., 2010)(L. a. Michener et al., 2013) (Maenhout, Dhooge, Van Herzeele, Palmans, & Cools, 2015) and shoulder tendon thicknesses such as supraspinatus(Joensen, Couppe, & Magnus, 2009)(Michener et al., 2013) have been used due to this suspicion of being related with the patients' symptoms. Furthermore, there are other studies that have carried out similar procedures on shoulder pain-free patients(Luque-Suarez et al., 2013)(Schneebeli et al., 2014).

However, the relation between AHD values and severity of pain and disability in patients with RC tendinopathy remains unclear. Desmeules et al (Desmeules et al., 2004) found a strong correlation between AHD and pain and disability, though in a reduced sample of patients diagnosed of suabcromial impingement syndrome (SIS). Despite this promising result, a recent clinical commentary(Bailey, Beattie, Shanley, Seitz, & Thigpen, 2015b) suggests to accomplish more quality studies to confirm this connection. Even though it is unclear that a reduction in the subacromial space is a cause or a consequence in shoulder pain disorders(Mackenzie, Herrington, Horlsey, & Cools, 2015) especially in RC tendinopathy, there is a need to determine whether a correlation between AHD, pain and disability and shoulder ROM exists. If so, clinical practise could be focused on improving AHD and, furthermore, AHD could be used for researchers as an outcome measure to report results of their interventions, as the same manner as pain, function and ROM are used nowadays. Moreover, if there was a correlation between AHD and pain, disability and ROM, it would be possible to determine populations at risk of suffering and/or perpetuating chronic rotator cuff related shoulder pain (RCRSP).

Hence, the aim of this study was to determine the level of association between AHD, pain, disability and shoulder-ROM in patients with chronic shoulder pain.

4.2 Methods

Study design.

This was a cross-sectional study. The study was conducted according to the Declaration of Helsinki.

Ethical approval was obtained from the Ethics Committee of Malaga, Spain (PI9/012014).

Participants.

A convenience sample of 110 participants with chronic RCRSP (more than 3 months of duration) was recruited from three different primary care centres, from April 2014 to December 2015. General practitioners (GPs) carried out the recruitment. Then, research assistants assessed participants for eligibility. If participants satisfied the inclusion criteria, then they were studied. Three participants declined to participate, and 10 participants did not meet the inclusion criteria, hence, a sample comprised of 97 participants was assessed (Fig. 5). Research assistants collected the informed consent for every participant.

Participants had to meet at least three of the following inclusion criteria: i) positive Neer test; ii) positive Hawkins-Kennedy test; iii) positive Jobe test; iv) painful arc present during flexion or abduction; v) pain during resisted lateral rotation and/or abduction (Bury, West, Chamorro-Moriana, & Littlewood, 2016). Furthermore, other inclusion criteria had to be met: iv) both men and women aged between 18 and 55 years; (v) no history of significant shoulder trauma, such as fracture or clinically-suspected full thickness cuff tear. Participants were ineligible to participate in this study if any of these conditions were presented: (i) recent shoulder dislocation, systemic illnesses such as rheumatoid arthritis, and evidence of adhesive capsulitis as indicated by passive range of motion loss > 50 % in 2 planes of shoulder motion; (ii) shoulder pain that was deemed to be originating from any passive and/or neck movement or if there was a neurological impairment, osteoporosis, haemophilia and/or malignancies; iii) corticoid injections during the six months prior to the study; iv) analgesic-antiinflamatory medication intake 48 hours prior to the assessment.

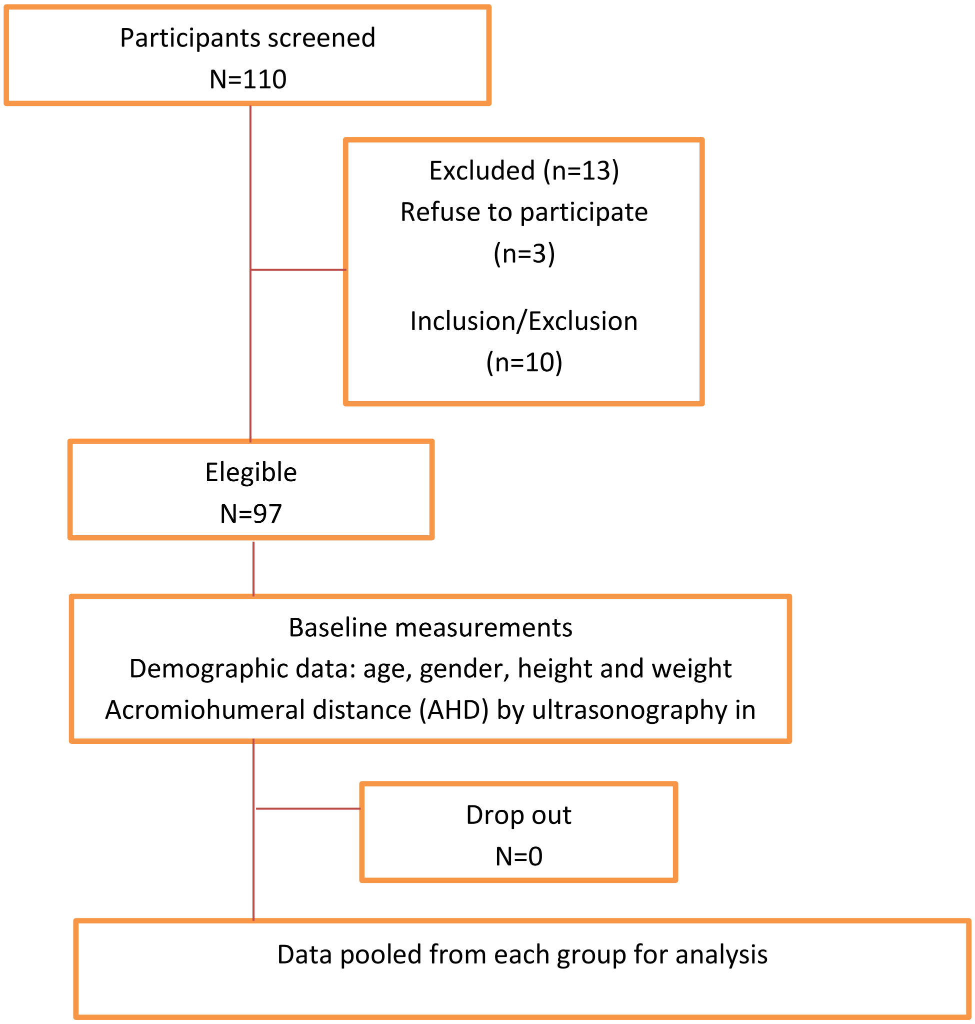

Figure 5: Participant flow diagram

Primary outcome.

Acromiohumeral distance

A diagnostic ultrasound unit, Sonosite M-turbo (GE Healthcare, Wauwatosa, WI) with a 6–13-MHz linear transducer was used to capture images in grey scale. Ultrasound images were obtained by a single examiner, who was a licensed physiotherapist with advanced training in musculoskeletal ultrasound imaging, and 4-years of experience. Three measurements were taken for all the structures and spaces by the examiner. An interval of one minute was provided between measures, encouraging the patient to move freely. Patients were then repositioned and the second and third set of measurements was successively taken. The ultrasound examiner was blind to all measurements (values were obscured by placing a sticker on the ultrasound screen, meanwhile a research assistant registered the data), and was blind to the previous condition of each patient (shoulder function and pain severity) as well as to the affected side and dominance upper limb. All the ultrasound measures were expressed in centimeters.

AHD was measured at 0 and 60 degrees of active shoulder elevation in the scapular plane, with the participant seated in an upright position. The process to evaluate AHD has been previously used in different populations, such as healthy volunteers(Luque-Suarez et al., 2013) and patients with shoulder pain(L. a. Michener et al., 2013). Patients were seated upright without back support, their feet flat on the ground. To guarantee 0 and 60 degrees shoulder elevation, a hydro-goniometer was placed on the patient's arm. AHD was defined as the shortest linear distance between the most inferior aspect of the acromion and the adjacent humeral head(Desmeules et al., 2004). The ultrasound transducer was placed on the most anterior aspect of the acromion edge, with the long axis of the transducer placed in the plane of the scapula and parallel to the flat surface of the acromion. AHD was measured in centimeters, using the calipers on the ultrasounds' screen.

Secondary outcomes.

Active ROM-free of pain at shoulder elevation in scapular plane

Active range of movement free of pain at shoulder elevation in scapular plane was taken using the same procedure as followed for AHD ultrasonography measures, excepting a change in the patient's position (stand up position). Three measures were taken separated by an interval of one minute, and mean was calculated. ROM was expressed in degrees.

Shoulder pain and disability index (SPADI)

The Shoulder Pain and Disability Index (SPADI)(Roach, Budiman-Mak, Songsiridej, & Lertratanakul, 1991) is a self-administered questionnaire that consists of two dimensions, one for pain and the other for functional activities. SPADI total score fluctuates between 0 to 100, being 0= best and 100=worst. The SPADI has shown a good internal consistency with a Cronbach's alpha of 0.95 for the total score, 0.92 for the pain subscale and 0.93 for the disability subscale as well as the ability to detect change over time(MacDermid, Solomon, & Prkachin, 2006).

Data analysis.

The Statistical Package for the Social Sciences was used for analysing the collected data (version 23.0 for Mac; SPSS Inc. Chicago, IL). Normality of the variables was visually tested for a Gaussian distribution and additionally tested with a 1-sample Kolmogorov-Smirnov goodness-of-fit test.

For the calculation of intrarater reliability of ultrasound measures (AHD at 0 and 60 degrees), the 3,1 model or a 2-way mixed consistency intraclass correlation coefficient (ICC) model was used. Hereby a reliability coefficient less than 0.50 was an indication of "poor" reliability; "moderate" between 0.50 and 0.75, "good" between 0.76 and 0.90; and "excellent" over 0.90. The Standard Error of Measurement (SEM) and the minimal detectable change with 95% confidence bounds (MDC95) were calculated.

To determine the correlation between AHD at 0 and 60 degrees with SPADI, and ROM free of pain in scapular plane, Pearson correlation coefficient was calculated for a data normal distribution, or Spearman´s coefficient in case of absence of normality. Strong correlation was defined as values greater than 0.7; between 0.5 and 0.7 correlation was considered moderate; between 0.3 and 0.5 was considered weak correlation.

Due to the fact that pain perception seems to be influenced by gender(Henderson, Gandevia, & Macefield, 2008)(Alabas, Tashani, Tabasam, & Johnson, 2012), sample characteristics for SPADI and ROM-free of pain values were shown based on this, in order to identify any bias in the homogeneity of the sample.

4.3 Results

Sample characteristics

Sample characteristics are shown in table 4. There were no significant differences between gender for demographic characteristics (with the exception of height) and for AHD, SPADI score and active ROM-free of pain in scaption movement. Regarding the duration of symptoms, 31% of the participants presented shoulder pain between 3-6 months at the beginning of this study; 18.6% between 6-12 months; and 50.4% greater than one year

Table 4: Sample characteristics expressed by mean and standard deviation.

	n=97	Female (n=63)	Male (n=34)	p-value
Age, years	45.42 (8.87)	46.08 (7.59)	44.21 (10.88)	.519
Height, cm	165.74 (7.43)	162.34 (5.92)	171.77 (5.87)	< .05*
AHD 0° (cm)	0.96 (0.14)	0.95 (0.15)	0.98 (0.16)	.523
AHD 60° (cm)	0.65 (0.19)	0,66 (0.22)	0.63 (0.01)	.599
SPADI	62.63 (18.31)	62.70(17.47)	62.51 (20.04)	.710
VAS-pain	7.75 (1.81)	7.67 (1.88)	7.91 (1.68)	.53
ROM-free of pain	91.09 (34.91)	89.29 (36.57)	94.41 (31.85)	.590

SPADI (shoulder pain and disability index)

Active ROM (range of movement) free of pain (degrees)

* Differences statistically significant (p< .05)

Reliability.

*Table 5: Intrarater reliability: ICC= intraclass correlation coefficient (*single measure; **average measure); SEM= Standard error of measurement-based on single measure ICC; MDC95= Minimal Detectable Change with 95% CI -based on single measure ICC.*

N(97)	Mean (SD)	ICC*	ICC**	SEM	MDC_{95}
AHD at 0 degrees	0.93 (0.15)	0.93 (0.91-0.95)	0.98 (0.97-0.98)	0,04	0,11
AHD at 60 degrees	0.66 (0.18)	0.95 (0.93-0.96)	0.98 (0.98-0.99)	0,04	0,11

Intrarater reliability was excellent for AHD at 0 and 60 degrees (table 5).

Association between AHD and both SPADI and shoulder ROM.

Correlations between AHD and SPADI and shoulder ROM are shown in table 6. Weak negative, statistically significant correlation was found between AHD at 0 degrees and SPADI, what means that the more disability the patient reported, the smaller the ADH appeared to be. Likewise, weak negative correlations were found between AHD at 60 degrees and SPADI, with no statistically significance. Also, weak/absence of any correlations was found between AHD measurements and active ROM-free of pain at shoulder elevation.

Table 6: correlations between subacromial space measured by AHD at 0 and 60 degrees of shoulder elevation, and SPADI and shoulder ROM free of pain.

	SPADI	ROM
AHD 0 degrees	-0,215*	-0,080
AHD 60 degrees	-0,148	0,163

*: statistically significant

4.4 Discussion

This study aimed to investigate level of association between AHD, pain-disability and shoulder-ROM in patients with chronic RCRSP. There was a statistically significant correlation between AHD at 0 degrees of shoulder elevation and pain and disability measured by SPADI: the more pain and disability found, the smaller AHD appeared to be. However, this correlation was smaller than weak. When active ROM-free of pain was analysed, none correlation was found with AHD at 0 and 60 degrees. The results showed excellent intrarater reliability for both AHD measures.

Acromiohumeral distance has been considered as one of the possible extrinsic mechanisms for developing RCRSP, which resulted in the so-called shoulder impingement syndrome theory. However, whether the perpetuation of symptoms in advanced stages (chronicity) is associated with a maintained decreased AHD remains unclear, so it is crucial to establish the possible association between AHD and pain and disability, as well as active ROM-free of pain in chronic shoulder pain. Our results showed weak correlations between AHD at both 0 and 60 degrees and SPADI. To our knowledge there are few studies investigating this association. Desmeules et al (Desmeules et al., 2004) found a significative correlation between increases in AHD and function after a physical therapy program applied to seven patients with SIS in acute-subacute stage, during 4 weeks, in a pre-post rehabilitation analysis. Comparisons with our findings are difficult due to the small sample size (7 patients) of the aforementioned study, and for the acute-subacute stage of the patients included. In a recent clinical study (Savoie, Mercier, Desmeules, Frémont, & Roy, 2015) an increase of AHD in 25 patients with subacromial pain syndrome (chronic pain) after a rehabilitation program centered on movement training, as well as an improvement in shoulder function, were found. Nevertheless, the degree of correlation between AHD and shoulder function findings was not reported. Regarding the association between AHD measures and ROM-free of pain in shoulder elevation in scapular plane, small correlations were found with AHD measures (0 and 60 degrees of shoulder elevation). A larger AHD measure was associated with more active pain free ROM. However, again, this association was smaller than weak. To our knowledge, there are no studies correlating AHD measured by ultrasonography to active shoulder ROM in patients with RCRSP.

There are potential several reasons that could explain the low association between AHD, pain-function and ROM found in this study. Shoulder impingement syndrome (SIS) is not a homogenous entity. SIS seems to appear as a combination of intrinsic factors (age, tendon histology and genetics), and extrinsic factors, which are those more closely related to AHD, such as acromion shape, glenohumeral and scapular kinematic factors, and, on the other hand, ergonomic adaptation factors and/or muscle extensibility and performance factors

(Mackenzie et al., 2015; Seitz, McClure, Finucane, Boardman, & Michener, 2011). It is reasonable that there is controversy with regard to the exact pathomechanics and biomechanical causes of subacromial pain syndrome (SAPS) (Mackenzie et al., 2015), due to its multifactorial character, and, hence, a controversy about the real role of AHD in the explanation of pain, disability and shoulder ROM in SAPS. In fact, there was an evolution in this terminology, shifting from SIS to the label of SAPS(L. a. Michener & Kulig, 2015). However, this labelling kept the subacromial space as a key contributing factor, which might not be the case in all patients with mechanical shoulder pain. Therefore, the present study emphasizes the use of RCRSP to describe this condition best, as current evidence supports RCRSP terminology instead of the subacromial or impingement based terminology (Jeremy Lewis, 2016).

There are some limitations that should be taken into account. Firstly, inter-rater reliability for ultrasonography measures was not calculated; hence, caution should be taken into account about the psychometric properties of this diagnostic tool. Secondly, the difficulty of classifying shoulder pain disorders, even though a recognized guideline to identify SIS/RC tendinopathy throughout a combination of orthopaedic and movement tests were used in this study as inclusion criteria could mean that the sample analysed presented heterogeneity. In this sense, previous studies have remarked the lack of uniformity and reliability of the current diagnostic classification system for shoulder pain,(Klintberg et al., 2015; Schellingerhout, Verhagen, Thomas, & Koes, 2008) suggesting to reconsider the use of these diagnostic labels (i.e., SIS). Thirdly, the results regarding the relation between AHD and chronic shoulder pain only shows level of association and not a cause-effect relation. Finally, AHD is a two dimensional measure of a three dimensional space. In this sense there is a difficulty of viewing the undersurface of the acromion due to the acoustic shadow when AHD is assessed.

This study means a first step showing the absence of any week/moderate/strong correlation between chronic RCRSP and AHD measured by ultrasonography. Future studies should be conducted to determine the real scope of AHD within clinical practise, in patients suffering from chronic RCRSP. Furthermore, more research is need to determine the amount of improvement in AHD that could be functionally and clinically meaningful for populations with different shoulder disorders, e.g. RCRSP, as this represents a key gap in the available literature.

4.5 Conclusions

In patients with chronic RCRSP, the association between AHD and shoulder pain and function, as well as with shoulder ROM-free of pain, is absent. Hence, clinicians should consider other possibilities rather than focusing their therapies only in increasing AHD when patients with chronic RCRSP are treated.

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CHAPTER V

The coracohumeral distance in chronic anterior shoulder pain. Is it associated with pain-function, and shoulder range of movement?

Chapter V

The coracohumeral distance in chronic anterior shoulder pain. Is it associated with pain-function, and shoulder range of movement?

5.1 Introduction

Shoulder pain is one of the most common musculoskeletal conditions in primary care, with a prevalence fluctuating from 6.9 to 26% for point prevalence, 18.6–31% for 1-month prevalence, 4.7–46.7% for 1-year prevalence and 6.7–66.7% for lifetime prevalence (J. Luime et al., 2004) and with 12-month recurrence rates approximately twice the prevalence rates (J. J. Luime, Koes, Miedem, Verhaar, & Burdorf, 2005). In working population, prevalence for shoulder pain associated to musculoskeletal disorders is even higher (Roquelaure et al., 2006).

Anterior shoulder pain has been traditionally underestimated in the assessment of shoulder pain, (Brunkhorst, Giphart, LaPrade, & Millett, 2013). Although it can occur alone, it is usually presented with anterolateral shoulder pain (labeled as subacromial pain syndrome), sharing similar symptoms(Misirlioglu et al., 2012) and making difficult it diagnosis. The most related cause of anterior shoulder pain is the subcoracoid impingement syndrome, defined as the encroachment of the posterolateral coracoid process upon the lesser tuberosity of the humerus(Gerber et al., 1985), causing a compression of soft tissues, such as the subscapularis tendon, glenohumeral joint capsule and subcoracoid bursa, and occasionally the long head of the biceps tendon(Radas & Pieper, 2004) . Anatomic differences for humerus lesser tuberosity and coracoid process(Gerber et al., 1985; Giaroli, Major, Lemley, & Lee, 2006) , as well as anteversion and internal humeral rotation(Radas & Pieper, 2004) , and a history of chronic overuse of persisted flexion, adduction and internal rotation shoulder positions(Okoro, Reddy, & Pimpelnarkar, 2009), have been also established as possible causes of anterior shoulder pain.

Diagnosis of anterior shoulder pain has not been widely investigated, but the physical examination (cross-arm adduction test) and radiographic features are the most commonly used (Okoro et al., 2009) . The coracohumeral interval (CHI) has been measured in previous investigations using the coracohumeral distance (CHD) to determine the severity of anterior shoulder pain(Gerber et al., 1985; Misirlioglu et al., 2012), sometimes by means of computed tomography or resonance magnetic imaging. However, there is a clear lack of standard procedure to quantify it. Ultrasonography (US) is a non-invasive tool without ionizing effects that permits the dynamic evaluation, and is more accessible than the previous described. It has been widely used in the determination of the acromiohumeral distance (AHD)(Desmeules et al., 2004; Hébert et al., 2003). Two studies have investigated the use of US in the evaluation of CHD(MR Tracy, TA Trella, LN Nazarian, CJ Tuohy, 2010; Oh JH, Song BW, Choi JA, Lee GY, Kim SH, 2016). Oh et al recently found a good correlation (>0.7) between US and MRI in quantifying CHD, as well as an excellent intra-rater reliability (>0.90) in patients with rotator cuff tear, supporting the use of the US in the evaluation of coracohumeral interval. However, there is a lack of a clear measuring process, normative values and reliability dat for CHD, measured by US, in patients suffering from anterior shoulder pain. There is also inconclusive evidence on the association of anterior shoulder pain and pain-function and shoulder range of movement (ROM), in patients with chronic anterior shoulder pain. The role of acromiohumeral distance (AHD) as explanatory factor for symptoms in RC tendinopathy is starting to be questioned(J. Lewis, 2014). However, the evidence about whether CHD could play an important role in the explanation of anterior shoulder pain, is unfinished. If a strong relationship between a reduced CHD and high levels of pain, decreased shoulder function and limited shoulder ROM was identified, preventive and therapeutic efforts could be focused on increasing this space. Hence, the aim of this study was twofold: i) to assess the intrarater reliability of CHD at 0 and 60 degrees of scapular elevation measured by US, in patients suffering from chronic anterior shoulder pain; ii) to determine the association between CHD with shoulder pain, function and shoulder-ROM free of pain.

5.2 METHOD

Procedure

A convenience sample of 102 patients with chronic anterior shoulder pain (more than three months), and with clinical symptoms of anterior shoulder pain, was recruited from three different primary care centers. General practitioners (GPs) carried out the recruitment. Then, research assistants assessed participants for eligibility. If participants satisfied the inclusion criteria, then they were studied. Five participants declined to participate, and 10 participants did not meet the inclusion criteria, hence, a sample comprised of 87 participants was assessed (Figure 6). Research assistants collected the informed consent for every participant

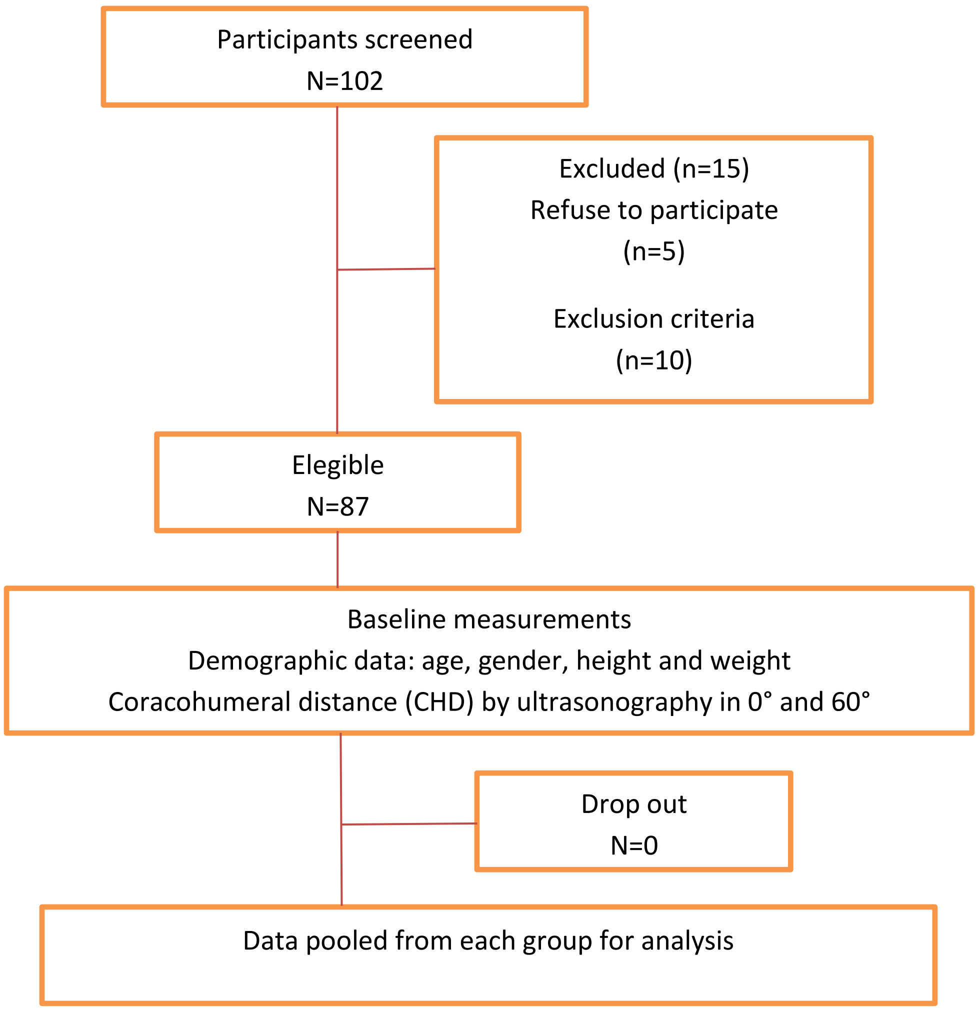

Figure 6: Participant flow diagram

All participants in the study gave their written informed consent. Participants had to meet the following inclusion criteria to be classified as anterior shoulder pain (Dines, Warren, Inglis, & Pavlov, 1990; Okoro et al., 2009; Russo & Togo, 1991): i) positive cross-arm test; ii) painful arc of movement during forward flexion and/or internal rotation; (iii) elicitation of tenderness throughout palpation of the coracoid process.

Furthermore, other inclusion criteria had to be met: both men and women aged between 18 and 55 years; no history of significant shoulder trauma, such as fracture or clinically/ultrasonographic-suspected full thickness rotator-cuff tear. Participants were excluded from this study if any of these conditions were presented: (i) recent shoulder dislocation, systemic illnesses such as rheumatoid arthritis, and evidence of adhesive capsulitis, as indicated by passive range of motion loss > 25 % in 2 planes of shoulder motion, and loss > 50% in external rotation; (ii) shoulder pain that was deemed to be originating from any passive and/or neck movement or if there was a neurological impairment, osteoporosis, haemophilia and/or malignancies; (iii) shoulder surgery in the last year, (iv) corticoid injections during the six months prior to the study; (v) analgesic-antiinflamatory medication intake during 48 hours prior to the study.

Outcome measures

Coracohumeral distance (CHD).

A diagnostic ultrasound unit, Sonosite M-turbo (GE Healthcare, Wauwatosa, WI) with a 6–13-MHz linear transducer was used to capture images in grey scale. Ultrasound images were obtained by a single examiner, who was a licensed physiotherapist with advanced training in musculoskeletal ultrasound imaging, and 4-years of experience. Three measurements were taken. An interval of one minute was provided between measures, encouraging the patient to move freely. Patients were then repositioned and the second and third set of measurements was successively taken. The ultrasound examiner was blind to all measurements (values were obscured by placing a sticker on the ultrasound screen, meanwhile a research assistant took them and put into a dataset). All the ultrasound measures were expressed in centimeters. CHD was measured at 0 and 60 degrees of active shoulder elevation in the scapular plane, neutral shoulder rotation, with the participant seated in an upright position.

Patients were seated upright without back support, their feet flat on the ground. To guarantee 0 and 60 degrees shoulder elevation, a hydro-goniometer was placed on the patient's arm(Hbert, Moffet, McFadyen, & Dionne, 2002). CHD was defined as the shortest linear distance between the coracoid and the adjacent humeral head(Okoro et al., 2009). The ultrasound transducer was placed over the most anterior aspect of the shoulder (see Chapter VIII: Attachments), observing the coracoid process and the humeral head on the screen, taking the shortest distance between them. CHD was measured in centimeters, using the calipers on the ultrasound screen. (Figure 7 and 8)

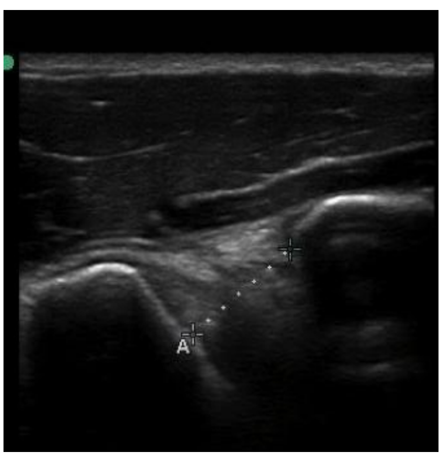

Figure 7: CHD at 0 degrees of shoulder elevation

Figure 8: CHD at 60 degrees of shoulder elevation

ROM-free of pain at shoulder elevation.

Range of movement free of pain at shoulder elevation was taken using the same procedure as followed for CHD ultrasonography measures, excepting a change in the patient's position (stand up position). Three measures were taken separated by an interval of one minute, and mean was calculated. ROM was expressed in degrees.

Shoulder pain and disability index (SPADI).

The Shoulder Pain and Disability Index (SPADI)(Roach et al., 1991) is a self-administered questionnaire that consists of two dimensions, one for pain and another for functional activities. SPADI total score fluctuates between 0 to 100, with 0 = best and 100 = worst. SPADI has shown to have good internal consistency (overall Cronbach's alpha = 0.95; for the pain subscale=0.92; for the disability subscale=0.93), as well as the ability to detect change over time(MacDermid et al., 2006).

Data analysis

The Statistical Package for the Social Sciences was used for analyzing the collected data (version 23.0 for Mac; SPSS Inc. Chicago, IL). Normality of the variables was visually tested for a Gaussian distribution and additionally tested with a 1-sample Kolmogorov-Smirnov goodness-of-fit test.

For the calculation of reliability of CHI the model or a 2-way mixed consistency intraclass correlation coefficient (ICC) model was used. Hereby a reliability coefficient less than 0.50 was an indication of “poor” reliability; “moderate” between 0.50 and 0.75, “good” between 0.76 and 0.90; and “excellent” over 0.90 (Portney & Watkins, 2000). The Standard Error of Measurement (SEM) and the minimal detectable change with 95% confidence bounds (MDC95) were calculated.

To determine the correlation between CHD at 0 and 60 degrees with SPADI, and ROM free of pain in scapular plane, Pearson correlation coefficient was calculated for normally distributed data, or Spearman´s coefficient in case of absence of normality. Strong correlation was defined as values greater than 0.7; between 0.5 and 0.7 correlation was considered moderate; between 0.3 and 0.5 was considered weak correlation (Mukaka, 2012).

5.3 Results

A total sample of 87 patients (71% women); mean age 43.9 (SD=9.1) years; mean SPADI score of 59.7 (SD=19.2); and a shoulder ROM free of pain of 93.1(SD=33.9) degrees, was analyzed. Regarding the duration of symptoms, 26.4% of the participants presented shoulder pain between 3-6 months at the beginning of this study; 13.8% between 6-12 months; and 59.8% greater than one year.

Mean values for CHD at both 0 and 60 degrees are shown in table 7.

CHD Intra-rater reliability.

Intrarater reliability for CHD showed excellent values at both 0 and 60 degrees of shoulder elevation (table 7).

Table 7: intra-rater reliability for CHD at 0 and 60 degrees of shoulder elevation.

n (87)	mean(SD)	ICC*	ICC**	SEM	MDC_{95}
CHD at 0 degrees	1.03 (0.26)	0.988 (0.982-0.992)	0.996 (0.994-0.997)	0,04	0,11
CHD at 60 degrees	0.94 (0.27)	0.989 (0.984-0.993	0.996 (0.995-0.998)	0,04	0,11

Intrarater reliability: ICC= intraclass correlation coefficient (*single measure; **average measure); SEM= Standard error of measurement-based on single measure ICC; MDC95= Minimal Detectable Change with 95% CI -based on single measure ICC.

Association between CHD with shoulder pain-function and shoulder-ROM free of pain.

Correlations between CHD, SPADI and shoulder ROM are shown in table 8.

Absence of any correlation was found between CHD and SPADI at both 0 and 60 degrees of shoulder elevation. Furthermore, absence of any correlation was found between CHD measurements and active ROM-free of pain at shoulder elevation.

Table 8: correlations between coracohumeral distance measured by US at 0 and 60 degrees of shoulder elevation, and SPADI and shoulder ROM free of pain.

	SPADI	ROM	CHD 0 degrees	CHD 60 degrees
CHD 0 degrees	-0,24*	0.23*	1	0,62**
CHD 60 degrees	-0,15	0,19	0,62**	1

*: statistically significant (p < .05)

**: statistically significant (p < .01)

5.4 Discussion

The first aim of this study was to determine the intra-rater reliability for CHD measured by US in patients suffering from anterior chronic shoulder pain. The results showed an excellent reliability for both 0 and 60 degrees of shoulder elevation. The second aim was to analyze the level of association between CHD and shoulder pain-function as well as shoulder ROM free of pain. Absence of associations was noted between all the outcomes.

To the best of our knowledge, this is the first and largest study reporting CHD measurements in people suffering from chronic anterior shoulder pain by means of US. This study provides results in response to the lack of quality studies in the field of coracohumeral reliability, measured by US. Our findings demonstrated excellent reliability for CHD at 0 and 60 degrees (0.98), which are in consonance with Tracy et al.,(MR Tracy, TA Trella, LN Nazarian, CJ Tuohy, 2010) who found an ICC of 0.89 at 0 degrees, in a smaller sample of 19 participants free of shoulder pain. Likewise, Oh et al.(Oh JH, Song BW, Choi JA, Lee GY, Kim SH, 2016) achieved intrarater reliability greater than 0.90, in patients with rotator cuff tears. However, the position used in both studies to measured CHD (cross arm position) was different in comparison to the present study. The excellent values achieved for CHD measurements are similar to those obtained in similar studies reporting AHD also measured by US, in patients with shoulder pain(McCreesh et al., 2015)(Pijls, Kok, Penning, Guldemond, & Arens, 2009). These promising findings are supported by different aspects that were considered in the present study in order to provide a higher quality: (1) the ultrasound examiner was blind about the fact of knowing the affected shoulder before measures were taken; (2) every measure was collected with a wash-out period of one minute between measures, permitting patients to move freely between measures; (3) no landmarks were used on the skin in an attempt of making every measure independent with respect to the others; 4) the issue of examiner experience. With respect to the normative values for CHD in people with shoulder pain, our results showed values of 1.03 (0.21) cms at 0 degrees of shoulder elevation, and 0.95 (0.25) cms at 60 degrees. Only one study(MR Tracy, TA Trella, LN Nazarian, CJ Tuohy, 2010) has reported CHD using US, obtaining values of 0.70 (1.4) cms, although CHD was taken in adduction and internal shoulder rotation. This position reduces CHD and, so, makes difficult the comparison between findings. MRI has been also used in the assessment of CHD. Specifically, one study has reported values of 0,72 cms (Misirlioglu et al., 2012) in maximal shoulder internal rotation, while, with shoulder neutral rotation, values of 1.12 (0.33) cms have been found (Hekimoglu, Aydin, Kizilgoz, Tatar, & Ersan, 2013) , which are in consonance with ours results.

According to the determination of the level of association between CHD values and shoulder pain-function and ROM, to our knowledge this is the first study investigating this relationship. It is highly important to establish the possible association between anterior shoulder pain, and CHD measured by US, as well as with active shoulder ROM-free of pain. That would steer treatments in one or another direction. Our results showed an absence of correlation between CHD and both SPADI and ROM-free of pain.

There are possible underlying mechanisms to explain the low association between CHD, pain and function, and active shoulder ROM-free of pain. Anterior shoulder pain is not a homogenous entity. It seems to appear as a combination of intrinsic factors (age, tendon histology and genetics), and extrinsic factors, which are those more closely related to CHD, such as anatomic differences for humerus lesser tuberosity and coracoid process (Gerber et al., 1985; Giaroli et al., 2006), as well as anteversion and internal humeral rotation(Radas & Pieper, 2004) , and a history of chronic overuse of persisted flexion, adduction and internal rotation shoulder position(Okoro et al., 2009). It is reasonable that there is controversy with regard to the exact pathomechanics and biomechanical causes of shoulder pain. Although this study only shows the level of association between the CHD and symptoms referred by the patient, and not a cause-effect relationship, it seems that, due to the multifactorial character of anterior shoulder pain, the CHD could only explain a little amount of patient's pain perception and ROM. Moreover, the chronic character of shoulder pain suffered by the patients included in the present study, would mean the confluence of other possible explanation factors, such as the presence of peripheral-central sensitization, that has been reported previously in shoulder injuries(Sanchis, Lluch, Nijs, Struyf, & Kangasperko, 2015). As these conditions were not measured in the present study we can just only speculate about their real influence.

About the normative values achieved in this study for CHD, although there was not an objective in this study, our values were similar in CHD at 0 degrees of shoulder evaluation (1.03 ± 0.21 cms) that obtained by Oh et al.(Oh JH, Song BW, Choi JA, Lee GY, Kim SH, 2016) (1.01 ± 0.21 cms), but in different sample of patients (anterior shoulder pain vs full rotator cuff tear).

There are some limitations that should be taken into consideration. Firstly, inter-rater reliability for ultrasonography measures was not determined; hence, results should be taken with caution. Secondly, the difficulty of classifying shoulder pain disorders could mean that the analyzed sample presented heterogeneity. In this sense, previous studies have remarked the lack of uniformity and reliability of the current diagnostic classification system for shoulder pain(Schellingerhout et al., 2008)(Klintberg et al., 2015) . Thirdly, CHD is a two dimensional measure of a three dimensional space. Compromise of this volume cannot be totally quantified by measure of CHD in isolation, so this should be taken into account.

This study provides promising results regarding the excellent intra-rater reliability of US in the determination of CHD that quantifies the CHI. Moreover, normative values for CHD at both 0 and 60 degrees of shoulder elevation in patients with chronic shoulder pain has been identified. However, the real role of the CHD in the explanation of severity of pain, alteration of shoulder function and limitation of ROM, in patients with anterior shoulder pain, is not sufficiently clarified yet. Hence, future studies should be focused on determine its real importance along with other intrinsic and extrinsic factors, in order to determine whether it could be considered as a prognostic factor for chronic anterior shoulder pain, and whether it could be an essential factor that would steer physical treatments. Furthermore, a standard patient position should be agreed using US. This would make possible comparisons between studies.

5.5 Conclusions

In patients with chronic anterior shoulder pain, there is no association between CHD, and shoulder pain and function, as well as with shoulder ROM-free of pain. Hence, clinicians should consider other possibilities rather than focusing their therapies only in increasing this space, when patients with anterior shoulder pain are treated.

Ethical approval was obtained from the Ethics Committee of Malaga, Spain (PI9/012014). All the authors, their immediate family, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article. The authors declare no conflict of interests.

Chapter VI

General discussion

Chapter VI

General discussion

Main findings and research discussion

The aim of the present thesis was to study the use of RUSI in the assessment of shoulder disorders. Shoulder complex ultrasonography assessment includes a great number of structures and conditions. Furthermore, shoulder pain presents a multifactorial character(Lewis, Green, & Dekel, 2001). By that reason, due to the huge applicability of RUSI in shoulder assessment, this project has been carried out focused on the AHD and CHD, which means that the conclusions are based on these specific measurements, and not on the full usefulness of RUSI in shoulder pain assessment. Thus, recommendations for future research are developed from our prospective.

There is enough evidence to support the use of ultrasonography when the shoulder complex is assessed(Bailey, Beattie, Shanley, Seitz, & Thigpen, 2015a)(Luque-Suarez et al., 2013)(Hébert et al., 2003)(Michener et al., 2013)(Kibler et al., 2013). Furthermore, there exist some studies which correlate AHD with function(Desmeules et al., 2004)(Savoie et al., 2015). Nevertheless, a relationship between AHD and/or CHD with pain, function and mobility had not been established before. Our results showed that the association between AHD and shoulder pain-function, as well as with shoulder ROM-free of pain, is weak in patients suffering from chronic shoulder pain. Desmeules et al (Desmeules et al., 2004) found a significative correlation between increases in AHD and function after a physical therapy program applied to seven patients with SIS in acute-subacute stage, during 4 weeks, in a pre-post rehabilitation analysis. Comparisons with our findings are difficult due to the small sample size (7 patients) of the aforementioned study, and for the acute-subacute stage of the patients included. In a recent clinical study (Savoie, Mercier, Desmeules, Frémont, & Roy, 2015) an increase of AHD in 25 patients with subacromial pain syndrome (chronic pain) after a rehabilitation program centered on movement training, as well as an improvement in shoulder function, were found. Nevertheless, the degree of correlation between AHD and shoulder function findings was not reported. Regarding the association between AHD measures and ROM-free of pain in shoulder elevation in scapular plane, small correlations were found with AHD measures (0 and 60 degrees of shoulder elevation). A larger AHD measure was associated with more active pain free ROM. However, again, this association was smaller than weak. To our knowledge, there are no studies correlating AHD measured by ultrasonography to active shoulder ROM in patients with RCRSP. Furthermore, our results show absence of association between CHD and shoulder pain, function and mobility, in patients with chronic anterior shoulder pain. To the best of our knowledge, there are no studies which analyze such correlations either at baseline or after a physiotherapy treatment. Therefore, to the best of our knowledge, this is the first and largest study reporting CHD measurements in people suffering from chronic anterior shoulder pain by means of US, which makes difficult comparisons with other studies. However, in relation to the intra rater reliability, uur findings demonstrated excellent reliability for CHD at 0 and 60 degrees (0.98), which are in consonance with Tracy et al.,(MR Tracy, TA Trella, LN Nazarian, CJ Tuohy, 2010) who found an ICC of 0.89 at 0 degrees, in a smaller sample of 19 participants free of shoulder pain. Likewise, Oh et al.(Oh JH, Song BW, Choi JA, Lee GY, Kim SH, 2016) achieved intra rater reliability greater than 0.90, in patients with rotator cuff tears. However, the position used in both studies to measured CHD (cross arm position) was different in comparison to the present study.

On the other hand, a kinesio taping application increased AHD in healthy subjects (Luque-Suarez et al., 2013). Future studies should analyze if the use of RUSI, measuring changes in AHD after application of different physiotherapy programs, including the aforementioned kinesio tape technique, could serve as a monitoring assessment tool in shoulder pain patients.

Limitations of the study

There are many limitations in this doctoral thesis that need to be recognized. Due to the fact that ultrasound imaging is a highly user-dependent assessment tool, the absence of inter rater reliability determination could mean bias. In this project, the intra rater reliability was excellent in each study, but inter rater reliability was not measured. This should be taken into account when the results are interpreted.

On the other hand, it is also important to point out the “acoustic shadow” artifact in the ultrasonography shoulder assessment, especially when acromiohumeral distance is measured at 60 degrees. The acoustic shadow is the anechoic image produced as a consequence of the wave passing through osseous tissue, making the visibility under the bone difficult. Thus, the acromion acoustic shadow worsens its inferior aspect visibility, influencing both quality and accuracy in the acromiohumeral distance measurement.

The acromiohumeral distance is a two dimensional measurement for assessing a tridimensional space, therefore, its whole magnitude is really difficult to measure using ultrasonography.

Due to a lack of information regarding the posture of the patient while taking the CHD, standardized methodological guidelines could not be followed. Only a few studies use ultrasound imaging as an assessment tool in the subcoracoid space and the methods used are not well defined(MR Tracy, TA Trella, LN Nazarian, CJ Tuohy, 2010). Equally, as in the subacromial space, the subcoracoid space is a tridimensional entity measured with a two dimensional tool, not having been duly assessed.

Furthermore, to date it is difficult to recruit patients with similar characteristics and symptoms, as well as suffering from the same pathology. In fact, it is of great importance to take into consideration the current controversy regarding the labeling used when a diagnosis of shoulder pain is needed(Schellingerhout et al., 2008)(Klintberg et al., 2015). “Impingement syndrome” is the most common diagnosis in people suffering from shoulder pain, but it is ambiguous and not more informative than others such as “anterior shoulder pain”. However, there is a current concept, coined “rotator cuff related shoulder pain” (RCRSP)(Jeremy Lewis, 2016), which is believed to be more appropriate since it does not refer to an anatomical tissue pathology as the cause of pain, but also includes other factors such as bio-psychosocial or peripheral and central sensitization.

Future research

Do ultrasound differences exist between a painful and a non-painful shoulder in patients when compared to subjects free of pain?

In recent years, the use of US has increased in the field of shoulder assessment, because of its non-ionizing effect, non-invasive character, and low cost, as well as the possibility of dynamic evaluation(Hides et al., 1998). It has attained a good correlation with MRI, which has the best sensitivity, and comparable specificity for the detection of full- and partial-thickness tears of the rotator cuff(Lenza et al., 2013). Furthermore, it has been demonstrated that US is comparable to MRI in regard to rotator cuff and biceps tendon integrity evaluation(Fischer, Christian Alexander, Weber et al., 2015). In addition, when considering accuracy, cost, and safety, US has been proven to be the best option(Roy et al., 2015), showing a strong potential to contribute to rehabilitation(Hodges, 2005). Many studies exist detailing shoulder injuries and their different structures, such as tendons(Arend et al., 2014), muscles(Juul-kristensen et al., 2000) or bursa(Drakes et al., 2015), both in healthy(Juul-kristensen et al., 2000) and shoulder pain populations, measured by US. Different tendon thicknesses (Schneebeli et al., 2014), spaces such as AHD (Desmeules et al., 2004) and CHD (MR Tracy, TA Trella, LN Nazarian, CJ Tuohy, 2010) have been assessed. Also, the presence of tears and its progress with age related to pain, have been reported (Yamaguchi et al., 2006),(Teunis et al., 2014).

The study of shoulder characteristics between different shoulder populations (painful shoulder, contralateral asymptomatic shoulder and healthy subjects), measured by ultrasonography, is challenging nowadays. Related to this, Yamaguchi et al(Yamaguchi et al., 2006) compared morphological features of the rotator cuff between symptomatic and asymptomatic shoulder. They found that bilateral rotator cuff disease, either symptomatic or asymptomatic, was common in patients who presented with unilateral symptomatic disease. On the other hand, Ro et al(Ro, Park, Lee, & Song, 2015) reported a higher prevalence of rotator cuff tear (RCT) in the asymptomatic shoulder in those suffering from unilateral symptomatic RCT. In a recent study, Kijima et al(Kijima et al., 2015) found kinematic differences in patients with symptomatic and asymptomatic RCT, and healthy shoulders, using 3D/2-dimensional model-image registration techniques, but recruiting a small numbers of participants, and not reporting data about morphological changes between different populations measured by US.

Most of the studies analyzing shoulder tendon thicknesses have been carried out in patients with rotator cuff tear(Mall et al., 2010), or in populations with shoulders free of pain(Schneebeli et al., 2014). A lack of information exists regarding comparisons between both the symptomatic and the asymptomatic shoulder in patients with unilateral chronic shoulder pain, and subjects who are pain free. Additionally, little is known on studies establishing and clustering normative values for different shoulder tendon thicknesses and spaces (AHD, CHD), not only on the affected but also on the unaffected shoulder, and in individuals with both shoulders free of pain. Some studies have measured shoulder tendon thicknesses, assessing the rotator cuff as a whole(Bretzke, Crass, Craig, & Samuel, 1985),(Cholewinski, Kusz, Wojciechowski, Cielinski, & Zoladz, 2008),(Yamaguchi et al., 2006) , but not distinguishing between the different tendons (mainly the supraspinatus, the biceps, and the subscapularis). Furthermore, an absence of data related to standard tendon thickness values and the presence of structural changes in the contralateral asymptomatic shoulder exist.

Improved knowledge in this area would help to clarify whether different morphological features exist between symptomatic and contralateral asymptomatic shoulders, as well as in healthy people. Hence, the aim of this study would be to analyze the differences between RC tendon thicknesses, AHD and CHD, in symptomatic shoulders, non-symptomatic shoulders, and the healthy population, measured by US.

Analyzing changes in acromiohumeral distance after different physiotherapy techniques. Is it correlated with pain, function and mobility?

The present thesis (Chapter IV: Does acromiohumeral distance matter in chronic shoulder pain?) has found the association between AHD and shoulder pain-function, and shoulder ROM-free of pain in patients with chronic shoulder pain to be weak. However, we have to take into consideration that all these findings belong to a cross sectional study (baseline), in which patients had not been treated, and whose results tells us about correlations which can lead us to a partially better understanding of the real role of AHD in chronic shoulder pain. Thus, prospective longitudinal trials to dissipate current gaps in the scientific literature are necessary.

Therefore, if changes in AHD measured by US can be correlated to pain, function and ROM, an important prognostic factor and monitoring tool would be defined. To the best of our knowledge, in comparison with other studies which analyze the AHD after a physical therapy program(Desmeules et al., 2004)(Savoie et al., 2015), no studies exist which correlate AHD and pain, function and mobility, either as a cross sectional study or a longitudinal clinical trial.

For this reason, analyzing changes in AHD would clarify the real role of AHD in people suffering from chronic shoulder pain.

Hence, the aim of this study will be i) to analyze changes in AHD after different physiotherapy treatment programs, with a one-month follow-up, and ii) to correlate these changes with pain, function and active ROM free of pain in shoulder elevation.

Analyzing changes in coracohumeral distance after different physiotherapy techniques in patients with anterior shoulder pain. Does it correlate with pain, function and mobility?

As with AHD, the present thesis has found that the CHD is not associated with shoulder pain, function and shoulder ROM-free of pain. Equally, our results belong to a cross sectional study, so care should be taken when making conclusions. Analyzing changes in CHD after different physiotherapy programs would definitely help to give a better understanding of the role of CHD in people with chronic anterior shoulder pain. Thus, it would clarify whether clinicians should focus their treatments on increasing CHD or to pay more attention to other factors such as peripheral or central sensitization.

Hence, the aim of this study will be i) to analyze changes in CHD after different physiotherapy treatment programs with a follow-up after a month, and ii) to correlate these changes with pain, function and active ROM free of pain in shoulder elevation.

Occupation ratio concept as a new way of explaining shoulder pain

New ideas are appearing to improve the understanding of which factors are more correlated with chronic shoulder pain. This is the case in the occupation ratio concept described by Michener(Michener et al., 2013), understood as the tendon thickness as a percentage of the space through which it runs.

According to this study, which analyzes the supraspinatus occupation ratio in patients suffering from SIS, these patients had less available unoccupied AHD compared to healthy subjects, supporting the occupation ratio concept which encompasses both supraspinatus and AHD structures, instead of the measurement AHD in isolation. AHD is currently considered insufficient within the extrinsic factor mechanism in response to shoulder pain syndrome as we have shown in the present thesis.

Increased knowledge in this field would help the understanding of how important the extrinsic factors are in mechanic shoulder pain, and it would also allow clinicians to properly define guidelines on diagnostic and therapeutic options.

To the best of our knowledge, no studies analyze the supraspinatus ratio at 0 degrees of shoulder abduction in people suffering from chronic shoulder pain, together with contralateral asymptomatic shoulder and healthy subjects, measured by US. Furthermore, to date there are no studies analyzing subscapularis tendon thickness in proportion to CHD, in people with shoulder pain. Thus, it would be the first study clustering standard values from supraspinatus and subscapularis ratios in different shoulder populations as well as establishing a correlation between them in those with chronic shoulder pain.

Also, there is a lack of evidence regarding a relationship between occupation ratios and shoulder pain, function and shoulder ROM free of pain.

We would like to test the hypothesis that the supraspinatus tendon occupies a greater proportion of the AHD, the same as with the subscapularis tendon in CHD, in those suffering from chronic shoulder pain. This could uncover new findings in shoulder pain management. If not, it may support factors such as bio-psychosocial or peripheral/central sensitization, instead of the extrinsic factors.

Hence, the aims of this study would be i) to characterize supraspinatus/subscapularis tendon thickness in proportion to AHD/CHD measured by ultrasound imaging in patients with unilateral chronic shoulder pain, asymptomatic contralateral shoulder, and healthy subjects, ii) to compare ratios in those with unilateral chronic shoulder pain with contralateral asymptomatic shoulder and healthy subjects, as well as iii) to establish a relationship between both ratios with both pain-function and shoulder ROM-free of pain.

Chapter VII

Conclusions

Chapter VII

Conclusions

1. Kinesio taping increases the AHD in individuals without shoulder pain immediately following application of tape, compared with sham kinesio tape.
2. The direction in which the tape is applied does not influence AHD.
3. In patients with chronic shoulder pain, the association between AHD and shoulder pain-function, as well as with shoulder ROM-free of pain, is weak.
4. In patients with chronic anterior shoulder pain, there is no association between CHD and shoulder pain-function, as well as with shoulder ROM-free of pain.
5. The intra-rater reliability of acromiohumeral distance, measured by ultrasound imaging, in patients with chronic shoulder pain, is excellent.
6. The intra-rater reliability of coracohumeral distance, measured by ultrasound imaging, in patients with anterior chronic shoulder pain, is excellent.
7. There is no a clear and standard method of measuring coracohumeral distance by ultrasound imaging. This is the first study describing a possible guideline to follow.

Chapter VIII

Bibliography

Chapter VIII

Bibliography

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Chapter IX

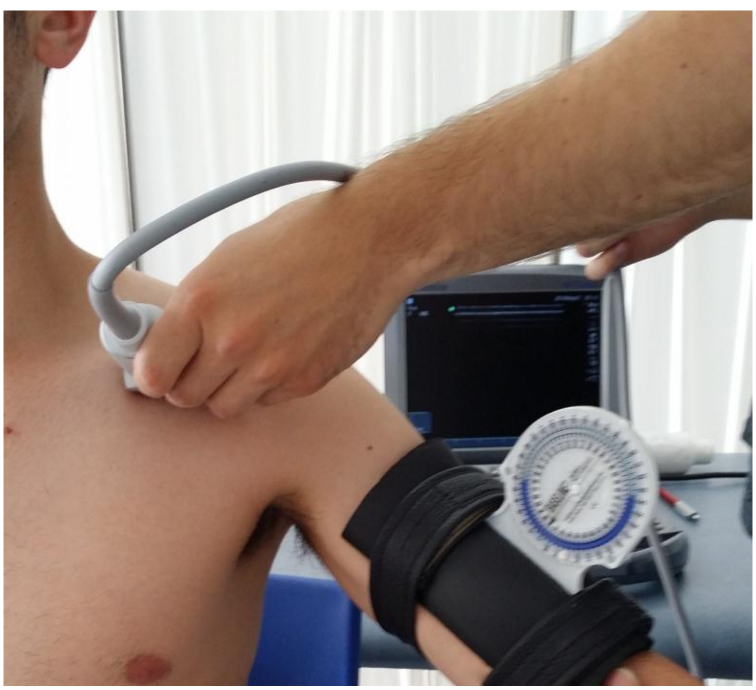
Attachments

Chapter IX

Attachments

ATTACHMENT I: Probe position in the coracohumeral distance measurement at 0 degrees of shoulder abduction.

ATTACHMENT II: Probe position in the coracohumeral distance measurement at 60 degrees of shoulder abduction.



ATTACHMENT III: SHOULDER PAIN AND DISSABILITY INDEX (SPADI) QUESTIONNAIRE QUESTIONAIRE

INDICE DE DOLOR Y DISCAPACIDAD DEL HOMBRO

NOMBRE:____ ID_________FECHA:

HOMBRO AFECTO: DERECHO:_______ IZQUIERDO: ________ AMBOS:_____

Cada una de las líneas siguientes representa la cantidad de dolor que tiene en cada situación. La parte izquierda de la línea representa "no dolor", y la parte derecha "el peor dolor imaginable". Coloque una marca sobre la línea para indicar cuánto dolor tuvo durante la pasada semana en cada una de las siguientes situaciones. Escriba NA (no aplicable) si no experimentó alguno de las situaciones durante la pasada semana.

ESCALA DE DOLOR

A. ¿Qué intensidad tiene su dolor?

Puntuación

¿En su peor momento?

No dolor____ Peor dolor imaginable _____

¿Cuándo esta tumbado del lado del hombro malo?

No dolor____ Peor dolor imaginable _____

¿Para coger algo de una estantería en alto?

No dolor____ Peor dolor imaginable _____

¿Al tocarse detrás del cuello?

No dolor____ Peor dolor imaginable _____

¿Empujar con el brazo del hombro malo?

No dolor____ Peor dolor imaginable _____

Total _____ / Posible_______ = ________ %

NOMBRE:____ ID_________FECHA:

Cada una de las líneas siguientes representa la dificultad que tuvo haciendo esa actividad. La parte más a la izquierda de la línea representa “sin dificultad”, y la parte derecha “tan difícil que se necesito ayuda”. Coloque una marca sobre la línea para indicar cuanta dificultad tuvo durante la pasada semana en cada una de las siguientes actividades. Escriba NA (no aplicable) si no realizó la actividad durante la pasada semana.

ESCALA DE DISCAPACIDAD

B. ¿Qué dificultad tiene para hacer cosas como?

Puntuación

¿Lavarse la cabeza?

Sin dificultad________________________________ Tan difícil que se necesitó ayuda _____

¿Lavarse la espalda?

Sin dificultad_________________________________ Tan difícil que se necesitó ayuda_____

¿Ponerse una camiseta o un jersey?

Sin dificultad________________________________ Tan difícil que se necesitó ayuda _____

¿Ponerse una camisa con los botones por delante?

Sin dificultad________________________________ Tan difícil que se necesitó ayuda _____

¿Ponerse unos pantalones?

Sin dificultad________________________________ Tan difícil que se necesitó ayuda _____

¿Poner algo en una estantería en alto?

Sin dificultad________________________________ Tan difícil que se necesitó ayuda _____

¿Llevar algo pesado de 4,5 kilos?

Sin dificultad________________________________ Tan difícil que se necesitó ayuda _____

¿Sacarse algo del bolsillo trasero?

Sin dificultad________________________________ Tan difícil que se necesitó ayuda _____

Total _____ / Posible_______ = ________ %

ATTACHMENT IV: INFORMED CONSENT

CONSENTIMIENTO INFORMADO

D./ña. ____, de ____ años de edad y con DNI nº ___________________, manifiesta que ha sido informado/a sobre los objetivos del Proyecto de Investigación titulado "vendaje neuromuscular, terapia manual y ejercicio terapéutico en el dolor de hombro".

He sido informado/a que mi participación en este estudio no supone ningún perjuicio sobre mi bienestar y salud. He sido también informado/a de que mis datos personales serán protegidos. Y he sido informado que, una vez acabado el proyecto, no recibirá ningún otro tratamiento adicional.

Tomando ello en consideración, OTORGO mi CONSENTIMIENTO a que este tratamiento sobre el dolor de hombro que padezco, así como las encuestas y medición tengan lugar y sea utilizada para cubrir los objetivos especificados en el proyecto.

Málaga, a ______ de _____________ de 20__

Chapter X

Publications

I

Short term effects of kinesiotaping on acromiohumeral distance in asymptomatic subjects: a randomised controlled trial.

Manual Therapy 18 (2013) 573–577

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Original article

Short term effects of kinesiotaping on acromiohumeral distance in asymptomatic subjects: A randomised controlled trial

A. Luque-Suarez [a,*], S. Navarro-Ledesma [a], P. Petocz [b], M.J. Hancock [c], J. Hush [c]

[a] *Physiotherapy Department, University of Malaga, Malaga, Spain*
[b] *Department of Statistics, Macquarie University, Sydney, Australia*
[c] *Department of Health Professions, Faculty of Human Sciences, Macquarie University, Sydney, Australia*

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ABSTRACT

Objectives: The first aim of this study was to investigate whether kinesiotaping (KT) can increase the acromiohumeral distance (AHD) in asymptomatic subjects in the short term. The second aim was to investigate whether the direction of kinesiotaping application influences AHD.
Background: In recent years, the use of KT has become increasingly popular for a range of musculoskeletal conditions and for sport injuries. To date, we are unaware of any research investigating the effect of kinesiotaping on AHD. Moreover, it is unknown whether the direction of kinesiotaping application for the shoulder is important.
Methods: Forty nine participants were randomly assigned to one of three groups: kinesiotaping group 1 (KT1), kinesiotaping group 2 (KT2) and sham kinesiotaping (KT3). AHD ultrasound measurements at 0° and 60° of shoulder elevation were collected at baseline and immediately after kinesiotape application.
Results: The results showed significant improvements in AHD after kinesiotaping, compared with sham taping. The mean difference in AHD between KT1 and KT3 groups was 1.28 mm (95% CI: 0.55, 2.03), and between KT2 and KT3 was 0.98 mm (95% CI: 0.23, 1.74). Comparison of KT1 and KT2 groups, which was performed to identify whether the direction of taping influences the AHD, indicated there were no significant differences.
Conclusion: KT increases AHD in healthy individuals immediately following application, compared with sham kinesiotape. No differences were found with respect to the direction in which KT was applied.

1. Background

Maintenance of the subacromial space in the shoulder girdle is crucial for normal shoulder function. The subacromial space can be assessed by measurement of the acromiohumeral distance (AHD), which is the distance between the most cranial part of the humeral head and the acromion. Reduced AHD occurs when the humeral head migrates superiorly with inadequate external rotation, and correlates with shoulder impingement severity (Desmeules et al., 2004; Mayerhoefer et al., 2009; Matsuki et al., 2012) and rotator cuff disease (Seitz and Michener, 2011). The measure of AHD can also be used to identify patients who are most likely to benefit from active rehabilitation for shoulder impingement (Desmeules et al., 2004) or surgical repair of the rotator cuff (Saupe et al., 2006). In asymptomatic individuals, reduced AHD during shoulder abduction correlates with scapular dyskinesia (Silva et al., 2010) and may therefore be a useful pre-symptomatic indicator of subacromial impingement.

AHD can be measured by radiography or magnetic resonance imaging (Saupe et al., 2006), although ultrasonography is a less expensive tool that has additional benefits (Azzoni et al., 2004; Desmeules et al., 2004). For example, real-time ultrasonography enables the radiologist to measure AHD in different degrees of shoulder elevation or rotation (Michener et al., 2003). This approach has been used to detect subacromial space narrowing in young athletes as an early sign of shoulder impingement (Girometti et al., 2006).

In recent years, the use of a therapeutic taping technique known as kinesiotaping has become increasingly popular for a range of musculoskeletal conditions and for sport injuries. For those with

* Corresponding author. Facultad de Ciencias de la Salud, Universidad de Malaga, Paseo de Martiricos s/n 29009 Malaga, Spain. Tel.: +34 952137068; fax: +34 952132913.
E-mail address: aluques@uma.es (A. Luque-Suarez).

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rotator cuff tendinopathy and shoulder impingement, kinesiotaping has been found to improve self-reported outcomes such as pain and disability (Thelen et al., 2008; Hsu et al., 2009; Kaya et al., 2011). However, the mechanism of action of kinesiotaping is currently unknown and no studies have used diagnostic imaging to obtain quantitative measures of the effect of kinesiotape on the AHD. We hypothesize that kinesiotaping increases the AHD.

The primary aim of this study was to investigate whether kinesiotaping can increase the AHD. We chose to examine this initially in asymptomatic subjects to investigate the mechanism of action of kinesiotaping in the absence of pain. A secondary aim was to investigate whether the technique of kinesiotaping application influences any effects on the AHD.

2. Method

2.1. Design: randomised controlled trial

2.1.1. Participants

We recruited sixty-two participants, who volunteered from the student body of the Health Sciences School at Malaga University (Spain), and were screened for inclusion between January and March 2012. To be included, participants had to meet all of the following criteria: (i) no shoulder pain in the previous month, (ii) no previous shoulder surgery, (iii) negative Neer test: pain ≤3/10 when the upper limb is elevated in the plane between flexion and abduction with prevention of scapular rotation (Neer, 1983), (iv) no painful arc with shoulder flexion or abduction (pain ≤3/10 on a visual analogue scale), (v) between 18 and 40 years of age, (vi) AHD ≥7 mm with arm at their side and (vii) able to provide informed, written consent. Exclusion criteria were as follows: (i) presence of a skin injury or condition on the shoulder that would contraindicate the use of KT, (ii) refusal to participate once the conditions of the study were known. Forty-nine participants were enrolled into the study (Fig. 1).

Informed written and verbal consent were obtained from all participants before enrolment and baseline demographic and clinical data were collected. The study was approved by The Medical Research Ethics Committee of the Faculty of Nursing, Physiotherapy, Podiatry and Occupational Therapy, University of Malaga and conducted in accordance with the Declaration of Helsinki.

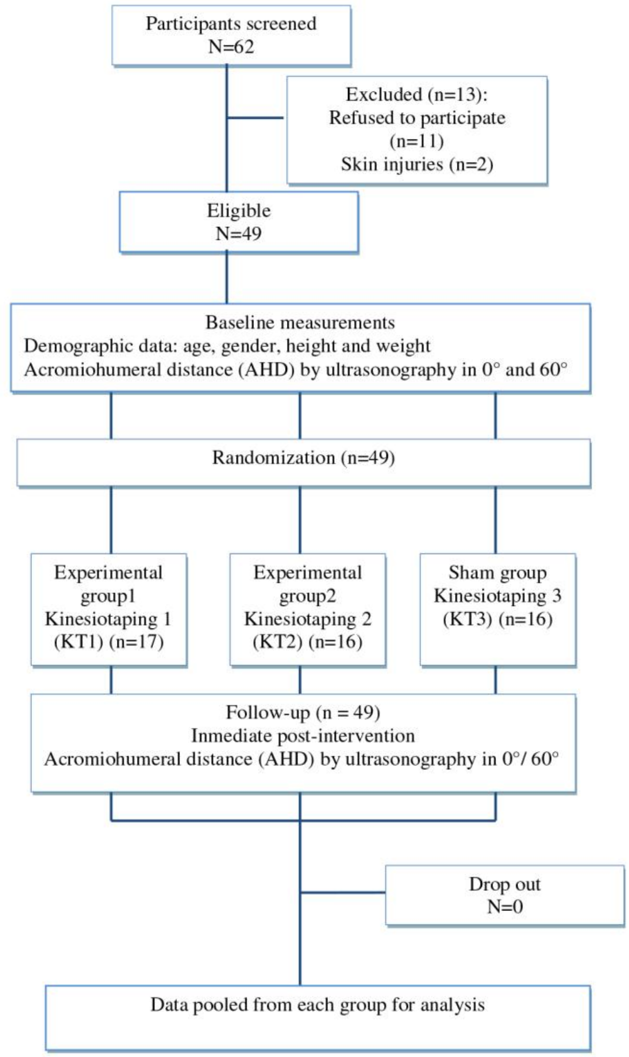

Fig. 1. Participant flow diagram.

2.2. Procedure

Participants were randomly assigned to 1 of 3 groups using a random-number generator and concealed allocation. Group 1 (KT1) received kinesiotape applied in the traditional manner from anterior to posterior. Group 2 (KT2) received kinesiotape applied from posterior to anterior and group 3 (KT3) received sham kinesiotape. All participants received the kinesiotape application the day after the initial examination by the primary author. Each participant had ultrasound measures of AHD taken before and after the initial kinesiotape application, in 0° and 60° of active shoulder elevation in the scapular plane (Fig. 1).

2.3. Taping techniques

All taping was applied by the primary author who has 15 years experience as a musculoskeletal physiotherapist (ALS), to the shoulder of the dominant upper limb of each participant. The skin was first cleaned with alcohol to aid adherence of the tape. Standard 5 cm wide blue k-tape© was used for all taping techniques. The KT1 group received a kinesiotape application. The goal of taping in this group was to facilitate shoulder external rotation in order to increase AHD. A single strip was applied with the subject in erect standing, with the shoulder in maximal external rotation, palm facing forward (Fig. 2). The tape was applied from the coracoid process anteriorly to the superior scapular angle posteriorly, to maintain shoulder external rotation. The tape was stretched to 100% and immediately applied to the skin. Once applied, the adhesion of the tape to the skin was enhanced by rubbing the surface of the tape three times in an anterior to posterior direction.

The KT2 group received an identical treatment to the KT1 group, except that the tape was applied in the opposite direction: from the superior scapular angle to the coracoid process.

The KT3 group received a sham kinesiotaping technique, whereby a single strip was applied in the same place as KT1 and KT2, but without tension and with the shoulder in neutral rather than external rotation (Fig. 2). All tape applications looked similar.

In all groups, kinesiotape was removed by the physiotherapist after outcome data were collected.

2.4. Ultrasound measurements

The ultrasound examination of the shoulder was carried out by the second author (SNL). To reduce bias, the assessor was blinded to group allocation. Each participant was issued an identification number, and this was the only information provided to the

Fig. 2. KT1 (left), applied with 100% tension in maximal external rotation. KT3 (right) applied with no tension and in neutral rotation (sham taping).

examiner. Outcome data were collected for all participants. The ultrasound examinations were carried out using the MyLab™25Gold device (Esaote company, Genoa, Italy) with a 5–12 MHz linear transducer. AHD was measured at 0° and 60° of shoulder elevation in the scapular plane, with the participant seated in an upright position (Kalra et al., 2010). To achieve an upright position, with shoulder retraction and cervical and thoracic extension, subjects were instructed to sit against the back rest of the chair, sit up straight, pull their shoulders back and look straight ahead. We chose 60° of elevation because the AHD is smallest between 60° and 120° (Flatow et al., 1994). A hydrogoniometer placed on the participant's arm was used to position the arm at 0° and 60° of scapular plane elevation (Hebert et al., 2000). To assist in positioning arm elevation in the scapular plane, a room divider was positioned at an angle of 30° forward from the subject's frontal plane, which was marked with tape on the floor (Theodoridis and Ruston, 2002). The participants were asked to maintain their arm elevated actively with enough tension to maintain the position of the hydrogoniometer (Fig. 3). Between measurements, participants were instructed to bring their arm down to a resting position to minimise shoulder fatigue (Theodoridis and Ruston, 2002).

To measure the AHD in 0° and 60° the ultrasound transducer was positioned along the major axis of the humerus and parallel to the flat superior aspect of the acromion, so that both the acromion and humerus could be visualised. The AHD was measured going straight down (vertically) from the acromion to the humeral head (Girometti et al., 2006) (Fig. 4). Measurements of the AHD were made at two locations: (1) at the most anterior part of the acromial arch and (2) 1 cm behind the first measure. The mean of the two measures was recorded (Desmeules et al., 2004). Excellent intra-rater within-day reliability for ultrasonographic measurements of acromion-greater tuberosity distance in healthy individuals has been reported previously (ICC 0.97–0.99) (Kumar et al., 2010), (ICC 0.88–0.91) (Kumar et al., 2011).

We evaluated the intra-rater reliability of the ultrasound measurement of AHD. Three AHD measurements were taken for all participants by the same examiner, in 0° and 60° of shoulder elevation, prior to kinesiotape application. A time interval of 2 min was provided between each measurement. During that period, participants were encouraged to move out of the standardised position. Participants were then repositioned and the second set of measurements taken. The ultrasound examiner was blind to their initial measurements (values were obscured by placing a sticker on the ultrasound screen).

2.5. Data analysis

A power analysis was carried out using ΔAHD, (change in AHD = AHD after treatment minus AHD before treatment) as the

Fig. 3. Participant's position for AHD assessment with ultrasonography.

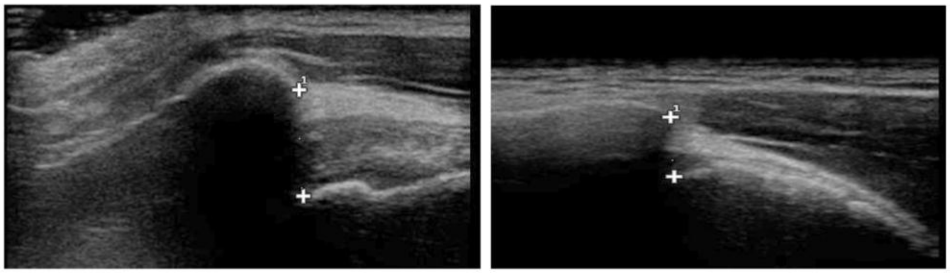

Fig. 4. Ultrasound measurements of the AHD in 0° (left) and 60° (right) of scapular plane elevation. The area of subacromial space is equivalent to the distance between the two white cross symbols.

primary response variable. A one-way analysis of variance with three groups required samples of size 17 in each group in order to identify between-group differences equal to 1 standard deviation of within-group values with a power of at least 70%. This approach was utilised as there was no prior information on variability of change values for AHD.

Analysis of variance models were constructed for ΔAHD, using the repeated measures nature of the data, with subject as a random factor (nested within group), and group and angle as fixed factors. The three groups were compared pairwise with a Bonferroni adjustment for multiple comparisons. The data were analysed using SPSS version 20. A p value of <0.05 was considered statistically significant.

Intrarater reliability of measuring AHD by ultrasound was estimated by calculating the intraclass correlation coefficient (ICC) for the second author, using a one-way random effect model.

3. Results

Sixty-two participants were screened and 13 were excluded because of skin conditions or preference not to participate. This resulted in 49 participants who were enrolled into the study (Fig. 1): 17 in KT1 group and 16 participants each in KT2 and KT3 groups. Demographic characteristics and baseline ultrasound measures of AHD are shown in Table 1. The mean age of the participants was 23 years, 70 kg weight and 170 cm height, and 47% of the participants in the study were female. The mean baseline AHD was 10.5 mm at 0° and 7.2 mm at 60°. There were no significant differences in the demographic characteristic or AHD between the three groups at baseline.

Table 1
Baseline characteristics of subjects.

	Experimental group 1 (KT1) $n = 17$	Experimental group 2 (KT2) $n = 16$	Sham group (KT3) $n = 16$	P values
Age in years, mean (SD)	24.7 (5.3)	22.9 (4.1)	21.1 (2.6)	0.06
Females (n) %	(8) 47%	(10) 62%	(6) 37%	0.376
Weight (kg), mean (SD)	68.6 (12.5)	70.2 (11.7)	72.3 (15.5)	0.726
Height (cm), mean (SD)	168.5 (8.6)	168.6 (9.7)	169.1 (18.5)	0.191
AHD (mm) in 0°, mean (SD)	11.2 (3.3)	10.3 (1.8)	10.1 (1.2)	0.298
AHD (mm) in 60°, mean (SD)	7.3 (1.9)	7.4 (1.5)	7.0 (1.6)	0.781

AHD: acromiohumeral distance.

No adverse effects were reported by any of the participants during the treatment and follow-up periods.

The intra-rater reliability of the AHD measurements was excellent (ICC 0.94 (95% CI: 0.90, 0.96) at 0°, and 0.87 (0.80, 0.92) at 60°). The ANOVA model for ΔAHD found that groups were significantly different ($p = 0.001$), but angles were not significant ($p = 0.72$), nor were inter-subject differences ($p = 0.30$). Group-by-angle interaction was not required in the model, and its exclusion made no appreciable difference to the results. Each active group was significantly different to the control/sham group (KT1 $p < 0.001$, KT 2 $p = 0.006$) but the two active groups were not significantly different from each other (p=0.95, all with Bonferroni adjustment). Table 2 presents the ΔAHD for the 3 groups and Table 3 presents the effect sizes for comparisons between each of the 3 groups.

4. Discussion

This study investigated whether kinesiotaping increases the AHD in asymptomatic individuals compared with sham taping. The results demonstrate that the AHD, measured by ultrasound, can be significantly increased by kinesiotaping. Our results also suggest that there is no difference in the effect on the AHD if kinesiotape is applied in the anterior to posterior direction or the opposite direction.

The main strength of our study is methodological rigour. We used a randomised controlled trial design with true randomisation and concealed allocation. We attained a follow-up of 100% of study participants and there was blinding of the assessor and statistician. However, there are limitations of the current study that should be recognized. First, we only investigated short-term effects of kinesiotaping so we cannot make inferences about long-term effects. Second, these results inform us about the effects of kinesiotaping on healthy individuals, and so the effects on AHD in people with subacromial impingement are unknown.

Our results that kinesiotaping can increase the AHD in asymptomatic subjects provides a good foundation to further investigate the effects in those at risk of developing subacromial impingement or those with established pain and dysfunction. A further limitation is that measurements of AHD over 60° of abduction were not attained because of technical limitations with ultrasonography (Desmeules et al., 2004).

Table 2
ΔAHD (mm) for the 3 intervention groups; CI: confidence interval.

Group	Mean	Standard error	95% CI
KT1	1.158[a]	0.208	(0.741–1.576)
KT2	0.856[a]	0.214	(0.426–1.287)
KT3	−0.128[a]	0.214	(−0.559 to 0.302)

[a] Based on modified population marginal mean.

Table 3
ΔAHD (mm) and effect size for comparisons between 3 intervention groups; CI: confidence interval.

Group comparison	Effect size	95% CI	*P* value
KT1 vs KT3	1.28*	(0.55–2.03)	<0.001
KT2 vs KT3	0.98*	(0.23–1.74)	0.006
KT1 vs KT2	0.30	(−0.44 to 1.04)	0.95

*: Indicates a statically significant difference between groups.

To the authors' knowledge, this is the first study to use diagnostic imaging to obtain quantitative measures of the effect of kinesiotaping on AHD distance. Our results provide evidence for a possible mechanism by which kinesiotaping may provide benefits for people with subacromial impingement, as one component of a multimodal treatment programme.

It is not known whether changes in AHD of the magnitude attained by kinesiotaping in this study are sufficient to be clinically important. ΔAHD and effect size between KT1 and KT3 were 1.28 (0.55, 2.03) and between KT2 and KT3 0.98 (0.23, 1.74). Future research needs to investigate the association between changes in AHD and changes in important clinical outcomes.

We are unaware of any other research about whether the direction of kinesiotape application influences outcomes. In the present study we did not find any significant differences between two application techniques, but it is unknown whether this would be the case in those with pathology. Based on our findings it does not seem that applying the tape in the direction of the movement that is desired is important.

We can only speculate about the physiological mechanisms by which kinesiotaping increased the AHD in this study. One possibility is that kinesiotaping caused a change in the firing pattern of the rotator cuff motor units, which could increase humeral head external rotation. There is some evidence that kinesiotaping applied to the shoulder increases trapezius muscle activity in baseball players with shoulder impingement (Hsu et al., 2009). However, in healthy individuals, traditional taping has been shown not to significantly increase muscular activity, measured with electromyography (Cools et al., 2002; Alexander et al., 2003). In future research it will be interesting to use electromyography to ascertain whether rotator cuff muscle activity is altered by kinesiotaping.

5. Conclusion

Kinesiotaping increases the AHD in individuals without shoulder pain immediately following application of tape, compared with sham kinesiotape. No differences were found with respect to the direction in which the tape was applied. It will be useful for future studies to investigate whether kinesiotaping improves treatment outcomes in individuals at risk of or with subacromial impingement, and whether these changes are clinically meaningful.

Conflict of interests

The authors declare no conflicts of interest and that this study was not funded by any source.

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II
Does the acromiohumeral distance matter in chronic rotator cuff related shoulder pain?

Introduction

Shoulder pain is one of the most common musculoskeletal conditions in primary care(Urwin et al., 1998), with a prevalence fluctuating from 6.9 to 26% for point prevalence, 18.6–31% for 1-month prevalence, 4.7–46.7% for 1-year prevalence and 6.7–66.7% for lifetime prevalence(J. Luime et al., 2004) and with 12-month recurrence rates approximately twice the prevalence rates. In working population, prevalence for shoulder pain associated to musculoskeletal disorders is even higher(Roquelaure et al., 2006). The prevalence of shoulder pain is higher in women(Bergman et al., 2010), and increases with age(Linsell et al., 2006). Rotator cuff tendinopathy (RCT) is the most common cause of shoulder pain(J. S. Lewis, 2010).

Acromiohumeral distance (AHD), defined as the shortest linear distance between the most inferior aspect of the acromion and the adjacent humeral head(Hébert et al., 2003), has been suggested to be related with the presence and severity of some shoulder disorders, such as subacromial impingement syndrome (SIS) and rotator cuff (RC) tendinopathy (Kibler et al., 2013) (L. a. Michener et al., 2013) The use of ultrasound imaging in the determination of AHD(Hébert et al., 2003) (Desmeules et al., 2004)(Kalra et al., 2010)(L. a. Michener et al., 2013) (Maenhout et al., 2015) and shoulder tendon thicknesses such as supraspinatus(Joensen et al., 2009)(L. a. Michener et al., 2013) have been used due to this suspicion of being related with the patients' symptoms. Furthermore, there are other studies that have carried out similar procedures on shoulder pain-free patients(Luque-Suarez et al., 2013)(Schneebeli et al., 2014).

However, the relation between AHD values and severity of pain and disability in patients with RC tendinopathy remains unclear. Desmeules et al (Desmeules et al., 2004) found a strong correlation between AHD and pain and disability, though in a reduced sample of patients diagnosed of suabcromial impingement syndrome (SIS). Despite this promising result, a recent clinical commentary(Bailey et al., 2015b) suggests to accomplish more quality studies to confirm this connection. Even though it is unclear that a reduction in the subacromial space is a cause or a consequence in shoulder pain disorders(Mackenzie et al., 2015) especially in RC tendinopathy, there is a need to determine whether a correlation between AHD, pain and disability and shoulder ROM exists. If so, clinical practise could be focused on improving AHD and, furthermore, AHD could be used for researchers as an outcome measure to report results of their interventions, as the same manner as pain, function and ROM are used nowadays. Moreover, if there was a correlation between AHD and pain, disability and ROM, it would be possible to determine populations at risk of suffering and/or perpetuating chronic rotator cuff related shoulder pain (RCRSP).

Hence, the aim of this study was to determine the level of association between AHD, pain, disability and shoulder-ROM in patients with chronic shoulder pain.

Methods

Study design

This was a cross-sectional study. The study was conducted according to the Declaration of Helsinki.
Ethical approval was obtained from the Ethics Committee of Malaga, Spain (PI9/012014).

Participants

A convenience sample of 110 participants with chronic RCRSP (more than 3 months of duration) was recruited from three different primary care centres, from April 2014 to December 2015. General practitioners (GPs) carried out the recruitment. Then, research assistants assessed participants for eligibility. If participants satisfied the inclusion criteria, then they were studied. Three participants declined to participate, and 10 participants did not meet the inclusion criteria, hence, a sample comprised of 97 participants was assessed (Fig. 5). Research assistants collected the informed consent for every participant.

Participants had to meet at least three of the following inclusion criteria: i) positive Neer test; ii) positive Hawkins-Kennedy test; iii) positive Jobe test; iv) painful arc present during flexion or abduction; v) pain during resisted lateral rotation and/or abduction (Bury et al., 2016). Furthermore, other inclusion criteria had to be met: iv) both men and women aged between 18 and 55 years; (v) no history of significant shoulder trauma, such as fracture or clinically-suspected full thickness cuff tear. Participants were ineligible to participate in this study if any of these conditions were presented: (i) recent shoulder dislocation, systemic illnesses such as rheumatoid arthritis, and evidence of adhesive capsulitis as indicated by passive range of motion loss > 50 % in 2 planes of shoulder motion; (ii) shoulder pain that was deemed to be originating from any passive and/or neck movement or if there was a neurological impairment, osteoporosis, haemophilia and/or malignancies; iii) corticoid injections during the six months prior to the study; iv) analgesic-antiinflamatory medication intake 48 hours prior to the assessment.

Primary outcome

Acromiohumeral distance

A diagnostic ultrasound unit, Sonosite M-turbo (GE Healthcare, Wauwatosa, WI) with a 6–13-MHz linear transducer was used to capture images in grey scale. Ultrasound images were obtained by a single examiner, who was a licensed physiotherapist with advanced training in musculoskeletal ultrasound imaging, and 4-years of experience. Three measurements were taken for all the structures and spaces by the examiner. An interval of one minute was provided between measures, encouraging the patient to move freely. Patients were then repositioned and the second and third set of measurements was successively taken. The ultrasound examiner was blind to all measurements (values were obscured by placing a sticker on the ultrasound screen, meanwhile a research assistant registered the data), and was blind to the previous condition of each patient (shoulder function and pain severity) as well as to the affected side and dominance upper limb. All the ultrasound measures were expressed in centimeters.

AHD was measured at 0 and 60 degrees of active shoulder elevation in the scapular plane, with the participant seated in an upright position. The process to evaluate AHD has been previously used in different populations, such as healthy volunteers(Luque-Suarez et al., 2013) and patients with shoulder pain(L. a. Michener et al., 2013). Patients were seated upright without back support, their feet flat on the ground. To guarantee 0 and 60 degrees shoulder elevation, a hydro-goniometer was placed on the patient's arm. AHD was defined as the shortest linear distance between the most inferior aspect of the acromion and the adjacent humeral head(Desmeules et al., 2004). The ultrasound transducer was placed on the most anterior aspect of the acromion edge, with the long axis of the transducer placed in the plane of the scapula and parallel to the flat surface of the acromion. AHD was measured in centimeters, using the calipers on the ultrasounds' screen.

Secondary outcomes

Active ROM-free of pain at shoulder elevation in scapular plane

Active range of movement free of pain at shoulder elevation in scapular plane was taken using the same procedure as followed for AHD ultrasonography measures, excepting a change in the patient's position (stand up position). Three measures were taken separated by an interval of one minute, and mean was calculated. ROM was expressed in degrees.

Shoulder pain and disability index (SPADI)

The Shoulder Pain and Disability Index (SPADI)(Roach et al., 1991) is a self-administered questionnaire that consists of two dimensions, one for pain and the other for functional activities. SPADI total score fluctuates between 0 to 100, being 0= best and 100=worst. The SPADI has shown a good internal consistency with a Cronbach's alpha of 0.95 for the total score, 0.92 for the pain subscale and 0.93 for the disability subscale as well as the ability to detect change over time(MacDermid et al., 2006).

Data analysis

The Statistical Package for the Social Sciences was used for analysing the collected data (version 23.0 for Mac; SPSS Inc. Chicago, IL). Normality of the variables was visually tested for a Gaussian distribution and additionally tested with a 1-sample Kolmogorov-Smirnov goodness-of-fit test.

For the calculation of intrarater reliability of ultrasound measures (AHD at 0 and 60 degrees), the 3,1 model or a 2-way mixed consistency intraclass correlation coefficient (ICC) model was used. Hereby a reliability coefficient less than 0.50 was an indication of "poor" reliability; "moderate" between 0.50 and 0.75, "good" between 0.76 and 0.90; and "excellent" over 0.90. The Standard Error of Measurement (SEM) and the minimal detectable change with 95% confidence bounds (MDC95) were calculated.

To determine the correlation between AHD at 0 and 60 degrees with SPADI, and ROM free of pain in scapular plane, Pearson correlation coefficient was calculated for a data normal distribution, or Spearman´s coefficient in case of absence of normality. Strong correlation was defined as values greater than 0.7; between 0.5 and 0.7 correlation was considered moderate; between 0.3 and 0.5 was considered weak correlation.
Due to the fact that pain perception seems to be influenced by gender(Henderson et al., 2008)(Alabas et al., 2012), sample characteristics for SPADI and ROM-free of pain values were shown based on this, in order to identify any bias in the homogeneity of the sample.

RESULTS

Sample characteristics

Sample characteristics are shown in table 4. There were no significant differences between gender for demographic characteristics (with the exception of height) and for AHD, SPADI score and active ROM-free of pain in scaption movement. Regarding the duration of symptoms, 31% of the participants presented shoulder pain between 3-6 months at the beginning of this study; 18.6% between 6-12 months; and 50.4% greater than one year

	n=97	Female (n=63)	Male (n=34)	p-value
Age, years	45.42 (8.87)	46.08 (7.59)	44.21 (10.88)	.519
Height, cm	165.74 (7.43)	162.34 (5.92)	171.77 (5.87)	< .05*
AHD 0° (cm)	0.96 (0.14)	0.95 (0.15)	0.98 (0.16)	.523
AHD 60° (cm)	0.65 (0.19)	0,66 (0.22)	0.63 (0.01)	.599
SPADI	62.63 (18.31)	62.70(17.47)	62.51 (20.04)	.710
VAS-pain	7.75 (1.81)	7.67 (1.88)	7.91 (1.68)	.53
ROM-free of pain	91.09 (34.91)	89.29 (36.57)	94.41 (31.85)	.590

Table 4: Sample characteristics expressed by mean and standard deviation.

SPADI (shoulder pain and disability index)

Active ROM (range of movement) free of pain (degrees)

* Differences statistically significant (p< .05)

Reliability

n(97)	Mean (SD)	ICC*	ICC**	SEM	MDC_{95}
AHD at 0 degrees	0.93 (0.15)	0.93 (0.91-0.95)	0.98 (0.97-0.98)	0,04	0,11
AHD at 60 degrees	0.66 (0.18)	0.95 (0.93-0.96)	0.98 (0.98-0.99)	0,04	0,11

Table 5: Intrarater reliability: ICC= intraclass correlation coefficient (*single measure; **average measure); SEM= Standard error of measurement-based on single measure ICC; MDC95= Minimal Detectable Change with 95% CI -based on single measure ICC.

Intrarater reliability was excellent for AHD at 0 and 60 degrees (table 5).

Association between AHD and both SPADI and shoulder ROM

Correlations between AHD and SPADI and shoulder ROM are shown in table 6. Weak negative, statistically significant correlation was found between AHD at 0 degrees and SPADI, what means that the more disability the patient reported, the smaller the ADH appeared to be. Likewise, weak negative correlations were found between AHD at 60 degrees and SPADI, with no statistically significance. Also, weak/absence of any correlations was found between AHD measurements and active ROM-free of pain at shoulder elevation.

	SPADI	ROM
AHD 0 degrees	-0,215*	-0,080
AHD 60 degrees	-0,148	0,163

Table 6: correlations between subacromial space measured by AHD at 0 and 60 degrees of shoulder elevation, and SPADI and shoulder ROM free of pain.

*: statistically significant

Discussion

This study aimed to investigate level of association between AHD, pain-disability and shoulder-ROM in patients with chronic RCRSP. There was a statistically significant correlation between AHD at 0 degrees of shoulder elevation and pain and disability measured by SPADI: the more pain and disability found, the smaller AHD appeared to be. However, this correlation was smaller than weak. When active ROM-free of pain was analysed, none correlation was found with AHD at 0 and 60 degrees. The results showed excellent intrarater reliability for both AHD measures.

Acromiohumeral distance has been considered as one of the possible extrinsic mechanisms for developing RCRSP, which resulted in the so-called shoulder impingement syndrome theory. However, whether the perpetuation of symptoms in advanced stages (chronicity) is associated with a maintained decreased AHD remains unclear, so it is crucial to establish the possible association between AHD and pain and disability, as well as active ROM-free of pain in chronic shoulder pain. Our results showed weak correlations between AHD at both 0 and 60 degrees and SPADI. To our knowledge there are few studies investigating this association. Desmeules et al (Desmeules et al., 2004) found a significative correlation between increases in AHD and function after a physical therapy program applied to seven patients with SIS in acute-subacute stage, during 4 weeks, in a pre-post rehabilitation analysis. Comparisons with our findings are difficult due to the small sample size (7 patients) of the aforementioned study, and for the acute-subacute stage of the patients included. In a recent clinical study (Savoie et al., 2015) an increase of AHD in 25 patients with subacromial pain syndrome (chronic pain) after a rehabilitation program centered on movement training, as well as an improvement in shoulder function, were found. Nevertheless, the degree of correlation between AHD and shoulder function findings was not reported. Regarding the association between AHD measures and ROM-free of pain in shoulder elevation in scapular plane, small correlations were found with AHD measures (0 and 60 degrees of shoulder elevation). A larger AHD measure was associated with more active pain free ROM. However, again, this association was smaller than weak. To our knowledge, there are no studies correlating AHD measured by ultrasonography to active shoulder ROM in patients with RCRSP.

There are potential several reasons that could explain the low association between AHD, pain-function and ROM found in this study. Shoulder impingement syndrome (SIS) is not a homogenous entity. SIS seems to appear as a combination of intrinsic factors (age, tendon histology and genetics), and extrinsic factors, which are those more closely related to AHD, such as acromion shape, glenohumeral and scapular kinematic factors, and, on the other hand, ergonomic adaptation factors and/or muscle extensibility and performance factors (Mackenzie et al., 2015; Seitz et al., 2011). It is reasonable that there is controversy with regard to the exact pathomechanics and biomechanical causes of subacromial pain syndrome (SAPS) (Mackenzie et al., 2015), due to its multifactorial character, and, hence, a controversy about the real role of AHD in the explanation of pain, disability and shoulder ROM in SAPS. In fact, there was an evolution in this terminology, shifting from SIS to the label of SAPS(L. a. Michener & Kulig, 2015). However, this labelling kept the subacromial space as a key contributing factor, which might not be the case in all patients with mechanical shoulder pain. Therefore, the present study emphasizes the use of RCRSP to describe this condition best, as current evidence supports RCRSP terminology instead of the subacromial or impingement based terminology (Jeremy Lewis, 2016).

There are some limitations that should be taken into account. Firstly, inter-rater reliability for ultrasonography measures was not calculated; hence, caution should be taken into account about the psychometric properties of this diagnostic tool. Secondly, the difficulty of classifying shoulder pain disorders, even though a recognized guideline to identify SIS/RC tendinopathy throughout a combination of orthopaedic and movement tests were used in this study as inclusion criteria could mean that the sample analysed presented heterogeneity. In this sense, previous studies have remarked the lack of uniformity and reliability of the current diagnostic classification system for shoulder pain,(Klintberg et al., 2015; Schellingerhout et al., 2008) suggesting to reconsider the use of these diagnostic labels (i.e., SIS). Thirdly, the results regarding the relation between AHD and chronic shoulder pain only shows level of association and not a cause-effect relation. Finally, AHD is a two dimensional measure of a three dimensional space. In this sense there is a difficulty of viewing the undersurface of the acromion due to the acoustic shadow when AHD is assessed.

This study means a first step showing the absence of any week/moderate/strong correlation between chronic RCRSP and AHD measured by ultrasonography. Future studies should be conducted to determine the real scope of AHD within clinical practise, in patients suffering from chronic RCRSP. Furthermore, more research is need to determine the amount of improvement in AHD that could be functionally and clinically meaningful for populations with different shoulder disorders, e.g. RCRSP, as this represents a key gap in the available literature.

Conclusions

In patients with chronic RCRSP, the association between AHD and shoulder pain and function, as well as with shoulder ROM-free of pain, is absent. Hence, clinicians should consider other possibilities rather than focusing their therapies only in increasing AHD when patients with chronic RCRSP are treated.

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III

The coracohumeral distance in chronic anterior shoulder pain. Is it associated with pain-function, and shoulder range of movement?

Introduction

Shoulder pain is one of the most common musculoskeletal conditions in primary care, with a prevalence fluctuating from 6.9 to 26% for point prevalence, 18.6–31% for 1-month prevalence, 4.7–46.7% for 1-year prevalence and 6.7–66.7% for lifetime prevalence (J. Luime et al., 2004) and with 12-month recurrence rates approximately twice the prevalence rates (J. J. Luime et al., 2005). In working population, prevalence for shoulder pain associated to musculoskeletal disorders is even higher (Roquelaure et al., 2006).

Anterior shoulder pain has been traditionally underestimated in the assessment of shoulder pain, (Brunkhorst et al., 2013). Although it can occur alone, it is usually presented with anterolateral shoulder pain (labeled as subacromial pain syndrome), sharing similar symptoms(Misirlioglu et al., 2012) and making difficult it diagnosis. The most related cause of anterior shoulder pain is the subcoracoid impingement syndrome, defined as the encroachment of the posterolateral coracoid process upon the lesser tuberosity of the humerus(Gerber et al., 1985), causing a compression of soft tissues, such as the subscapularis tendon, glenohumeral joint capsule and subcoracoid bursa, and occasionally the long head of the biceps tendon(Radas & Pieper, 2004) . Anatomic differences for humerus lesser tuberosity and coracoid process(Gerber et al., 1985; Giaroli et al., 2006) , as well as anteversion and internal humeral rotation(Radas & Pieper, 2004) , and a history of chronic overuse of persisted flexion, adduction and internal rotation shoulder positions(Okoro et al., 2009), have been also established as possible causes of anterior shoulder pain.

Diagnosis of anterior shoulder pain has not been widely investigated, but the physical examination (cross-arm adduction test) and radiographic features are the most commonly used (Okoro et al., 2009) . The coracohumeral interval (CHI) has been measured in previous investigations using the coracohumeral distance (CHD) to determine the severity of anterior shoulder pain(Gerber et al., 1985; Misirlioglu et al., 2012), sometimes by means of computed tomography or resonance magnetic imaging. However, there is a clear lack of standard procedure to quantify it.

Ultrasonography (US) is a non-invasive tool without ionizing effects that permits the dynamic evaluation, and is more accessible than the previous described. It has been widely used in the determination of the acromiohumeral distance (AHD)(Desmeules et al., 2004; Hébert et al., 2003). Two studies have investigated the use of US in the evaluation of CHD(MR Tracy, TA Trella, LN Nazarian, CJ Tuohy, 2010; Oh JH, Song BW, Choi JA, Lee GY, Kim SH, 2016). Oh et al recently found a good correlation (>0.7) between US and MRI in quantifying CHD, as well as an excellent intra-rater reliability (>0.90) in patients with rotator cuff tear, supporting the use of the US in the evaluation of coracohumeral interval. However, there is a lack of a clear measuring process, normative values and reliability dat for CHD, measured by US, in patients suffering from anterior shoulder pain. There is also inconclusive evidence on the association of anterior shoulder pain and pain-function and shoulder range of movement (ROM), in patients with chronic anterior shoulder pain. The role of acromiohumeral distance (AHD) as explanatory factor for symptoms in RC tendinopathy is starting to be questioned(J. Lewis, 2014). However, the evidence about whether CHD could play an important role in the explanation of anterior shoulder pain, is unfinished. If a strong relationship between a reduced CHD and high levels of pain, decreased shoulder function and limited shoulder ROM was identified, preventive and therapeutic efforts could be focused on increasing this space. Hence, the aim of this study was twofold: i) to assess the intrarater reliability of CHD at 0 and 60 degrees of scapular elevation measured by US, in patients suffering from chronic anterior shoulder pain; ii) to determine the association between CHD with shoulder pain, function and shoulder-ROM free of pain.

Method

Procedure

A convenience sample of 102 patients with chronic anterior shoulder pain (more than three months), and with clinical symptoms of anterior shoulder pain, was recruited from three different primary care centers. General practitioners (GPs) carried out the recruitment. Then, research assistants assessed participants for eligibility. If participants satisfied the inclusion criteria, then they were studied. Five participants declined to participate, and 10 participants did not meet the inclusion criteria, hence, a sample comprised of 87 participants was assessed (Figure 6). Research assistants collected the informed consent for every participant.

All participants in the study gave their written informed consent. Participants had to meet the following inclusion criteria to be classified as anterior shoulder pain (Dines et al., 1990; Okoro et al., 2009; Russo & Togo, 1991): i) positive cross-arm test; ii) painful arc of movement during forward flexion and/or internal rotation; (iii) elicitation of tenderness throughout palpation of the coracoid process.

Furthermore, other inclusion criteria had to be met: both men and women aged between 18 and 55 years; no history of significant shoulder trauma, such as fracture or clinically/ultrasonographic-suspected full thickness rotator-cuff tear. Participants were excluded from this study if any of these conditions were presented: (i) recent shoulder dislocation, systemic illnesses such as rheumatoid arthritis, and evidence of adhesive capsulitis, as indicated by passive range of motion loss > 25 % in 2 planes of shoulder motion, and loss > 50% in external rotation; (ii) shoulder pain that was deemed to be originating from any passive and/or neck movement or if there was a neurological impairment, osteoporosis, haemophilia and/or malignancies; (iii) shoulder surgery in the last year, (iv) corticoid injections during the six months prior to the study; (v) analgesic-antiinflamatory medication intake during 48 hours prior to the study.

Outcome measures

Coracohumeral distance (CHD)

A diagnostic ultrasound unit, Sonosite M-turbo (GE Healthcare, Wauwatosa, WI) with a 6–13-MHz linear transducer was used to capture images in grey scale. Ultrasound images were obtained by a single examiner, who was a licensed physiotherapist with advanced training in musculoskeletal ultrasound imaging, and 4-years of experience. Three measurements were taken. An interval of one minute was provided between measures, encouraging the patient to move freely. Patients were then repositioned and the second and third set of measurements was successively taken. The ultrasound examiner was blind to all measurements (values were obscured by placing a sticker on the ultrasound screen,

meanwhile a research assistant took them and put into a dataset). All the ultrasound measures were expressed in centimeters. CHD was measured at 0 and 60 degrees of active shoulder elevation in the scapular plane, neutral shoulder rotation, with the participant seated in an upright position.
Patients were seated upright without back support, their feet flat on the ground. To guarantee 0 and 60 degrees shoulder elevation, a hydro-goniometer was placed on the patient's arm(Hbert et al., 2002). CHD was defined as the shortest linear distance between the coracoid and the adjacent humeral head(Okoro et al., 2009). The ultrasound transducer was placed over the most anterior aspect of the shoulder (see Chapter VIII: Attachments), observing the coracoid process and the humeral head on the screen, taking the shortest distance between them. CHD was measured in centimeters, using the calipers on the ultrasound screen. (Figure 1 and 2)

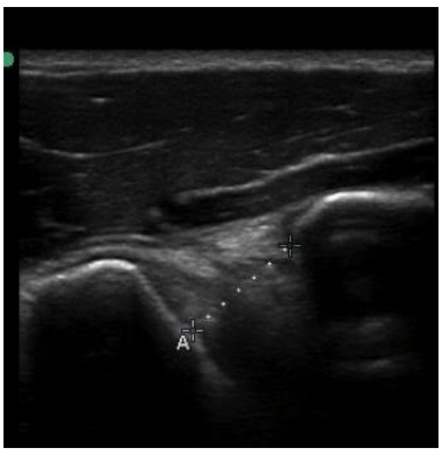

Figure 1: CHD at 0 degrees of shoulder elevation

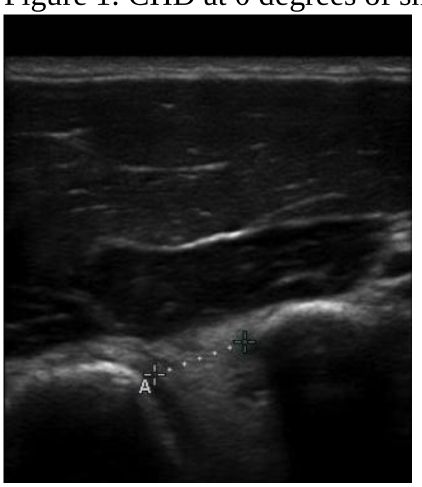

Figure 2: CHD at 60 degrees of shoulder elevation

ROM-free of pain at shoulder elevation

Range of movement free of pain at shoulder elevation was taken using the same procedure as followed for CHD ultrasonography measures, excepting a change in the patient's position (stand up position). Three measures were taken separated by an interval of one minute, and mean was calculated. ROM was expressed in degrees.

Shoulder pain and disability index (SPADI)

The Shoulder Pain and Disability Index (SPADI)(Roach et al., 1991) is a self-administered questionnaire that consists of two dimensions, one for pain and another for functional activities. SPADI total score fluctuates between 0 to 100, with 0 = best and 100 = worst. SPADI has shown to have good internal consistency (overall Cronbach's alpha = 0.95; for the pain subscale=0.92; for the disability subscale=0.93), as well as the ability to detect change over time(MacDermid et al., 2006).

Data analysis

The Statistical Package for the Social Sciences was used for analyzing the collected data (version 23.0 for Mac; SPSS Inc. Chicago, IL). Normality of the variables was visually tested for a Gaussian distribution and additionally tested with a 1-sample Kolmogorov-Smirnov goodness-of-fit test.
For the calculation of reliability of CHI the model or a 2-way mixed consistency intraclass correlation coefficient (ICC) model was used. Hereby a reliability coefficient less than 0.50 was an indication of "poor" reliability; "moderate" between 0.50 and 0.75, "good" between 0.76 and 0.90; and "excellent" over 0.90 (Portney & Watkins, 2000). The Standard Error of Measurement (SEM) and the minimal detectable change with 95% confidence bounds (MDC95) were calculated.
To determine the correlation between CHD at 0 and 60 degrees with SPADI, and ROM free of pain in scapular plane, Pearson correlation coefficient was calculated for normally distributed data, or Spearman´s coefficient in case of absence of normality. Strong correlation was defined as values greater than 0.7; between 0.5 and 0.7 correlation was considered moderate; between 0.3 and 0.5 was considered weak correlation (Mukaka, 2012).

Results

A total sample of 87 patients (71% women); mean age 43.9 (SD=9.1) years; mean SPADI score of 59.7 (SD=19.2); and a shoulder ROM free of pain of 93.1(SD=33.9) degrees, was analyzed. Regarding the duration of symptoms, 26.4% of the participants presented shoulder pain between 3-6 months at the beginning of this study; 13.8% between 6-12 months; and 59.8% greater than one year.
Mean values for CHD at both 0 and 60 degrees are shown in table 1.

CHD Intra-rater reliability

Intrarater reliability for CHD showed excellent values at both 0 and 60 degrees of shoulder elevation (table 7).

n (87)	mean(SD)	ICC*	ICC**	SEM	MDC_{95}
CHD at 0 degrees	1.03 (0.26)	0.988 (0.982-0.992)	0.996 (0.994-0.997)	0,04	0,11

CHD at 60 degrees	0.94 (0.27)	0.989 (0.984-0.993	0.996 (0.995-0.998)	0,04	0,11

Table 1: intra-rater reliability for CHD at 0 and 60 degrees of shoulder elevation.

Intrarater reliability: ICC= intraclass correlation coefficient (*single measure; **average measure); SEM= Standard error of measurement-based on single measure ICC; MDC95= Minimal Detectable Change with 95% CI -based on single measure ICC.

Association between CHD with shoulder pain-function and shoulder-ROM free of pain
Correlations between CHD, SPADI and shoulder ROM are shown in table 2.
Absence of any correlation was found between CHD and SPADI at both 0 and 60 degrees of shoulder elevation. Furthermore, absence of any correlation was found between CHD measurements and active ROM-free of pain at shoulder elevation.

	SPADI	ROM	CHD 0 degrees	CHD 60 degrees
CHD 0 degrees	-0,24*	0.23*	1	0,62**
CHD 60 degrees	-0,15	0,19	0,62**	1

Table 2: correlations between coracohumeral distance measured by US at 0 and 60 degrees of shoulder elevation, and SPADI and shoulder ROM free of pain.
*: statistically significant (p < .05)
**: statistically significant (p < .01)

Discussion

The first aim of this study was to determine the intra-rater reliability for CHD measured by US in patients suffering from anterior chronic shoulder pain. The results showed an excellent reliability for both 0 and 60 degrees of shoulder elevation. The second aim was to analyze the level of association between CHD and shoulder pain-function as well as shoulder ROM free of pain. Absence of associations was noted between all the outcomes.
To the best of our knowledge, this is the first and largest study reporting CHD measurements in people suffering from chronic anterior shoulder pain by means of US. This study provides results in response to the lack of quality studies in the field of coracohumeral reliability, measured by US. Our findings demonstrated excellent reliability for CHD at 0 and 60 degrees (0.98), which are in consonance with Tracy et al.,(MR Tracy, TA Trella, LN Nazarian, CJ Tuohy, 2010) who found an ICC of 0.89 at 0 degrees, in a smaller sample of 19 participants free of shoulder pain. Likewise, Oh et al.(Oh JH, Song BW, Choi JA, Lee GY, Kim SH, 2016) achieved intrarater reliability greater than 0.90, in patients with rotator cuff tears. However, the position used in both studies to measured CHD (cross arm position) was different in comparison to the present study. The excellent values achieved for CHD measurements are similar to those obtained in similar studies reporting AHD also measured by US, in patients with shoulder pain(McCreesh et al.,

2015)(Pijls et al., 2009). These promising findings are supported by different aspects that were considered in the present study in order to provide a higher quality: (1) the ultrasound examiner was blind about the fact of knowing the affected shoulder before measures were taken; (2) every measure was collected with a wash-out period of one minute between measures, permitting patients to move freely between measures; (3) no landmarks were used on the skin in an attempt of making every measure independent with respect to the others; 4) the issue of examiner experience. With respect to the normative values for CHD in people with shoulder pain, our results showed values of 1.03 (0.21) cms at 0 degrees of shoulder elevation, and 0.95 (0.25) cms at 60 degrees. Only one study(MR Tracy, TA Trella, LN Nazarian, CJ Tuohy, 2010) has reported CHD using US, obtaining values of 0.70 (1.4) cms, although CHD was taken in adduction and internal shoulder rotation. This position reduces CHD and, so, makes difficult the comparison between findings. MRI has been also used in the assessment of CHD. Specifically, one study has reported values of 0,72 cms (Misirlioglu et al., 2012) in maximal shoulder internal rotation, while, with shoulder neutral rotation, values of 1.12 (0.33) cms have been found (Hekimoglu et al., 2013) , which are in consonance with ours results.

According to the determination of the level of association between CHD values and shoulder pain-function and ROM, to our knowledge this is the first study investigating this relationship. It is highly important to establish the possible association between anterior shoulder pain, and CHD measured by US, as well as with active shoulder ROM-free of pain. That would steer treatments in one or another direction. Our results showed an absence of correlation between CHD and both SPADI and ROM-free of pain. There are possible underlying mechanisms to explain the low association between CHD, pain and function, and active shoulder ROM-free of pain. Anterior shoulder pain is not a homogenous entity. It seems to appear as a combination of intrinsic factors (age, tendon histology and genetics), and extrinsic factors, which are those more closely related to CHD, such as anatomic differences for humerus lesser tuberosity and coracoid process (Gerber et al., 1985; Giaroli et al., 2006), as well as anteversion and internal humeral rotation(Radas & Pieper, 2004) , and a history of chronic overuse of persisted flexion, adduction and internal rotation shoulder position(Okoro et al., 2009). It is reasonable that there is controversy with regard to the exact pathomechanics and biomechanical causes of shoulder pain. Although this study only shows the level of association between the CHD and symptoms referred by the patient, and not a cause-effect relationship, it seems that, due to the multifactorial character of anterior shoulder pain, the CHD could only explain a little amount of patient's pain perception and ROM. Moreover, the chronic character of shoulder pain suffered by the patients included in the present study, would mean the confluence of other possible explanation factors, such as the presence of peripheral-central sensitization, that has been reported previously in shoulder injuries(Sanchis et al., 2015). As these conditions were not measured in the present study we can just only speculate about their real influence.

About the normative values achieved in this study for CHD, although there was not an objective in this study, our values were similar in CHD at 0 degrees of shoulder evaluation (1.03 ± 0.21 cms) that obtained by Oh et al.(Oh JH, Song BW, Choi JA, Lee GY, Kim SH, 2016) (1.01 ± 0.21 cms), but in different sample of patients (anterior shoulder pain vs full rotator cuff tear).

There are some limitations that should be taken into consideration. Firstly, inter-rater reliability for ultrasonography measures was not determined; hence, results should be taken with caution. Secondly, the difficulty of classifying shoulder pain disorders could mean that the analyzed sample presented heterogeneity. In this sense, previous studies have remarked the lack of uniformity and reliability of the current diagnostic classification system for shoulder pain(Schellingerhout et al., 2008)(Klintberg et al., 2015) . Thirdly, CHD is a two dimensional measure of a three dimensional space. Compromise of this volume cannot be totally quantified by measure of CHD in isolation, so this should be taken into account.

This study provides promising results regarding the excellent intra-rater reliability of US in the determination of CHD that quantifies the CHI. Moreover, normative values for CHD at both 0 and 60 degrees of shoulder elevation in patients with chronic shoulder pain has been identified. However, the real role of the CHD in the explanation of severity of pain, alteration of shoulder function and limitation of ROM, in patients with anterior shoulder pain, is not sufficiently clarified yet. Hence, future studies should be focused on determine its real importance along with other intrinsic and extrinsic factors, in order to determine whether it could be considered as a prognostic factor for chronic anterior shoulder pain, and whether it could be an essential factor that would steer physical treatments. Furthermore, a standard patient position should be agreed using US. This would make possible comparisons between studies.

Conclusions

In patients with chronic anterior shoulder pain, there is no association between CHD, and shoulder pain and function, as well as with shoulder ROM-free of pain. Hence, clinicians should consider other possibilities rather than focusing their therapies only in increasing this space, when patients with anterior shoulder pain are treated.

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Resumen en castellano

La presente tesis, con título *"Exploración ecográfica en la valoración músculo esquelética en pacientes con hombro doloroso"* ha sido realizada en régimen de cotutela entre la Universidad de Málaga y la Universidad de Amberes, Bélgica.

A continuación, se expone un resumen en castellano sobre el contenido de la misma.

El primer capítulo sirve de introducción general, a través de un marco conceptual donde se abordan conceptos generales de la ecografía y su uso dentro de la valoración del hombro, utilizado en la clínica diaria.

El segundo y tercer capítulos justifican el motivo de la tesis y enumeran los objetivos del presente proyecto, que estudia el uso de la ecografía en la valoración del hombro. Hay que añadir que el presente estudio centra su trabajo en la cuantificación de la distancia acromiohumeral y la distancia coracohumeral, en relación al dolor crónico de hombro, siendo el estudio de otros usos de la ecografía en la valoración del hombro parte de la prospectiva.

Así, debido a que la distancia acromiohumeral (DAH), definida como la distancia más corta entre el aspecto inferior del acromion y la cabeza humeral, ha sido relacionada con la presencia y severidad de algunas lesiones en el hombro, tal y como el síndrome del impingement subacromial (SIS) y la tendinopatía del manguito rotador, empezamos un proyecto de investigación a través de la presente tesis, en el que nuestro primer estudio tuvo el objetivo de investigar si la distancia acromiohumeral medida por ecografía, podría aumentarse tras la aplicación de un kinesio taping.

Inicialmente, decidimos examinarlo en sujetos sanos para investigar el efecto del kinesio taping en el espacio acromiohumeral en ausencia de dolor, así como la capacidad de la ecografía en la valoración de los cambios de la DAH tras la aplicación de una técnica de fisioterapia. El segundo objetivo fue investigar si distintas técnicas de kinesio taping influían de distinta forma sobre la DAH.

Una vez realizado el estudio mencionado, diseñamos un segundo estudio cuyo objetivo fue determinar si existe correlación entre la DAH medida por ecografía, con el dolor-funcionalidad y movilidad en pacientes con hombro doloroso crónico en relación al manguito rotador. Si dicha correlación fuese encontrada, los tratamientos deberían enfocarse en aumentar la DAH y, además, la DAH podría servir para los investigadores como indicador de cambios tras distintas intervenciones de fisioterapia, tal y como el dolor, la funcionalidad y el ROM son usados actualmente. Del mismo modo, se podrían detectar poblaciones en riesgo de sufrir y/o perpetuar dolor de hombro crónico en relación al manguito rotador.

Por último, diseñamos el tercer estudio con el propósito de analizar la fiabilidad intraobservador en la medición de la distancia coracohumeral (DCH), medida por ecografía, en pacientes con dolor crónico anterior de hombro, así como determinar la correlación entre la DCH con dolor-funcionalidad y ROM libre de dolor. Conociendo su nivel de correlación, tanto el abordaje terapéutico como preventivo podrían ser beneficiados.

De este modo, los principales objetivos del estudio fueron los expuestos a continuación, pertenecientes a los capítulos 3, 4 y 5 respectivamente:

- Analizar si la distancia acromiohumeral (DAH) puede ser aumentada tras la aplicación de kinesio taping. Además, investigar si la técnica realizada de kinesio taping (de anterior a posterior o viceversa) influye en la DAH.

- Investigar el nivel de asociación entre la distancia acromiohumeral, medida por ecografía, con el dolor, discapacidad y rango de movimiento (ROM), en pacientes con dolor de hombro crónico.
- Determinar el nivel de asociación entre la distancia coracohumeral (DCH), medido por ecografía, con el dolor, discapacidad y rango de movimiento (ROM), en pacientes con dolor crónico anterior de hombro.

En el tercer capítulo, se desarrolla el primer objetivo de la tesis, a través del estudio bajo el título “Efectos a corto plazo del kinesio taping en el espacio acromiohumeral en sujetos sanos: un ensayo controlado aleatorizado”. En dicho estudio, reclutamos sesenta y dos participantes sin dolor de hombro, y fueron evaluados para su inclusión en el estudio. Finalmente, cuarenta y nueve sujetos fueron incluidos. Se investigó si el kinesio taping puede aumentar la DAH en sujetos asintomáticos en comparación con el tape placebo. Los participantes fueron asignados aleatoriamente entre los grupos 1 y 3. Al grupo 1 (KT1) se le aplicó kinesio taping de la forma tradicional, de anterior a posterior. Al grupo 2 (KT2) se le aplicó el kinesio taping de posterior a anterior, y al grupo 3 (KT3) se le aplicó kinesio taping placebo. A todos los participantes se les aplicó el kinesio taping el día después del examen inicial y se les midió la DAH antes y después de la aplicación del kinesio taping, en 0 y 60 grados de elevación activa del hombro en el plano escapular.

Los resultados demostraron que la DAH, medida por ecografía, puede ser incrementada por el kinesio taping significativamente. Nuestros resultados también sugieren que no hay diferencia respecto a la aplicación del kinesio tape, si es de anterior a posterior o viceversa.

La principal fortaleza de nuestro estudio fue el rigor metodológico. Usamos un diseño de ensayo aleatorizado controlado con una verdadera aleatorización y asignación oculta. Conseguimos realizar un seguimiento del 100% de los participantes del estudio y hubo cegamiento del evaluador y del estadístico. Sin embargo, hay limitaciones del estudio que deberían ser reconocidas. Primero, sólo investigamos los efectos a corto plazo del kinesio taping, por lo tanto, no podemos hacer conclusiones sobre efectos a largo plazo. Segundo, los resultados nos informan sobre los efectos del kinesio taping en sujetos sanos, por tanto, los resultados sobre la DAH en pacientes con impingement subacromial son desconocidos.

Nuestros resultados muestran que el kinesio taping puede incrementar la DAH en sujetos asintomáticos, esto proporciona un buen fundamento para investigar más sobre los efectos en aquellas personas en riesgo de desarrollar impingement subacromial o aquellos con dolor y disfunción ya establecidos. Otra limitación es que las medidas sobre 60 grados de abducción no fueron conclusivas debido a las limitaciones técnicas con ecografía.

Para el conocimiento de los autores, este fue el primer estudio que usa la imagen por ecografía para obtener medidas cuantitativas del efecto del kinesio taping en la DAH. Nuestros resultados proporcionan evidencia de un posible mecanismo por el cual el kinesio taping podría aportar beneficios a personas con impingement subacromial, como componente de un programa de tratamiento multimodal.

Se desconoce si los cambios en la DAH producidas por el kinesio taping en este estudio son suficientes para ser clínicamente importantes. La diferencia de medias de la DAH y el efecto del tamaño entre KT1 y KT3 fueron 1.28 (0.55, 2.03) y entre KT2 y KT3 0.98 (0.23, 1.74). Futuras investigaciones deberían investigar la asociación entre cambios en la DAH y cambios en los resultados clínicos.

No conocemos de ninguna otra investigación sobre si la dirección de la aplicación del kinesio tape influye en los resultados. En el presente estudio, no encontramos ninguna diferencia significativa entre las dos técnicas de aplicación, pero se desconoce si éste sería el caso en pacientes con patología. Basado en nuestros hallazgos, no parece que aplicando el tape en dirección del movimiento deseado sea importante.

Solamente podemos especular sobre los mecanismos fisiológicos por los que el kinesio taping aumenta la DAH en este estudio. Una posibilidad es que el kinesio taping causa un cambio en el patrón de activación de las unidades motoras del manguito rotador, que podría aumentar la rotación externa de la cabeza humeral. Hay evidencia sobre el kinesio taping aplicado al hombro, que aumenta la actividad del trapecio en jugadores de beisbol con impingement subacromial. Sin embargo, en individuos sanos, se ha demostrado que el tape tradicional no aumenta significativamente la actividad muscular, medido con electromiografía.

Por otra parte, en el capítulo 4 se desarrolla el estudio realizado con el *título "¿Realmente importa la distancia acromiohumeral en el hombro doloroso crónico?"*, en el que se investiga el nivel de asociación entre la DAH, dolor-funcionalidad y ROM del hombro en pacientes con dolor crónico de hombro, antes de recibir un tratamiento de fisioterapia. Por tanto, el estudio sigue un diseño transversal.

Una muestra comprendida por 110 pacientes con dolor de hombro crónico (más de 3 meses de duración) fue reclutada en tres centros de atención primaria diferentes, de los que 97 fueron incluidos finalmente. Nuestros resultados mostraron una relación estadísticamente significativa pero débil entre la DAH en 0 grados de elevación del hombro, dolor y funcionalidad medido a través del SPADI: a mayor dolor y discapacidad del paciente, menor tamaño aparente de la DAH. Cuando fue analizado el ROM activo de elevación del hombro, no se encontró correlación con DAH en 0 y 60 grados. Los resultados mostraron una fiabilidad intraobservador excelente para ambas medidas de la DAH.

La DAH ha sido considerada como uno de los posibles mecanismos extrínsecos para desarrollar tendinopatía crónica del manguito rotador, que resultó en la conocida teoría del síndrome del impingement subacromial del hombro (SIS). Sin embargo, si la perpetuación de los síntomas en etapas avanzadas (cronicidad) es asociada con un descenso de la DAH mantenida permanece incierta, por lo tanto, es crucial establecer la asociación entre DAH, dolor y discapacidad, así como ROM activo libre de dolor en el hombro crónico doloroso. Nuestros resultados mostraron correlaciones débiles entre DAH en 0 y 60 grados con el SPADI. Para nuestro conocimiento, existen varios estudios investigando esta asociación.

Desmeules y colaboradores encontraron una correlación significativa entre incrementos de la DAH y función después de un programa de tratamiento de fisioterapia aplicado a siete pacientes con SIS en etapa aguda-subaguda, durante 4 semanas, en un análisis pre-post rehabilitación. Las comparaciones con nuestros resultados son complicadas debido a la pequeña muestra (7 pacientes) del estudio mencionado, y por la fase aguda-subaguda de los pacientes incluidos. En un estudio clínico reciente, encontraron un incremento de la DAH en 25 pacientes con SIS (dolor crónico) tras un programa de rehabilitación centrado en el entrenamiento del movimiento, así como en la mejora de la función del hombro. Sin embargo, los hallazgos del grado de correlación entre DAH y la función del hombro no fueron mostrados. Respecto a la asociación entre las mediciones de la DAH y ROM libre de dolor en la elevación del brazo en el plano escapular, se encontraron correlaciones muy débiles con diferentes medidas de DAH. Una mayor DAH era asociada con más ROM activo libre de dolor. En cambio, de nuevo, esta asociación fue pequeña. Por lo que sabemos, no hay estudios correlacionando mediciones de la DAH medido por ecografía con ROM activo del hombro en pacientes con dolor de hombro crónico.

Una vez analizados los resultados, existen posibles razones para explicar la baja asociación entre DAH, dolor-función y ROM activo libre de dolor.

El síndrome de impingement subacromial (SIS) no es una entidad homogénea. SIS aparece como una combinación de factores intrínsecos (edad, histología del tendón, genética), y factores extrínsecos, que son aquellos más cercanos a la DAH, tal y como la forma del acromion, movilidad escapular y glenohumeral y, por otra parte, factores ergonómicos de adaptación y/o extensibilidad de la musculatura, así como factores de conducta.

Es razonable que exista controversia respecto a la patomecánica y causas biomecánicas del SIS, debido a su carácter multifactorial, al igual que acerca del verdadero rol de la DAH en la explicación del dolor, discapacidad y ROM en esta entidad. De hecho, hubo una evolución en esta terminología, pasando de SIS a la etiqueta del "síndrome del dolor subacromial" (SAPS). Sin embargo, esta etiqueta mantiene al espacio subacromial como factor clave, que podría no ser el caso en todos los pacientes con dolor mecánico de hombro. No obstante, el presente estudio enfatiza el uso de la terminología "dolor de hombro relacionado con el manguito rotador" (RCRSP) en lugar de términos como "impingement".

Existen algunas limitaciones en este estudio que deberían tenerse en cuenta. En primer lugar, la fiabilidad inter observador para las mediciones ecográficas no fue calculada; además, deberíamos tener precaución sobre las propiedades psicométricas de esta herramienta.

En segundo lugar, la dificultad de clasificar las lesiones del hombro. Aunque en este estudio se siguieron guías reconocidas para identificar SIS/tendinopatía del manguito rotador a través de la combinación de test ortopédicos y movimientos como criterios de inclusión, podría significar que la muestra analizada presentó heterogeneidad. En este sentido, previos estudios han señalado la falta de uniformidad y fiabilidad de los sistemas de clasificación de diagnóstico actuales para el dolor de hombro, sugiriendo reconsiderar el uso de estas etiquetas diagnósticas (SIS, etc).

En tercer lugar, los resultados respecto a la relación entre la DAH y dolor crónico de hombro solo muestran niveles de asociación y no una relación causa-efecto. Finalmente, la DAH es una medición bidimensional de un espacio tridimensional y, además, la dificultad de ver la superficie bajo el acromion debido a la sombra acústica producida por el hueso provoca que esta área no sea vista o medida rigurosamente.

Este es el primer estudio mostrando la ausencia de alguna moderada/fuerte correlación entre hombro crónico doloroso y DAH medido por ecografía. Futuros estudios deberían determinar el alcance real de la DAH en la práctica clínica, analizando sus cambios tras la aplicación de distintos tratamientos de fisioterapia, en pacientes que sufren de dolor de hombro crónico. Además, se necesita más investigación para determinar qué cantidad de incremento en la DAH podría ser funcional y clínicamente importante en esta población, lo que representa una laguna en la literatura científica actual.

En el capítulo 5 desarrollamos el estudio con el título *"El espacio coracohumeral en el dolor crónico anterior de hombro. ¿Está asociado con el dolor, función y rango de movimiento?"*. Una muestra comprendida por 102 pacientes con dolor crónico anterior de hombro fue reclutada de tres centros diferentes de atención primaria. Un número de 87 sujetos fueron finalmente incluidos en el estudio, siguiendo un diseño transversal, y evaluados antes de recibir tratamiento de fisioterapia. El primer objetivo del estudio fue determinar la fiabilidad intraobservador de la DCH medida por ecografía en pacientes con dolor crónico anterior del hombro. Los resultados muestran una excelente fiabilidad tanto en 0 como 60 grados de elevación del hombro. El segundo objetivo fue analizar el nivel de asociación entre la DCH y el dolor de hombro, la función y ROM libre de dolor. No existió ninguna correlación entre todas las mediciones.

Desde nuestro conocimiento, este es el primer y mayor estudio mostrando mediciones de la DCH en pacientes con dolor crónico anterior de hombro medido por ecografía. Este estudio proporciona resultados en respuesta a la falta de estudios de calidad en el campo de la fiabilidad de la DCH medido por ecografía.

Nuestros resultados muestran una excelente fiabilidad de la DCH en 0 y 60 grados (0.98), que están en consonancia con los obtenidos por Tracy y colaboradores que encontraron un ICC de 0.89 en 0 grados en una muestra menor de 19 pacientes sin dolor de hombro. Del mismo modo, Oh y colaboradores lograron una fiabilidad intraobservador superior a 0.90 en pacientes con rotura del manguito rotador. Sin embargo, la posición utilizada en ambos estudios para medir la DCH (posición de aproximación del brazo) fue diferente en comparación a la del presente estudio. Los excelentes valores logrados para las medidas de la DCH son similares a aquellas obtenidas en estudios similares sobre la DAH, también medido por ecografía, en pacientes con dolor de hombro. Estos prometedores hallazgos son avalados por diferentes aspectos que fueron considerados en el presente estudio para proporcionar una mayor calidad: (1) el examinador de la DCH fue cegado sobre el hecho de conocer el hombro afecto antes de la medición; (2) cada medición fue recogida con un periodo de descanso de un minuto entre mediciones, permitiendo a los pacientes moverse libremente; (3) no se usaron puntos de referencia en la piel para asegurar la independencia de cada medición respecto a las demás; (4) la experiencia del examinador. Respecto a los valores normativos de la DCH en pacientes con dolor anterior de hombro, nuestros resultados mostraron valores de 1.03 (0.21) cms en 0 grados de elevación del hombro y 0.95 (0.25) cms en 60 grados de elevación del hombro.

Solamente un estudio midió este espacio usando ecografía, obteniendo valores de 0.70 (1.4) cms, aunque fueron tomadas en aducción y rotación interna, posición que reduce la DCH, y dificulta su comparación con nuestros resultados. La resonancia magnética (RM) también ha sido usada en la valoración de la DCH. Específicamente, un estudio ha mostrado valores de de 0.72 cms en rotación interna máxima, mientras que en rotación neutra se han obtenido valores de 1.12 (0.33) cms en poblaciones similares, cuyos resultados están en consonancia con los nuestros.

Respecto a la determinación del nivel de asociación entre los valores de la DCH y dolor de hombro, función y ROM, hasta la fecha, este es el primer estudio investigando esta relación. Es importante establecer una posible asociación entre dolor crónico anterior de hombro, medido a través de la DCH por ecografía, y dolor y discapacidad, así como el ROM libre de dolor, para dirigir los tratamientos o no en esa dirección

Nuestros resultados mostraron ausencia de correlación entre DCH con SPADI y ROM libre de dolor. Existen posibles mecanismos ocultos para explicar la baja asociación entre la DCH, dolor y función, y ROM activo libre de dolor. El dolor crónico anterior de hombro no es una entidad homogénea, parece ser una combinación de factores intrínsecos (edad, histología del tendón y genética), y factores extrínsecos, que son aquellos más próximos a la DCH, como diferencias anatómicas en la tuberosidad menor y la apófisis coracoides, así como anterversión y rotación interna del húmero, y sobreuso crónico por posiciones persistentes de flexión, aducción y rotación interna. Aunque este estudio solamente muestra el nivel de asociación entre la distancia coracohumeral y los síntomas referidos por el paciente, y no una relación causa-efecto, parece que, debido al carácter multifactorial del dolor crónico anterior de hombro, la DCH solo puede explicar una pequeña parte de la percepción del dolor del paciente y ROM. Además, la condición crónica del dolor de hombro de los pacientes incluidos en el estudio implica la confluencia de otro posible factor explicativo, como la presencia de neurosensibilización central o periférica, que ha sido mostrada estar presente en lesiones de hombro. Como estas condiciones no fueron medidas en el presente estudio, sólo podemos especular acerca de su real influencia.

Acerca de los valores normativos de la DCH obtenidos, aunque no era un objetivo del mismo, nuestros valores (1.03 ± 0.21) cms fueron similares a los obtenidos por Oh et al. (1.01 ± 0.21) cms, pero en una muestra diferente de pacientes (dolor crónico anterior de hombro/roturas del manguito rotador)

Existen algunas limitaciones que debemos tener en cuenta. Primero, la fiabilidad inter observador en las mediciones ecográficas no fue determinada; de este modo, debería tenerse precaución en la interpretación de los resultados. En segundo lugar, la dificultad de clasificar las lesiones del hombro. En este sentido, previos estudios han señalado la falta de uniformidad y fiabilidad de los sistemas de clasificación de diagnóstico actuales para el dolor de hombro.

En tercer lugar, la DCH es una medida bidimensional de un espacio tridimensional. El compromiso de este volumen no puede ser cuantificado completamente a través de la medición de la DCH por sí sola, por tanto, toda conclusión debe ser tomada con cautela.

Este estudio aporta resultados prometedores respecto a la excelente fiabilidad intraobservador de US en la determinación de la DCH que cuantifica el intervalo coracohumeral. Además, se proporcionan valores normalizados de la DCH en 0 y 60 grados de elevación del hombro en pacientes con dolor crónico anterior de hombro. Sin embargo, el auténtico rol de la DCH en la explicación de la severidad del dolor, alteración de la función y limitación del ROM en pacientes con dolor crónico anterior de hombro, aún no está claro. Por tanto, futuros estudios deberían centrarse en determinar la importancia tanto de los factores extrínsecos como de los intrínsecos, y determinar si la DCH puede considerarse como factor pronóstico y predictor en la prevención y manejo del hombro crónico doloroso, y si podría ser el factor clave para direccionar hacia un tratamiento de fisioterapia y/o quirúrgico. Además, debería acordarse una posición estándar del paciente en el uso de la ecografía para dicha valoración, facilitando comparaciones entre distintos estudios, e identificar pacientes en riesgo o sufriendo dolor anterior de hombro.

Tras el resumen de los distintos estudios realizados en sus correspondientes capítulos, en el capítulo 6 presentamos una discusión general de la tesis, así como sus limitaciones y prospectivas para futuras investigaciones. Así, el presente trabajo evalúa el uso de la ecografía (RUSI) en la valoración del hombro. La exploración ecográfica del complejo articular del hombro incluye numerosas estructuras y, debido a su gran aplicabilidad, la presente tesis ha sido desarrollada centrándose en la distancia acromiohumeral y coracohumeral. Por lo tanto, todas las conclusiones obtenidas son respecto a dichas mediciones y no sobre la totalidad del uso de la ecografía en la valoración del hombro. En este sentido, proponemos futuros trabajos desarrollados en la prospectiva.

Actualmente existe suficiente evidencia para avalar el uso de la ecografía en la valoración del hombro. Además, existen estudios que correlacionan la DAH con la función del hombro, sin embargo, no se habían establecido estudios que correlacionen DAH/DCH con el dolor, funcionalidad y movilidad del hombro. Nuestros resultados mostraron que la asociación entre la DAH con el dolor, funcionalidad y rango articular libre de dolor del hombro, es débil en pacientes con dolor crónico de hombro antes de recibir un tratamiento de fisioterapia. Respecto a la DCH, también en pacientes con hombro doloroso crónico (anterior), no hubo ninguna asociación. Bajo nuestro conocimiento, no existen estudios que analicen la correlación entre los espacios DAH/DCH con el dolor, funcionalidad y movilidad, ni antes ni después de recibir un tratamiento de fisioterapia, en pacientes con dolor de hombro crónico.

Por otra parte, mostramos una aplicación de kinesio taping por la que aumentamos la DAH en sujetos sanos. Así, futuros estudios analizarán si la medición de la DAH mediante RUSI, tras la intervención con distintos programas de fisioterapia que además incluyan el propuesto vendaje, podría servir como herramienta de monitorización y seguimiento en los pacientes con hombro doloroso. Si existiese correlación, sería un importante hallazgo que guiaría a los tratamientos de fisioterapia en relación a la DAH con la sintomatología del paciente. En cambio, si no existiese correlación, se deberían tener en cuenta otros factores, como podrían ser la sensibilización central y periférica.

Respecto a las limitaciones de la tesis, dado que la ecografía es un instrumento de valoración dependiente del examinador, supondrá como principal hándicap la ausencia de una fiabilidad inter-observador. En nuestro estudio, el resultado del análisis de la fiabilidad intraobservador fue excelente, pero carecemos de la comparación con otro examinador, por lo que se debe de tener en cuenta a la hora de interpretar nuestros resultados.

Por otra parte, es importante conocer el artefacto de la sombra acústica en lo que respecta a la valoración ecográfica, especialmente cuando se realiza la medición del espacio acromiohumeral en 60°. La sombra acústica es la imagen anecoica que se produce como consecuencia del paso de la onda a través del tejido óseo, dificultando la visibilidad por debajo de él. Por lo tanto, la sombra acústica del acromion dificulta la visibilidad de su superficie inferior, influyendo en la calidad y exactitud de la medición del espacio acromiohumeral.

Además, la distancia acromiohumeral es una medición bidimensional para un espacio tridimensional, por lo que no estaríamos valorando toda su magnitud.

Respecto a la posición del paciente en la medición de la DCH, no fue posible seguir una guía apropiada debido a la falta de metodología descrita en este campo. Pocos estudios utilizan la ecografía en la valoración del espacio subcoracoideo, y el método utilizado no está plenamente definido. También, al igual que el espacio subacromial, el subcoracoideo es un espacio tridimensional, medido con una herramienta bidimensional, por lo que tampoco es valorado en su totalidad.

Por otra parte, actualmente es difícil reclutar pacientes que compartan mismas características demográficas, síntomas y patología. Es por tanto de gran importancia tener en cuenta la controversia que existe a la hora de etiquetar las distintas patologías del hombro. El síndrome del impingement es el diagnóstico más común en los pacientes con hombro doloroso, pero su significado es ambiguo y no más informativo que otros como "dolor anterior de hombro". Sin embargo, recientemente ha surgido un nuevo concepto conocido como "dolor de hombro en relación al manguito rotador" (RCRSP), considerado ser más apropiado ya que tiene en cuenta otros factores como los biopsicosociales o la sensibilización central y periférica.

Como prospectiva, presentamos distintos proyectos, de los cuales algunos se encuentran actualmente en desarrollo.

1. **Diferencias ecográficas entre el hombro sintomático, el contralateral asintomático y sujetos sanos.**

Otro de los campos no investigados en relación a la ecografía en la exploración del hombro doloroso crónico es su caracterización en pacientes con este dolor, y su comparación con el hombro no doloroso, así como con sujetos sanos**.** El uso de la ecografía (US) en la valoración del hombro ha aumentado ampliamente en las últimas décadas, gracias a su efecto no ionizante, no invasivo, bajo coste y la posibilidad de realizar una valoración dinámica. Ha alcanzado incluso una buena correlación con la resonancia magnética (RM) que tiene la mejor sensibilidad, y su especificidad es comparable en la detección de las roturas parciales y completas del manguito rotador. Además, se ha demostrado que la US es comparable a la RM respecto a la evaluación de la integridad del manguito rotador y del tendón del bíceps. Aparte, cuando consideramos precisión, coste, y seguridad, US es la mejor opción.

El estudio ecográfico de la morfología del hombro entre distintas poblaciones (hombro doloroso, contralateral no doloroso y sujetos sanos) es actualmente un reto. En este sentido, Yamaguchi y colaboradores compararon características morfológicas del manguito rotador entre hombros sintomáticos y asintomáticos. Encontraron que existía afectación del manguito rotador tanto en los hombros sintomáticos como en los asintomáticos. Por otra parte, Ro y colaboradores mostraron una alta prevalencia de roturas del manguito rotador en el hombro asintomático en pacientes con dolor unilateral del hombro por rotura del manguito.

La mayoría de los estudios que analizan el grosor de los tendones del hombro son realizados en pacientes con rotura del manguito rotador, o en sujetos sanos, creando una laguna en la literatura científica respecto a comparaciones morfológicas valoradas mediante ecografía entre el hombro doloroso en ausencia de rotura del manguito rotador, el hombro contralateral no doloroso y sujetos sanos. De igual modo, no existen estudios que caractericen y agrupen distintos valores normativos respecto a los grosores tendinosos del hombro, la DAH y la DCH, en las distintas poblaciones de hombros.

Aumentar el conocimiento en este sentido ayudaría a clarificar si existen diferencias morfológicas entre las distintas poblaciones de hombros. Además, valoraría la validez de comparar ecográficamente el hombro sintomático con el asintomático.

De este modo, el objetivo del estudio será analizar mediante ecografía las diferencias de los grosores tendinosos del hombro, la DAH y DCH entre las distintas poblaciones de hombros.

2. **Cambios en el espacio acromiohumeral tras distintos programas de fisioterapia. ¿está relacionado con el dolor, funcionalidad y rango de movimiento? Un estudio longitudinal prospectivo.**

La presente tesis encontró que la asociación entre la DAH con el dolor, funcionalidad y movilidad del hombro es débil, sin embargo, éste nivel de asociación corresponde a un período inicial en el que el paciente aún no había sido tratado. Por tanto, se requieren estudios que analicen la DAH de los pacientes tras recibir un tratamiento de fisioterapia, y ver si los cambios se correlacionan con la sintomatología y funcionalidad del paciente. Si así fuese, la medición de la DAH por ecografía serviría como factor pronóstico y herramienta de seguimiento en la evolución de los pacientes con dolor de hombro crónico. Para el conocimiento de los autores, no existen estudios que analicen cambios en la DAH con dolor, funcionalidad y movilidad en pacientes con dolor de hombro crónico, ni antes ni después de recibir distintos programas de fisioterapia.

Por tanto, el objetivo de este estudio será i) analizar cambios en la DAH en pacientes con dolor de hombro crónico después de recibir distintos programas de tratamiento de fisioterapia con un seguimiento de un mes y ii) correlacionar los cambios en la DAH con el dolor, funcionalidad y movilidad del hombro libre de dolor.

3. **Cambios en el espacio coracohumeral tras distintos programas de fisioterapia. ¿está relacionado con el dolor, funcionalidad y rango de movimiento? Un estudio longitudinal prospectivo.**

Al igual que la DAH, la DCH fue analizada en su correlación con el dolor, funcionalidad y movilidad del hombro en pacientes con dolor crónico anterior de hombro, la cual fue inexistente. Del mismo modo, nuestros resultados pertenecen a un estudio transversal, en el que los pacientes aún no habían sido tratados. Por tanto, se necesitarían estudios que analizasen cambios en la DCH en pacientes con dolor de hombro crónico tras recibir un tratamiento de fisioterapia. Así, se estudiaría la importancia de la correlación entre dicho espacio con el dolor, funcionalidad y movilidad del paciente, apoyando o no los tratamientos enfocados en la DCH, al mismo tiempo que se daría mayor o menor importancia a dicho espacio como indicador de cambios tras un tratamiento, y a otros factores como la sensibilización central y periférica en relación al hombro doloroso crónico.

Por tanto, el objetivo del estudio sería i) analizar cambios en la DCH en pacientes con dolor de hombro crónico después de recibir distintos programas de tratamiento de fisioterapia con un seguimiento de un mes y ii) correlacionar los cambios en la DCH con el dolor, funcionalidad y movilidad del hombro libre de dolor.

4. **Ratios del supraespinoso y subescapular en relación a los espacios subacromial y subcoracoideo.**

Actualmente están surgiendo nuevas ideas para mejorar la comprensión respecto a qué factores están más correlacionados con el dolor de hombro. Este es el caso del concepto “occupation ratio”, descrito por Michener, comprendido como el porcentaje que ocupa el grosor de un tendón al atravesar un espacio.

De acuerdo con su estudio, que analiza el “occupation ratio” del supraespinoso en su paso por el espacio subacromial en pacientes con síndrome de impingement subacromial, observa que éstos pacientes tenían menos DAH disponible en comparación con sujetos sanos, reforzando el concepto propuesto ya que éste engloba tanto al supraespinoso como a la DAH, en vez de la DAH por sí sola. Actualmente, la DAH se considera insuficiente dentro de los factores extrínsecos como mecanismo causante del dolor, tal y como muestran nuestros resultados en la presente tesis.

Además, bajo nuestro conocimiento no existen estudios que analicen la ratio del supraespinoso en pacientes con dolor de hombro crónico, el hombro contralateral no doloroso y sujetos sanos, en posición neutra del hombro medido por ecografía. Igualmente, no existen estudios que propongan el mismo concepto con el subescapular en su paso por el espacio subcoracoideo, obteniendo valores del hombro doloroso, del contralateral no doloroso, y sujetos sanos.

Por otra parte, tampoco existen estudios que correlacionen ambas ratios con el dolor, funcionalidad y movilidad libre de dolor en pacientes con dolor de hombro crónico. Así pues, este estudio sería el primero en investigarlo.

Por tanto, el objetivo de este estudio sería i) caracterizar la ratio del supraespinoso/subescapular en pacientes con hombro doloroso crónico, el hombro contralateral asintomático, y sujetos sanos y ii) correlacionar ambas ratios con el dolor, funcionalidad y rango de movimiento articular del hombro libre de dolor.

Conclusiones

1. El kinesio taping aumenta la distancia acromiohumeral en sujetos sin dolor de hombro inmediatamente tras la aplicación del tape, comparado con el grupo placebo.
2. No hubo diferencias respecto a la dirección de la aplicación del tape.
3. En pacientes con dolor de hombro crónico, la asociación entre la distancia acromiohumeral con dolor de hombro y función, así como el rango de movimiento articular del hombro libre de dolor, es débil.
4. En pacientes con dolor crónico anterior de hombro, la asociación entre la distancia coracohumeral con dolor de hombro y función, así como con el rango de movimiento articular libre de dolor del hombro, no existe.
5. El coeficiente de correlación intraclase en la determinación ecográfica de la distancia acromiohumeral en pacientes con dolor de hombro crónico es excelente.
6. El coeficiente de correlación intraclase en la determinación de la distancia coracohumeral en pacientes con dolor crónico anterior de hombro es excelente.
7. No existe un método claramente definido en la medición de la distancia coracohumeral por ecografía. Este estudio es el primero que describe una posible guía a seguir.