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Anatomical structure of the coracohumeral ligament and its effect on shoulder joint stability

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Background: *In this study, coracohumeral ligament (CHL) specimens were carefully dissected to observe its length, width, thickness and tension at different positions of the shoulder joint, thereby elucidating its effects on shoulder joint stability.*
Materials and methods: *Fresh frozen shoulder joints from 40 normal adult cadaveric specimens were dissected to reveal the CHL. With the shoulder joints placed at different positions, the length of the CHL and the width and thickness of the middle part of the ligament were measured. The changes in tension of the CHL were also observed. When the shoulder joint maintained the neutral position, the length of the CHL was 52.23 ± 1.02 mm and the width and thickness of the middle part of the ligament were 15.95 ± 0.59 mm and 1.46 ± 0.06 mm, respectively.*
Results: *When the shoulder joint moved from the neutral position to 90° external rotation, from the neutral position to 30° adduction or from the neutral position to 30° flexion/extension or when the shoulder joint is pulled down with a 5 kg weight, the CHL was elongated and thinned, maintaining a strained state. When the shoulder joint moved from the neutral position to 90° internal rotation, from the neutral position to 90° abduction or from the neutral position to 30° flexion/extension, the CHL was shortened and thickened, maintaining a relaxed state.*
Conclusions: *The CHL may limit the external rotation, adduction and downward movement of the shoulder joint and the process from the neutral position to the 30° flexion/extension, maintaining shoulder joint stability.* (Folia Morphol 2017; 76, 4: 720–729)

Key words: coracohumeral ligament, anatomy, measurement, shoulder join, stability

INTRODUCTION

The glenohumeral (GH) joint is also called the shoulder joint and is the most flexible ball-and-socket joint of the human body [3]. The flexible features of the GH joint depend primarily on two anatomical factors:

1. shallow glenoid and large humeral articular surface (the humeral articular surface is three times larger than the glenoid), with the humeral articular angle approximately 135° and the glenoid angle only 75° or so, and
2. relatively weak GH joint ligament [1]. However, these two anatomical factors are vulnerable to GH joint dislocation after injury, and the dislocation rate accounts for approximately 50% of joint dislocations all over the body [13, 22].

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Maintaining the GH joint stability mainly relies on the rotator cuff around the joint and the capsular ligament [1]. In 1970, Neer [16] first proposed the term "rotator interval" (RI) to describe the histological structure between supraspinatus tendon and subscapularis tendon, consisting of the coracohumeral ligament (CHL), the superior glenohumeral ligament (SGHL) and a part of the anterior articular capsule, and verified that the RI played a role in maintaining shoulder joint stability in subsequent studies with Foster [17]. Since Neer's study, Neer et al. [18] reported in 1992 that the CHL played an important limiting role on the external rotation of the shoulder joint; CHL release or amputation for patients with frozen shoulder joint obstruction during external rotation began clinically, having significant influences on the long-term anterior shoulder stability [2, 11, 14]. In this study, the length, width and thickness of the CHL at a specific position of the shoulder joint are measured anatomically, and changes in tension are described by observing the contraction state, with a view to illuminate the specific action mechanisms of CHL on maintaining shoulder joint stability.

MATERIALS AND METHODS

Materials

Fresh frozen shoulder joints were taken from 40 normal adult cadaveric specimens, consisting of 27 males and 13 females with the median age of 47.5 (19–57) years and 18 left shoulders and 22 right shoulders with intact skin and free of deformities, traumas and surgical alterations. This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of the Eighty-Ninth Hospital of People's Liberation Army. Written informed consent was obtained from all participants.

Anatomical observations of coracohumeral ligament

Conventional surgical instruments (Beijing Medical Instruments Factory, Beijing, China) were used to dislodge skin and subcutaneous tissues from the specimens (Fig. 1), with the deltoid and pectoralis major amputated from the starting point and opened to the ending point. Coracoclavicular ligament and capsula articularis acromioclavicularis were amputated in turn and the clavicle was dislodged (Figs. 2, 3). Whether the ending point of the pectoralis major

Figure 1. Specimens with skin and subcutaneous tissues dislodged.

Figure 2. Removed deltoid, pectoralis major, coracoclavicular ligament and capsula articularis acromioclavicularis.

Figure 3. Removed deltoid, pectoralis major, coracoclavicular ligament and capsula articularis acromioclavicularis and dislodged clavicle.

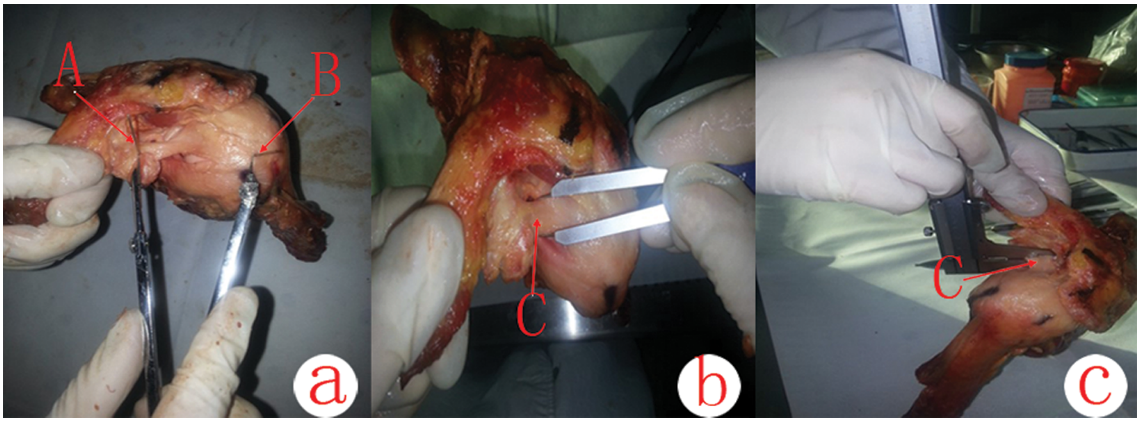

Figure 4. Measurement data in the normal neutral standing position; **a.** Measurement of the length of coracohumeral ligament (CHL): two 1.0 mm Kirschners needles were perpendicularly stroke into the initiation points of CHL (marked as point A and B), the distance between point A and B was then marked using one compass, followed by precision measurement using one sliding calliper; **b.** Measurement of the mid-length of CHL: the mid-point of CHL was marked as point C, the width of which was measured using marked using one compass and precisely measured using one sliding calliper; **c.** Measurement of the mid-thickness of CHL: the thickness of CHL was directly measured using one sliding calliper at point C.

extended from the tip of the coracoid and migrated to the capsula articularis humeri was observed. In case of any variation in the pectoralis minor, the pectoralis minor tendon might cross the CHL and intermingle with the moving part of the coracoid, and insignificant anatomical differences between them might be observed, such that the moving part was included in the present study as the CHL [26]. The pectoralis major, the coracobrachialis and the short head of the biceps femoris were amputated from the edge of the coracoid. The RI was exposed after all fatty tissues underneath the coracoacromial ligament and the subacromial bursa were dislodged, and the RI and its adjacent structures were observed [6]. The ending point of the coracoid below the CHL was revealed after the coracoacromial ligament was dislodged, the free edge of the CHL was dissected along the ending point of the coracoid until the ending point of the humerus was reached and the undersurface was cut from the articular capsule along the edge [26].

Data measurements of the coracohumeral ligament

Measuring the compliant specimens:

3. When the shoulder joints maintained the neutral position, the length of the CHL and the width and thickness of the middle part of the ligament were measured with vernier callipers (precision = 0.02 mm; Mitutoyo Instruments, Fujian, China) to obtain three sets of data, shown in Figure 4.

   The SPSS19.0 software (IBM Corporation, USA) was employed for the statistical analysis, with the results expressed as x ± s.
4. The normal range of shoulder motion is internal rotation about 70°–90°; external rotation about 60°–90°; adduction about 20°–40°; abduction about 160°–180°; anteflexion about 150°–170°; retroflexion about 40°–45°, we chose this normal range and trial tests for measurements.
   a) The shoulder joint specimens were placed in the internal rotation angles of 30°, 60° and 90° and external rotation angles of 30°, 60° and 90° using universal bevel protractors (Xuzhou Granville Electrical Co., Ltd., Xuzhou, China), shown in Figure 5. Two 2.0-mm Kirschner needles (Kirschner needle A and B) were fixed along the two measurement edges of one universal bevel protractor as the reference objects for the measurement. When the specimen's shoulder joint was in the normal neutral position, one 2.0 mm Kirschners needle (Kirschner needle C) was stroke into the midpoint of humeral greater tubercle and perpendicular to the humerus as the reference object for the rotation angle of the shoulder joint. The specimen's shoulder joint was then placed on the level of the dissecting table, and the universal bevel protractor was placed above the shoulder so that the rotation centre was positioned at

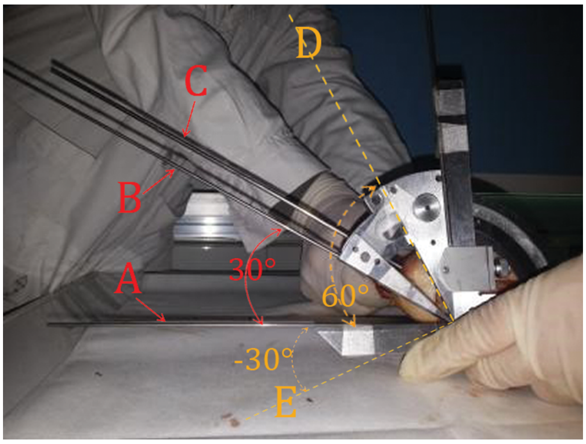

Figure 5. Positioning and data measurement of internal and external rotation. Description in the text.

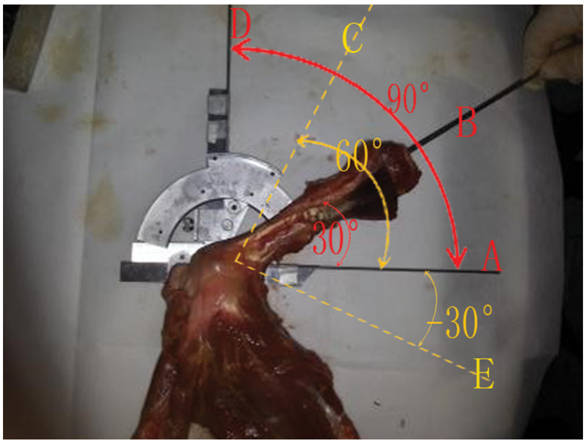

Figure 6. Positioning and data measurement of internal contract and external extension. Description in the text.

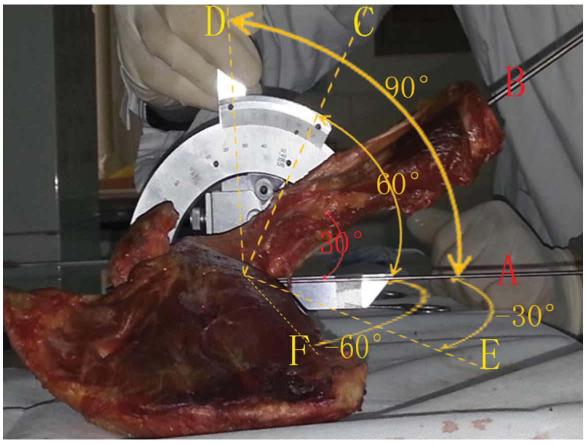

Figure 7. Positioning and data measurement of procurvation and backward extension. Description in the text.

the rotation centre of humeral head; rotated the shoulder joint, and gradually opened the universal bevel protractor with the shoulder joint while always maintained the Kirschner needles B and C parallel to each other; read the scale data and positioned the points. When the Kirschner needle B rotated to the position shown in the Figure 5, the shoulder joint inward-rotated 30°; when the Kirschner needle B rotated to the line D, the shoulder joint inward-rotated 60°; when the Kirschner needle B rotated to the line D, the shoulder joint externally rotated 30°. In addition, the three sets of data were measured with vernier callipers, recorded and analysed.

b) In the same manner, the shoulder joint specimens were placed and measured in the adduction angle of 30° and abduction angles of 30°, 60° and 90° (Fig. 6). The Kirschner needle A was fixed at the humeral long axis of shoulder specimen in normal neutral standing position, and then the shoulder specimen and the Kirschner needle B were rotated so as to maintain the humeral long axis continuously coincide with the Kirschner needle B; the data and position were then read using the universal bevel protractor. When the Kirschner needle B was in the position shown in the Figure 6, the shoulder joint externally extended 30°; when the Kirschner needle B was rotated to the line C, the shoulder joint externally extended 60°; when the Kirschner needle B was rotated to the line D, the shoulder joint externally extended 90°; when the Kirschner needle B was rotated to the line E, the shoulder joint internally contracted 30°.

c) Flexion angles of 30°, 60° and 90° and extension angles of 30° and 60° (Fig. 7). The shoulder joint was firstly fixed horizontally, and the universal bevel protractor was perpendicularly placed and closely attached to the lateral side of the shoulder to make the Kirschner needle A being kept in the horizontal place. The shoulder specimen and the Kirschner needle B were then rotated so as to maintain the humeral long axis continuously coincide with the Kirschner needle B; the data and position were then read using the universal bevel protractor. When the Kirschner needle B was in the

Table 1. Coracohumeral ligament (CHL) measurements and analyses between male and female or left and right groups

	Length	Width	Thickness
Male	50.91 ± 1.05	15.71 ± 0.49	1.49 ± 0.05
Female	50.62 ± 1.07	15.97 ± 0.61	1.39 ± 0.09
p	< 0.05	< 0.05	< 0.05
Left	50.89 ± 1.06	16.01 ± 0.47	1.42 ± 0.07
Right	50.77 ± 1.02	15.77 ± 0.43	1.41 ± 0.06
p	< 0.05	< 0.05	< 0.05

CHL measurements and analyses between left and right groups

Table 2. Coracohumeral ligament (CHL) measurements and analyses of the shoulder joint specimens in internal/external rotation

Positions of the shoulder joint specimens	CHL measurements and analyses		
	Length [mm]	Width in the middle [mm]	Thickness in the middle [mm]
Internal rotation 90°	21.07 ± 0.56	16.20 ± 0.47	1.59 ± 0.07
Internal rotation 60°	31.92 ± 0.46	16.12 ± 0.57	1.51 ± 0.06
Internal rotation 30°	34.76 ± 0.55	16.07 ± 0.63	1.49 ± 0.04
Neutral position	50.79 ± 1.02	15.95 ± 0.59	1.46 ± 0.06
External rotation 30°	58.41 ± 0.44	14.32 ± 0.56	1.43 ± 0.05
External rotation 60°	70.69 ± 0.37	14.29 ± 0.44	1.40 ± 0.07
External rotation 90°	80.77 ± 0.63	14.26 ± 0.62	1.37 ± 0.09

position shown in the Figure 7, the shoulder joint was 30° of antexion; when the Kirschner needle B was rotated to the line C, the shoulder joint was 60° of antexion; when the Kirschner needle B was rotated to the line D, the shoulder joint was 90° of antexion; when the Kirschner needle B was rotated to the line E, the shoulder joint backward extended 30°; when the Kirschner needle B was rotated to the line F, the shoulder joint backward extended 60°. The three sets of data were measured, recorded and analysed. Finally, the shoulder joints were placed in the neutral position and pulled down with a 5 kg weight, and the three sets of data were measured, recorded and analysed.

Tension observations of the coracohumeral ligament

The tension of the CHL was observed when the shoulder joint specimens were under each of the following conditions: neutral position, internal rotation, external rotation, flexion, extension, adduction, abduction and being pulled down with a 5 kg weight.

Coracohumeral ligament measurements

The CHL specimens complying with the inclusion criteria were measured, and when the shoulder joint specimens were in the neutral position, the length of the CHL was 50.79 ± 1.02 mm the width and thickness of the middle part of the ligament were 15.95 ± 0.59 mm and 1.46 ± 0.06 mm, respectively. Moreover, there was no statistical difference between male and female or left and right groups ($p < 0.05$) (Table 1). When the shoulder joint specimens were at the internal rotation angles of 30°, 60° and 90° and external rotation angles of 30°, 60° and 90°, the measured length of the CHL and the width and thickness of the middle part of the ligament were expressed as $x \pm s$, as shown in Table 2. With the adduction angle of 30° and the abduction angles of 30°, 60° and 90°, the three sets of data are shown in Table 3. With the flexion angles of 30°, 60° and 90° and the extension angles of 30° and 60°, the three sets of data are shown in Table 4. When the shoulder joint specimens were pulled down with a 5 kg weight, the three sets of data are shown in Table 5.

Table 3. Coracohumeral ligament (CHL) measurements and analyses of the shoulder joint specimens in adduction/abduction

Positions of the shoulder joint specimens	CHL measurements and analyses		
	Length [mm]	Width in the middle [mm]	Thickness in the middle [mm]
Adduction 30°	53.31 ± 0.87	15.87 ± 0.42	1.44 ± 0.04
Neutral position	50.79 ± 1.02	15.95 ± 0.59	1.46 ± 0.06
Abduction 30°	44.17 ± 0.77	16.09 ± 0.66	1.50 ± 0.07
Abduction 60°	43.47 ± 0.64	16.12 ± 0.75	1.51 ± 0.11
Abduction 90°	39.81 ± 0.69	16.21 ± 0.45	1.52 ± 0.05

Table 4. Coracohumeral ligament (CHL) measurements and analyses of the shoulder joint specimens in flexion/extension

Positions of the shoulder joint specimens	CHL measurements and analyses		
	Length [mm]	Width in the middle [mm]	Thickness in the middle [mm]
Flexion 90°	43.71 ± 0.61	15.78 ± 0.56	1.50 ± 0.06
Flexion 60°	46.41 ± 0.79	15.81 ± 0.76	1.48 ± 0.05
Flexion 30°	54.72 ± 0.80	15.91 ± 0.47	1.45 ± 0.07
Neutral position	50.79 ± 1.02	15.95 ± 0.59	1.46 ± 0.06
Extension 30°	52.76 ± 1.65	15.93 ± 0.69	1.45 ± 0.09
Extension 60°	47.20 ± 0.66	15.79 ± 0.46	1.48 ± 0.03

Table 5. Coracohumeral ligament (CHL) measurements and analyses of the shoulder joint specimens being pulled down with a 5 kg weight

Positions of the shoulder joint specimens	CHL measurements and analyses		
	Length [mm]	Width in the middle [mm]	Thickness in the middle [mm]
Neutral position	50.79 ± 1.02	15.95 ± 0.59	1.46 ± 0.06
Being pulled down with a 5 kg weight	69.53 ± 0.42	14.43 ± 0.37	1.41 ± 0.05

Changes in the tension of the coracohumeral ligament

The CHL did not have any lacklustre surface or any obvious tension on the rigidly connected bones like the coracoacromial ligament. The tension of the CHL in the neutral position was taken as a reference basis. The CHL in ± 30° external rotation/flexion/extension angle, from the neutral position to 30° adduction or when the shoulder joint being pulled down with a 5 kg weight was under strain. By contrast, the CHL in internal rotation, abduction or continual flexion/ /extension from ± 30° was in a relaxed state.

DISCUSSION

Currently studies on the coracohumeral ligament

Since Neer [16] first proposed to describe the portion of the rotator cuff between supraspinatus tendon and subscapularis tendon with the term "rotator interval" in 1970, many scholars have conducted a series of dissected anatomical and biomechanical studies on the RI and its composition [12, 21, 25]. In 1980, Neer and Foster [17] verified the effects of the RI on anterior shoulder stability. In 1987, Nobuhara and Ikeda [19] first reported and classified patients with injuries to the RI. After years of development, the RI has become a recognised independent anatomical structure maintaining shoulder joint stability in normal activities, has been the focus of considerable attention from scholars and has been widely considered the main structure bearing the RI functions [8].

Early in 1959, Basmajian and Bazant [4] reported that the anterior articular capsule and its associated ligaments countered a shift downward during shoulder abduction. Since then, the normal physiological function of the CHL has been reported in many studies. By selectively amputating the CHL and SGHL, Ovesen and Nielsen [20] observed that the CHL played an important role in maintaining the downward shoulder joint stability from the neutral position. Similarly, by analysing two kinds of ligament stretching resistances, Wellmann et al. [24] determined that the strength and ultimate load capacity of the CHL were greater than that of the SGHL. Therefore, they concluded that the CHL played a major role in maintaining shoulder joint stability at the RI [15]. However, the mechanism of action of the CHL in maintaining shoulder joint stability has not been clarified. In 1992, on the basis of their cadaver experiments on the RI functions, Harryman et al. [9] concluded that the RI could limit any excessive flexion, extension, adduction and/or external rotation of the shoulder joint and prevent the shoulder joint from any fall in adduction; however, the functions of structures and/or components inside the RI were not explained in detail. Therefore, in this study, the specific roles of the CHL on shoulder joint stability were separately explored based on the relevant measurements of functional anatomy.

Analysis of the measured data of the coracohumeral ligament in the present study

In the present study, 23 of the 40 anatomical specimens revealed fibrous tissues connecting the CHL and SGHL (i.e., the so-called CHL/SGHL complex) [5, 23], and the remaining 17 did not show any obvious distinction between the SGHL and the articular capsule, which indirectly indicated that the CHL was the thickened portion of the articular capsule that strengthened the upper part of the articular capsule, limited the external humeral rotation and avoided the upward humeral dislocation [23].

When the shoulder joint was in internal or external rotation, the correlation between the motion angle of the shoulder joint and the measured data (the length of the CHL and the width and thickness of the middle part of the ligament) was analysed by grouping and curve fitting. The resultant correlation coefficient was $0 < R < 1$, indicating that a certain relationship exists among the motion angle of the shoulder joint, the length of the CHL and the width and thickness of the middle part of the ligament. Figure 8 shows that the CHL in the internal rotation of the shoulder joint was gradually shortened, widened and thickened. Moreover, during the 90° external rotation of the shoulder joint from the neutral position, the CHL was elongated, narrowed and thinned. These findings indicate that the CHL could limit the external rotation of the shoulder joint.

When the shoulder joint was in the adduction/abduction process, the data processing method used was the same as that previously described. The resultant correlation coefficient was $0 < R < 1$, indicating that the CHL in 30° adduction of the shoulder joint from the neutral position was elongated, narrowed and thinned and the CHL in the process of shoulder joint abduction gradually shortened, widened and thickened (Fig. 9). Thus, the CHL could limit the abduction of the shoulder joint.

When the shoulder joint was in the flexion/extension process, the data processing method used was the same as that previously described. The resultant correlation coefficient was $0 < R < 1$, indicating that the CHL in 30° flexion of the shoulder joint from the neutral position was elongated, narrowed and thinned and the CHL in continual flexion gradually shortened, widened and thickened. Moreover, the CHL in 30° extension of the shoulder joint from the neutral position was elongated, narrowed and thinned and the CHL in continual extension gradually shortened, widened and thickened (Fig. 10). These findings indicated that the CHL had certain limitations within the ± 30° flexion/extension of the GH joint; thus, the CHL could maintain the initial GH joint stability.

When the shoulder joint specimens were being pulled down with a 5 kg weight, the three sets of data were measured and compared with those in the neutral position (Table 5). The results show that, when the shoulder joint was being pulled down with a 5 kg weight, the CHL was elongated, narrowed and thinned. This finding indicated that the CHL could limit the downward movement of the shoulder joint; thus, the CHL could maintain the downward GH joint stability. Therefore, several scholars have proposed that, in the event that the shoulder joint becomes unstable in a certain direction, the RI could be closed to increase the downward shoulder joint stability [7, 10].

In summary, the CHL has certain limitations on the external rotation, adduction and downward movement of the shoulder joint, maintaining a certain tension within the scope of ± 30° flexion/extension of the GH joint. Thus, the CHL is an important structure that maintains the shoulder joint stability.

Deficiencies and limitations of the present study

The present experiment has a small sample size, and owing to the incomplete information source of

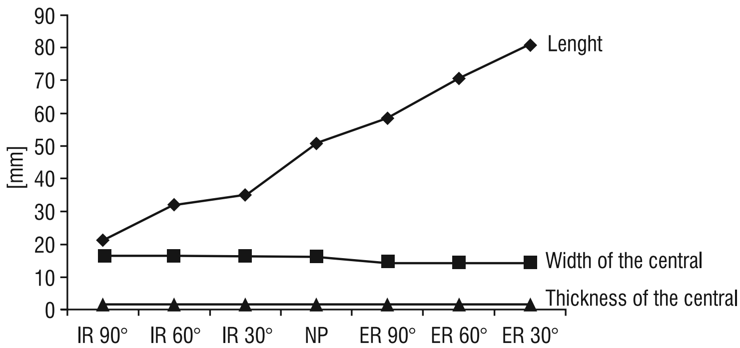

Figure 8. Variations in the measured coracohumeral ligament data during internal/external rotation of the shoulder joint; ER — external rotation; IR — internal rotation; NP — neutral position.

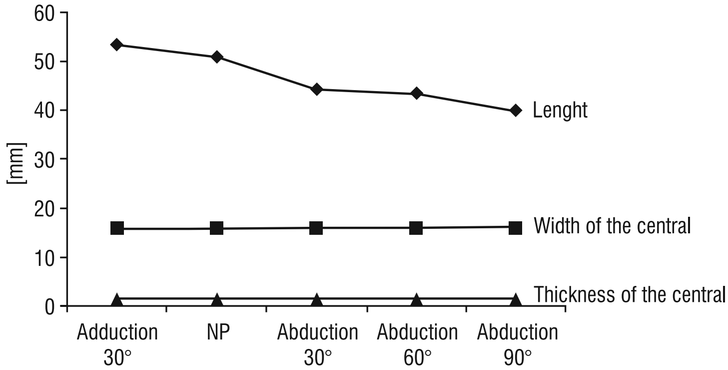

Figure 9. Variations in the measured coracohumeral ligament data during adduction/abduction of the shoulder joint; NP — neutral position.

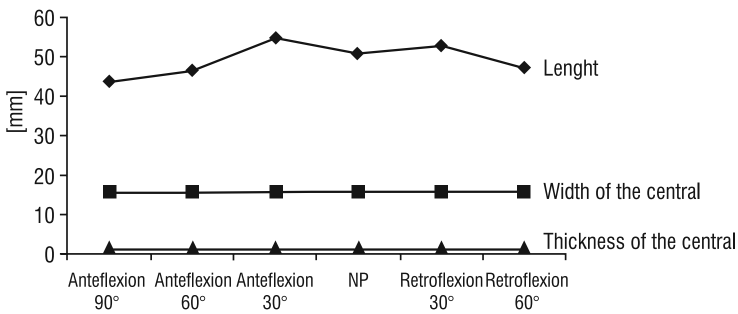

Figure 10. Variations in the measured coracohumeral ligament data during flexion/extension of the shoulder joint; NP — neutral position.

the specimens, specimen information errors, such as height, weight, age and residence of the donors, may lead to incorrect results or different mean values from the population mean.

During the movements of the shoulder joint, the caput humeri may also slide inside the glenoid, thus changing the trajectory of the caput humeri and leading to errors in measuring the CHL length at different angles.

When measuring the CHL data at different angles, the angular position is simple and the different planes where the humerus moves are incompletely parallel to the test bench, thus resulting in measurement errors.

CONCLUSIONS

The present study is a retrospective study based on the assumption that the CHL could limit the external rotation and adduction of the shoulder joint and maintain the shoulder joint stability in the movements previously described. However, whether the CHL could limit the downward movement of the shoulder joint is not clarified. The retrospective analysis of 40 shoulder joint specimens showed that the CHL could not only limit the external rotation, adduction and downward movement of the shoulder joint but also maintain a certain tension within the ± 30° flexion/extension of the GH joint. The results are in line with the expectations and hypotheses, and the present study can not only verify that the CHL maintains the shoulder joint stability but also argue that the CHL changes with the GH joint movement in different directions. This study provides a theoretical basis for clinically determining the specific mechanism of injuries due to GH joint instability.

Acknowledgements

This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of the Eighty-Ninth Hospital of People's Liberation Army. Written informed consent was obtained from all participants.

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